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Implications of Wood Collecting Activities on Invertebrates Diversity of Conservation Areas

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1. Introduction

Biomass, in the form of deadwood can be described as the end product of series of physiological processes that lead to the deterioration of a piece of wood or the entire tree (Käärik, 1974; Franklin *et al*., 1987). The rate at which this occurs depend on the exposure of the tree to various physical and physiological stresses (Savory, 1954; Bader *et al*, 1987; Jansson & Jansson, 1995). Once dead, the tree or part thereof can be harvested and used as a source of energy, mostly for cooking or heating in the household. While these are common uses of deadwood, what is also apparent is that deadwood supports ecological systems that are crucial for the maintenance of various components of biodiversity (Graham, 1925; Gosz *et al*., 1972; Ausmus, 1977; Harmon *et al*., 1993). As a result natural processes and systems of deadwood production which are often well preserved and maintained within the conserved environment (Graham, 1925; Raphael & Morrison, 1987; Harmon *et al*., 1993) requires that deadwood be regarded as critical part of biodiversity management (Harmon *et al*., 1993; Bergeron, 2000; Andrzej, 2002; Hagar, 2007).

In the past years, the management of deadwood within conservation areas has solely been based on observations that 1) deadwood provides habitat for different species of birds, bats and mammals (Brandlmaier *et al*., 2004), 2) deadwood serves as a source of food for various organisms (Raphael & White, 1984; Harmon *et al*., 1993) including the less visible invertebrates, fungi and lichens and that 3) deadwood has a potential of supplementing soil organic nutrient (Hart, 1999) and thus promoting soil fertility.

As with the case of standing dead trees (Andrzej, 2002), which are used by different vertebrates, such as birds for nesting sites (Johnston & Odum, 1956; Du Plessis, 1995), fallen dead trees are used by small mammals (Rhoades, 1986), reptiles and various species of invertebrates as mating sites, shelter or sources of food (Hirth, 1959; Harmon 1982). All these observations, combined have increased the value of deadwood as playing a key role in sustaining the efficiency and productivity of the ecological systems within conservation areas.

Unfortunately in most parts of the world deadwood still remain the main source of energy and is in great demand for domestic fuel. This is the main cause for concern among conservation agencies (Anderson & Fishwick, 1984; Wall & Reid, 1993; Abbot & Mace, 1999) as it poses a threat to biodiversity that is housed within deadwood (Kavin, 2001). Of considerable importance is that among certain societies dead wood is not only used for energy alone but has some cultural link (Furness, 1979). An example is the Xhosa, Vhenda and Zulu communities of South Africa where deadwood is specifically collected and used during traditional functions such as weddings, funerals and circumcision ceremonies (Furness, 1979). The combined effect of this has resulted in the decline of the availability of deadwood outside conservation areas (Shackleton, 1993a; Wall & Reid, 1993; Maruzane & Cutler, 2002). This has placed pressure on conservation areas to make this resource available to communities (Anderson & Fishwick, 1984; Bembridge, 1990). With the possible negative effects associated with deadwood harvesting, it is clear that the collection of deadwood from conserved areas might disturb and fragment some ecosystem processes and this could increase species loss and extinction.

The debate on deadwood availability outside conservation areas has largely been limited to its shortage as caused by over-harvesting and demand (Arnold, 1978; Anderson & Fishwick, 1984; Bembridge & Tarlton, 1990; Shackleton, 1993b) with its exploitation being reported as leading to habitat destruction for wood-inhabiting organisms and deforestation (Mainguet, 1991). Little attention has been given to the ecological effects of deadwood harvesting or the role of deadwood in maintaining ecological integrity and biodiversity (Banerjee, 1967; Bilby, 1981; Bilby & Likens, 1980) outside conservation areas.

This oversight is despite the well-recognized fact that the presence of wood-inhabiting organisms in deadwood attracts other organisms that are either predators of these organisms or their larvae (Fager, 1968; Harmon *et al*., 1993). This relationship has long been recognized and appreciated by entomologists and has generated some interest in research and management of biodiversity associated with deadwood (Graham, 1925; Fager, 1968; Käärik, 1974; Deyrup, 1981; Araya, 1993; Bennett *et al*., 1994; Lachat *et al*., 2006). Such plant-animal interactions has been identified as one of the dominant biotic interactions (Graham, 1925; Farrell *et al*., 1992) that sustains much of the terrestrial faunal diversity (Samways, 1993) through the support of ecological interactions that exist among terrestrial living organisms. Thus, activities such as collection of deadwood for energy from conservation areas may indirectly affect the maintenance of these interactions, and hence the conservation of the diversity of organisms that are associated with deadwood (Gandar, 1984; Anderson & Fishwick, 1984).

To highlight some of these threats and their possible effects on biodiversity, invertebrate diversity associated with deadwood was determined through an experimental study that was conducted in Vaalbos National Park (VNP, South Africa). The investigation addressed the hypothesis that the collection of deadwood for energy from conservation areas does not only endanger trees but also other elements of biodiversity. These may include those invertebrates whose existence is largely dependent on the presence of deadwood. In investigating this, it was hypothesized that the invertebrate diversity associated with deadwood correlate with the increasing wood size, and hence the value of the material as both fuelwood and in supporting biodiversity.

2. Materials and methods

Invertebrates in deadwood were harvested using the following procedure. Deadwood from a range of unidentified plant species of the park was randomly collected from three selected sites in the park, simulating the method of harvesting deadwood by communities and transported to a research station where the invertebrates were extracted from the deadwood.

As wood collectors prefer wood size that can be easily transported by hand (Bembridge & Tarlton, 1990), three deadwood sizes (i.e. Finger size (FS) (<2 cm in diameter), Arm-size (AS) (2 – 5 cm diameter), and Leg-size (LS) (> 5 cm diameter but less than 10 cm) were identified

and chosen for the study. These were also regarded as representing wood pieces that break and burn easily (Bembridge & Tarlton, 1990).
Collected deadwood was cut into 30 cm long pieces, weighed and loaded into 18 modified 100-litre drums that were divided into replicates of each wood size. The drums were modified such that the bottom one third of the drum was separated from the upper portion by a 38-mm mesh grid supported by iron bars. The lower separated portion was used as pitfall trap in which emerging invertebrates were collected. Each pitfall trap was filled with 5 litres of water that prevented invertebrates from leaving the trap.
Twelve of the drums served as an “illuminated” insect harvest, with each wood size class having four replicates. Drums were illuminated by 60 watt white light bulbs that were suspended 60 cm above the wood layer. This encouraged the mobility of the invertebrates to make them leave the wood. The lights were connected to a photo-sensor switch, which followed a reserve diurnal cycle to ensure 24-hour lighting so as to maintain light throughout the period of the experiment.
The six remaining drums (two replicates for each wood size class) were left without light and represented the uncontrolled condition without apparently induced invertebrate mobility. The top of each drum was covered with black cloth that ensured that sunlight did not interfere with the harvest process and that insects did not escape from or enter the drums from the outside. All drums were placed in the shade to reduce temperature variations during the experiment. The invertebrate harvest was conducted over two time periods, both during the summer months and both running for a period of nine months. These periods were selected because the activity of invertebrates is recognizably high during this period of the year (Davies, 1994).
Invertebrates were collected from the bases of the drums once a week, preserved in 70% alcohol and identified to family level (Davies, 1994). The families were categorized into the following functional guilds: obligate wood dwellers (OWD), semi-obligate wood dwellers (SOWD) and associates of deadwood (AODW), depending on their level of association with deadwood. After the experiment was completed, the deadwood was broken down with a chisel and hammer to determine whether any invertebrates remained within the wood. Invertebrates collected through this method were added to the sample of emerged invertebrates.

2.1 Statistical analysis

Data collected from the two seasons in which the experiment was conducted and from illuminated and non-illuminated drums were first tested for statistical differences. Where there was no statistical differences, data were pooled and analyzed together. Where there was a statistical difference, data were analyzed separately (e.g. numbers of invertebrates collected from illuminated drums with LS wood). The differences between numbers of invertebrates collected from illuminated and non-illuminated drums were compared statistically using one-way Kruskal-Wallis Analysis of Variance (Zar, 1984). Differences in a numbers of invertebrates and the larvae collected from three wood classes were also compared statistically using a one-way Kruskal-Wallis Analysis of Variance (Zar, 1984).

3. Results

In analysing and interpreting the results, it was considered that environmental factors, such as humidity, temperature and weather might have played a role in influencing the emergence of invertebrates from the wood. However, the fact that the drums were housed in the same conditions negated this concern. While attempts were made to identify all collected invertebrates into families some such as Pseudoscorpionida and Lepidoptera were identified to Order level only, this was due to a limited ability available to identify these invertebrates further.

The sequence of emergence of invertebrates from deadwood was such that the buprestids and cyrambecids were the first to emerge, while groups such as clerids and halictids (Table 1) emerged at the later stages of the experiments. One thousand seven hundred and fifty invertebrates were collected (Table 2). For two of the wood size classes (FS ($H = 3.71$, $df = 5$, $p>0.05$) and AS ($H = 4.56$, $df = 5$, $p > 0.05$) there was no statistically significant difference between the invertebrates collected from illuminated and non-illuminated drums (Table 2). For the leg size wood class, the illuminated drums yielded a significantly higher ($H = 23.24$, $df = 5$, $p < 0.001$) number of invertebrates than drums without light (Table 2).

An average of 1.5 ± 2.3 (Average ± SD) invertebrates per kilogram of FS wood, 2.5 ± 3.1 per kilogram of AS wood and 4.5 ± 5.6 per kilogram of LS wood (Figure 1) were harvested from each size class of wood. This was interpreted as indicating that a head-load of deadwood (Bembridge & Tarlton, 1990, Shackleton, 1993b) with an approximate mass of 20 kg of finger-size wood could contain an average of 30 ± 1.4 invertebrates, a head-load of arm-size wood could contain an average of 50 ± 2.7 invertebrates and a head-load of leg-size wood 90 ± 1.5 invertebrates of a variety of guilds, families and species.

3.1 Invertebrate guilds associated with deadwoods

The collected invertebrate fell into three broad functional guilds i.e. obligate wood dwellers (OWD), semi obligate wood dwellers (SOWD) and associate of dead woods (AODW) (Table 2). This classification was based on taxonomic categorization; feeding behavior and the maximum time an invertebrate was found to spend in deadwood (Scholtz & Holm, 1996). Nine of the identified families i.e. 26 % of the total numbers of families collected were identified as obligate wood dwellers (OWD) (Appendix). These invertebrates spend their entire lifecycle in deadwood. They inhabit the tree while it is still alive, with certain stages of their development (larval stage) being completed in dead wood (Harman *et al*., 1993). This group has a considerable pathological effect on trees and influence tree mortality (Harmon *et al*., 1993). The Halictidae (46.5 % of the total number of OWD collected), Buprestidae (25.1 %) and Cerambycidae (22.9 %) dominated this group.

The Pseudoscorpionidae (Order) and 14 (40 % of the total number of families collected) other identified families (Appendix) were classified as a group that depends on deadwood for only certain of their lives (Table 1). This group was referred to as semi-obligate wood dwellers (SOWD) and spends a portion of their lives in deadwood. They are either predators of OWD invertebrates (e.g. Histeridae), colonize holes excavated by the larvae of OWD group (e.g Carabidae) or are parasitoids (e.g. Chalcididae and Gasteruptidae) of these larvae. The dominant families that represented this group were Formicidae (20.4 %) of the total number of SOWD collected), Histeridae (15.6 %) and Lepismatidae (14.7 %).

Lepidoptera (Order) and 13 other families (33 % of the total number of families collected) were identified as those invertebrates that use deadwood either for hunting, hiding or feeding on fungi that grow on the deadwood. This group was referred to as associates of deadwood (AODW) (Scholtz & Holm, 1996) (Appendix). These invertebrates can survive and complete their life cycle in the absence of deadwood (Scholtz & Holm, 1996)

(Appendix). Megachilidae (21.2 %), Galleridae (11.9 %) and Tenebrionidae (11.0 %) represented this category.

Order	Family	FS			AS			LS		
		Non-illuminated	Illuminated	Total Mean	Non-illuminated	Illuminated	Total Mean	Non-illuminated	Illuminated	Total Mean
Coleoptera	Cerambycidae	2.3±1.3	6.3±5.1	8.6	19.0±7.1	25.0±12.2	44.0	7.5±3.5	22.5±17.1	30.0
Coleoptera	Buprestidae	0.5±0.4	0.5±1.0	1.0	21.0±11.3	20.3±10.1	41.3	9.5±0.7	37.0±14.2	46.5
Coleoptera	Bostrychidae	0.00	0.5±1.0	0.5	0.00	0.5±1.0	0.5	0.00	3.0±3.5	3.0
Coleoptera	Lyctidae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.5±1.0	0.5
Coleoptera	Mordelidae	0.00	0.00	0.0	0.00	0.00	0.0	1.3±2.4	0.8±1.5	2.1
Coleoptera	Anobiidae	0.00	0.00	0.0	0.00	1.0±2.0	1.0	0.00	2.8±2.5	2.8
Coleoptera	Cleridae	0.00	0.00	0.0	0.00	0.00	0.0	0.3±1.3	2.8±2.5	3.1
Coleoptera	Orussidae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.3±0.5	0.3
Hymenoptera	Halictidae	2.5±3.5	1.3±0.5	3.8	17.0±7.1	3.2±1.4	20.2	0.00	82.0±41.4	82.0
Coleoptera	Histeridae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	1.0±2.0	1.0
Coleoptera	Carabidae	6.5±3.5	2.7±1.4	9.2	0.00	4.0±6.1	4.0	0.00	4.3±1.8	4.3
Hemiptera	Aradidae	0.00	0.00	0.0	0.00	0.8±0.9	0.6	0.00	0.5±1.0	0.5
Coleoptera	Elateridae	0.00	0.00	0.0	0.00	0.00	0.0	0.5±1.3	3.0±3.5	3.5
Hymenoptera	Colletidae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	1.5±3.0	1.5
Hymenoptera	Chrysididae	0.00	0.00	0.0	0.00	0.5±0.9	0.5	0.00	2.0±2.4	2.0
Hymenoptera	Chalididae	0.00	0.00	0.0	0.5±1.4	0.8±0.3	1.3	0.00	1.3±2.5	1.3
Coleoptera	Curculionidae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	1.3±1.5	1.3
Hymenoptera	Gasteruptidae	0.00	0.00	0.0	0.5±2.3	1.0±1.4	1.5	0.00	3.5±2.3	3.5
Hymenoptera	Sphecidae	0.00	0.00	0.0	1.2±0.4	3.3±4.7	3.5	0.00	3.3±1.9	3.3
Hymenoptera	Chalcidoidae	0.00	0.00	0.0	3.7±0.3	4.3±6.6	8.0	0.00	0.3±0.5	0.3
Hymenoptera	Formicidae	0.00	0.00	0.0	4.2±1.6	8.8±4.7	13.0	3.0±4.2	8.3±3.5	11.3
Thysanura	Lepismatidae	0.00	0.00	0.0	1.4±2.6	7.5±4.2	8.9	3.2±2.3	9.5±6.1	12.7
Pseudoscorpionida		0.00	0.8±1.5	0.8	1.5±2.1	5.0±0.2	6.5	0.00	11.3±8.8	11.3
Hymenoptera	Megachilidae	0.00	0.00	0.0	2.5±3.5	18.5±1.0	21.0	2.0±2.8	2.5±2.1	4.5
Hemiptera	Coreidae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	1.0±2.0	1.0
Hemiptera	Pyrrhociridae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	1.5±1.2	1.5
Lepidoptera	Galleriidae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	1.5±1.7	1.5
Coleoptera	Chrysomelidae	0.00	0.00	0.0	0.00	2.3±0.5	2.3	0.00	1.5±2.3	1.5
Hemiptera	Cicadellidae	0.00	0.00	0.0	0.00	0.00	0.0	0.00	1.5±3.0	1.5
Coleoptera	Tenebrionidae	0.00	0.00	0.0	0.00	1.5±1.5	1.5	0.5±1.3	2.5±2.3	3.0
Hemiptera	Pentatomidae	0.00	0.00	0.0	0.5±1.3	1.2±0.3	1.7	0.00	0.8±1.5	0.8
Phasmotodea	Phasmotidae	0.00	0.00	0.0	0.5±1.5	0.00	0.5	0.00	1.0±1.2	1.0
Blattodea	Blattidae	0.00	0.00	0.0	0.6±1.3	0.5±0.5	1.1	1.0±1.4	2.3±1.7	3.3
Lepidoptera		0.00	0.00	0.0	0.00	0.00	0.0	0.00	2.0±1.7	2.0
Mantodea	Mantidea	1.2±0.2	2.8±3.2	4.0	0.00	0.00	0.0	0.00	0.0	0.0
Orthoptera	Gryllidae	0.00	0.00	0.0	0.5±1.2	0.5±1.2	1.0	0.00	0.5±1.0	0.5
		5	7		15	21		10	35	

Table 1. Mean number /kg (± SD) of invertebrates collected from three different sizes of deadwood (FS = finger size; AS = arm size, LS = leg size; OWD = Obligate wood dwellers; SOWD = Semi-obligate wood dwellers; AODW = Associate of dead wood). Invertebrates are arranged according to the sequence of emergence from the wood.

Taxon	Guild	FS			AS			LS			
		Illuminated	Non Illuminated	Total	Illuminated	Non-illuminated	Total	Illuminated	Non-illuminated	Total	Total
Cerambycidae	OWD	16	9	25	97	41	138	80	25	105	268
Buprestidae	OWD	2	1	3	67	56	123	154	13	167	293
Bostrychidae	OWD	2	0	2	2	0	2	12	0	12	16
Lyctidae	OWD	0	0	0	0	0	0	2	0	2	2
Mordelidae	OWD	0	0	0	0	0	0	3	0	3	3
Anobidae	OWD	0	0	0	4	0	4	8	3	11	15
Cleridae	OWD	0	0	0	7	3	10	14	2	16	26
Orissidae	OWD	0	0	0	0	0	0	1	0	1	1
Halictidae	OWD	32	8	40	123	21	144	358	0	358	542
Sub Total		52	18	70	300	121	421	632	43	675	1166
Histeridae	SOWD	0	0	0	0	0	0	4	0	4	4
Carabidae	SOWD	28	11	39	16	0	16	17	0	17	72
Aradidae	SOWD	0	0	0	3	0	3	2	0	0	5
Elateridae	SOWD	0	0	0	0	0	0	10	2	12	12
Colletidae	SOWD	0	0	0	0	0	0	5	0	5	5
Chrysididae	SOWD	0	0	0	4	0	4	8	0	8	12
Chalicididae	SOWD	0	0	0	2	1	3	5	0	5	8
Curculionidae	SOWD	0	0	0	0	0	0	5	0	5	5
Gasteruptidae	SOWD	0	0	0	3	1	4	17	0	17	21
Sphecidae	SOWD	0	0	0	10	3	13	16	0	16	29
Chalcidoidae	SOWD	0	0	0	12	17	29	1	0	1	30
Formicidae	SOWD	0	0	0	43	12	55	33	6	39	94
Lepismatidae	SOWD	0	0	0	22	8	30	31	7	38	68
Pseudoscorpionidae	SOWD	3	0	3	37	6	43	55	0	55	101
Sub Total		21	11	42	152	48	200	209	15	224	466
Megachilidae	AODW	0	0	0	11	0	11	10	4	14	25
Coreidae	AODW	0	0	0	0	0	0	4	0	4	4
Pyrrhociridae	AODW	0	0	0	0	0	0	6	0	6	6
Chrysomelidae	AODW	0	0	0	0	0	0	6	0	6	6
Cicadellidae	AODW	0	0	0	0	0	0	6	0	6	6
Tenebrionidae	AODW	0	0	0	2	1	3	8	2	10	13
Colletidae	AODW	1	1	1	0	0	0	0	0	0	2
Pentatomidae	AODW	0	0	0	0	0	0	3	0	3	3
Phasmotodea	AODW	0	0	0	2	2	4	4	0	4	8
Blattidae	AODW	0	0	0	3	3	6	9	2	11	17
Lepidoptera	AODW	0	0	0	0	0	0	6	0	6	6
Mantodea	AODW	6	5	11	0	0	0	0	0	0	11
Gryllidae	AODW	0	0	0	1	1	2	2	0	2	4
Sub Total		7	6	13	27	7	34	70	8	78	125
Total		90	35	125	479	176	655	911	66	977	1757

Table 2. Numbers (per kg) of invertebrates collected from the studied wood sizes. (FS = finger size; AS = arm size; LS = leg size; OWD = Obligate wood dwellers, SOWD = Semi-obligate wood dwellers, AODW = Associate of deadwood).

3.2 Deadwood diameter and invertebrate assemblage

Wood with larger diameter (AS and LS classes) were found to have a significantly higher number ($H = 34.3$, $df = 2$, $p < 0.001$) of invertebrates than those with a smaller diameter (finger size (<2cm) (Figure 1, Table 2). This was understood to be due to the size of the niche provided by this wood class.

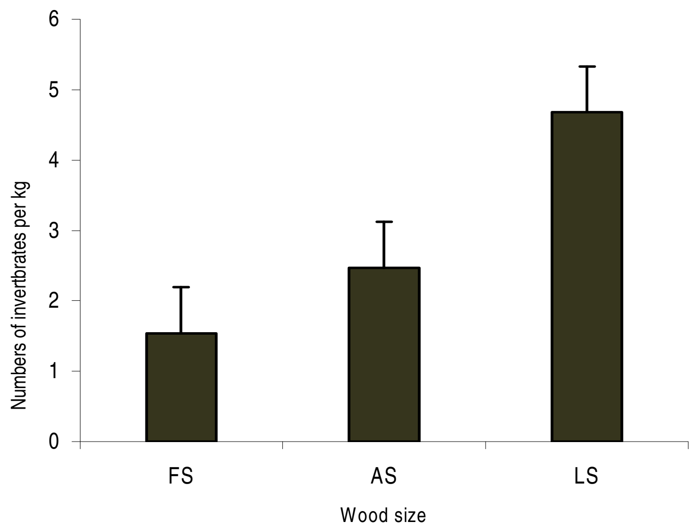

Fig. 1. Average numbers (±SD) of invertebrates recorded as occurring in a kilogram of the tree studied deadwood sizes. (FS = finger sizes, AS = arm size, LS = Leg size of deadwood).

Both arm- (AS) and leg-size (LS) wood classes had the higher numbers of the size-specific invertebrates (invertebrates limited to wood of specific diameter) (Table 2), with some invertebrates only occurring in wood of the largest diameter (LS) (Table 2). The diversity of invertebrates (i.e. number of families per wood size) calculated as occurring in a kilogram of each wood size did not differ significantly ($H = 0.00$, $df = 36$, $p > 0.05$) between the three studied wood sizes (Figure 3).

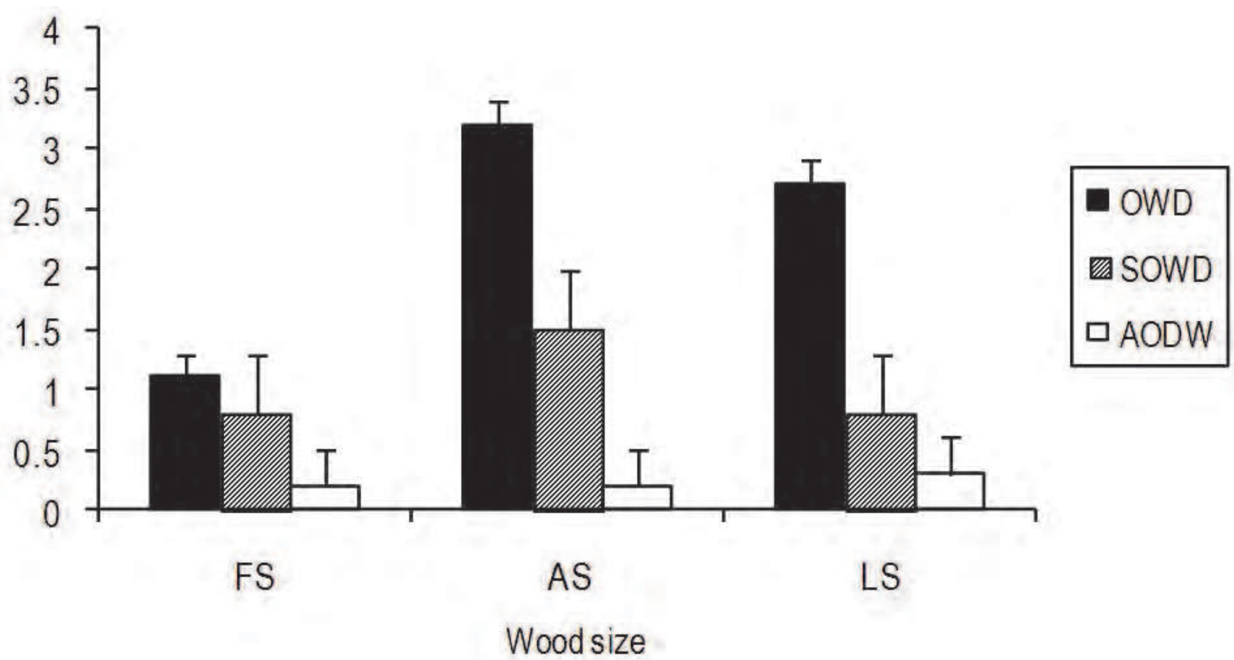

Fig. 2. Average number (±SD) of invertebrates from each category of invertebrates recorded as occurring in a kilogram of three studied wood sizes. (FS = Finger size, AS = Arm size, LS = Leg size).

In addition to adult invertebrates, an average of 13.2 ± 1.5 larvae per kg and 7.4 ± 0.6 larvae per kg (through breaking wood) were collected. Collected larvae were identified as belonging to four taxa (Table 3). Three of the families were those of OWD (Buprestidae, Cerambycidae and Cleridae) and one for the AODW (Lepidoptera (Order)(Table 3). Larvae for buprestids (74.5% of total collected larvae) and Cerambycids (12.8 % of total collected larvae) were significantly ($H = 6.12$, $df = 4$, $p < 0.01$) more abundant than those of Cleridae (10.6%) and Lepidoptera (2.1%).

Taxon	FS Average mass (g)	AS Average mass(g)	LS Average mass(g)
Buprestidae	0.001±3.4 (n = 9)	0.11±2.45(n = 33)	0.14±4.53(n = 63)
Cerambycidae	0.02±1.98(n = 5)	0.12±1.35(n = 7)	0.23±3.54(n = 6)
Cleridae	0.01±4.67(n = 2)	0.01±1.34(n = 5)	0.10±2.11(n = 8)
Lepidoptera	0.0 (n = 0)	0.13(n = 1)	0.13±3.59(n = 2)

Table 3. Total numbers and average (±SD) mass of larvae collected from three different sizes of deadwood (FS = finger size, AS = arm size and LS = leg size).

Larvae were more abundant in larger diameter wood than in smaller diameter wood ($H = 3.8$, $df = 2$, $p < 0.05$). Notably, larvae that occurred in all three sizes of deadwood differed in body size ($H = 5.7$, $df = 3$, $p < 0.01$) (Table 3), with larvae from deadwood of larger diameter (AS and LS) having higher average mass than those from deadwood with smaller diameter (finger-size) (Table 3).

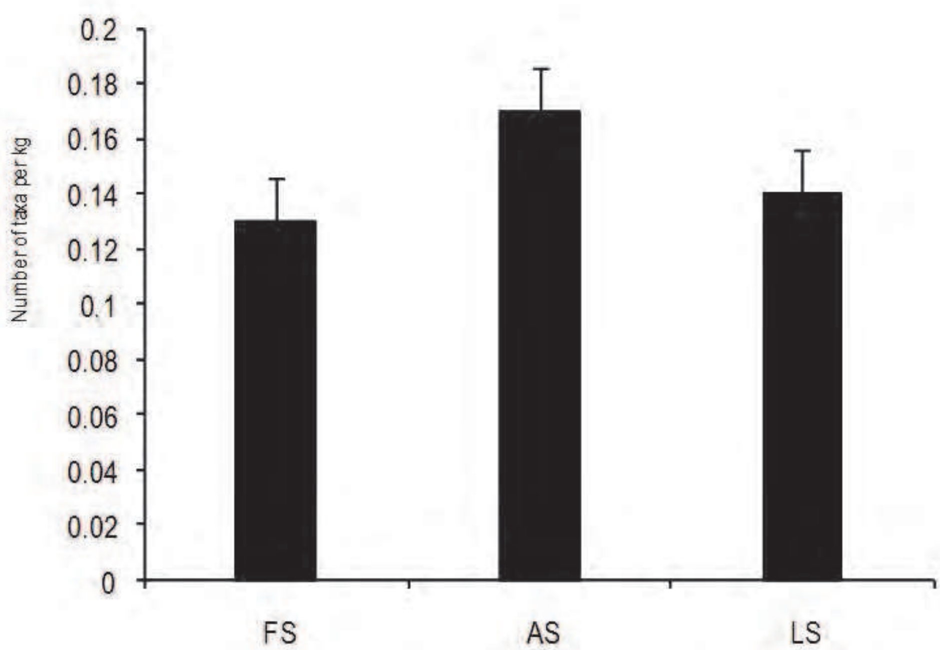

Fig. 3. Average numbers (±SD) of taxa recorded as occurring in a kilogram of three sampled wood sizes. (FS = finger size, AS = arm size, LS = leg size).

4. Discussion

This study shows that deadwood supports a broad diversity of invertebrates. These belong to a variety of guilds (Deyrup, 1976) and types (Graham, 1925) and differ in numbers (Deyrup, 1981; Harcombe & Marks, 1983) within the different sizes of deadwood (Fager, 1968; Harmon, 1982; Marshall, Setälä & Trofymow, 1998). Of notable significance is that, while Deyrup (1981) recorded more than 300 species of invertebrates from single species of Douglas-fir, this study recorded 1 757 individuals of invertebrates, identified as belonging to thirty-six families (Table 2). With such a high number of invertebrates species recorded and the wide variety of taxa found to be associated with deadwood, it is obvious that different tree species, although in different stages of their developments serve as a host to a diversity of invertebrate species (Saniga & Schütz, 2001). The fact that each stage of the tree is associated with a particular community of invertebrates (Araya, 1993; Bennett *et al*., 1994), indicates that a thorough investigation of the role and contribution of deadwood to the conservation of biodiversity needs to be investigated further to determine the other cryptic implications of collecting deadwood on biodiversity of conservation areas.

What this chapter highlights which is of critical importance in respect to wood inhabiting invertebrates and the conservation of invertebrate diversity through maintenance of deadwood in conservation areas, is that some invertebrates are distinctly characterized of and limited to the habitat that is only provided by deadwood (Brues, 1920; Deyrup, 1976). This is obvious for the OWD and SOWD guilds (Käärik, 1974; Ausmus, 1977) whose life history is confined within deadwood such that these invertebrates cannot survive in the absence of deadwood (Brues, 1920; Brumwell, Craig & Scudder, 1998) (Table 1). This indicates that the removal of deadwood from conservation areas could have direct negative effects on those organisms that rely on the presence of deadwood for survival (Blanchet & Shaw, 1978; Baker, 1979).

As each part (Deyrup, 1981) and size of wood is distinctly associated with different groups of invertebrates (Baumbeger, 1919; Deyrup, 1981) that colonize trees at different levels of decay (Christensen, 1984; Gashwiler, 1970), it is obvious that the removal of trees from conserved systems may interrupt the processes of ecological succession that takes place in dying or dead trees (Saunders, Hobbs & Margules, 1991; Harmon *et al.,* 1993; Sánchez-Azofeifa *et al.,* 1999). As these processes are associated with chemical changes that take place in a senescing tree, this would thus impede the progression of invertebrate from one group (e.g. truly wood eating (xylophagous) invertebrates (OWD) to those that are able to digest wood into fine powder (e.g. Lyctidae) (Deyrup, 1981). This progression is critical for the maintenance of the natural production of deadwood in a protected ecosystem. For example, true wood-eating invertebrates (xylophagous), with their ability to digest and assimilate food material from fresh wood tissues (Graham, 1925; Hickins, 1963; Käärik, 1974), trigger the death of the tree. Without this group, potential food material in wood can be locked up and the development of the succeeding stages of wood decay would be impeded such that the entire process of deadwood production would be retarded. This would normally lead to a scarcity of deadwood and would, in turn, trigger the destructive harvesting of wood through the cutting of live trees (Anderson & Fishwick, 1984; Gandar, 1984).

This process would then normally lead to vegetation clearing which is prevalent in unprotected areas. The evidence provided by this study suggest that it will be necessary to give serious consideration to all the effects associated with the removal of deadwood from conservation areas. Such effects may have long-term negative implications that would directly affect the biodiversity associated with deadwood.

This study has identified a group of wood-dwelling invertebrates that would be potentially vulnerable to habitat loss and population decline in the event of wood collection from conservation areas if deadwood harvesting is considered. It is therefore recommended that studies be undertaken to measure the impact of various proportions of wood being removed, and that the consequences of wood removal on this element of biodiversity and the processes provided by these species be monitored.

As the replacement of deadwood takes a long time, it is also obvious that the impacts associated with the removal of deadwood from conservation areas would have a long term affects and may have extended effects on those organisms that depend on the presence of deadwood for survival (Graham, 1925; Holmes & Sturges, 1975; du Plessis, 1995). These include woodpeckers, snakes and different species of reptile that colonize deadwood killed by wood inhabiting invertebrates (Elton, 1966; Fager, 1968; Losey & Vaughan, 2006).

In addition, as the presence of wood-inhabiting invertebrates attracts other organisms to wood, either as predators, parasitoids or through symbiotic relationships (Graham, 1925; Johnston & Odum, 1956; Conner, Miller & Adkisson, 1976; Mannan, Meslow & Weight, 1980; Bader, Jansson & Jansson, 1995), the removal of wood from conservation areas would limit this diversity of organisms (Hirth, 1959; Hamilton, 1978; Manna, Meslow & Weight, 1980; Farrell, Milter & Futuyma, 1992). Thus, maintaining the presence of deadwood as part of the ecosystem of conservation areas seem to enhance the success of conservation areas in conserving biodiversity (Brumwell, Craig & Scudder, 1998).

In conclusion, it could be mentioned that in the absence of firm evidence of the amount of wood that can be collected from conservation areas without incurring negative effects on the web of biodiversity associated with deadwood, it is difficult to commend wood harvesting from conservation areas as being sustainable. This calls for increased efforts towards developing an understanding of the importance of deadwood in mantaining biodiversity within protected ecosystems. This should include the development of methods of harvesting deadwood from conservation areas with little effects on biodiversity.

What is emerging is that deadwood (especially in Europe) is gaining much recognition as the indicator of ecosystem health such that in various parts of Europe researchers and government authorities have started to survey the role of deadwood in natural forests (Sippola *et al.*, 1998; Brandlmaier *et al.*, 2004). The aim of these studies is to determine how much deadwood should be mantained in natural forest so as to manage healthy forest ecosystem. Initiatives like these need to be extended to other areas sush as Africa where the use and demand for deadwood far exceeds production.

5. Appendix

Families of invertebrates collected from deadwood and the reasons for their association with deadwood. Reasons were extracted from Scholtz & Holm (1996).

Taxon	Guild	Reason
Cerambycidae	OWD	Larvae are wood borers.
Buprestidae	OWD	Adults attack moribund (i.e. dying) rather than dead wood, larvae are woodborers.
Bostrychidae	OWD	Both adult and larvae are woodborers.
Lyctidae	OWD	Both adult and larvae are wood borers, with larvae reducing wood to fine powder.

Taxon	Guild	Reason
Mordelidae	OWD	Larvae feed in live and decaying wood.
Anobiidae	OWD	Larvae bore in the wood and bark of dead trees.
Cleridae	OWD	Predaceous upon other insects, predominant food being larvae of lignicolous beetles.
Orussidae	OWD	Larval parasitoids of wood boring beetles of the buprestids and Cerambycids
Halictidae	SOWD	They nest in burrows either in the ground or less commonly in wood.
Histeridae	SOWD	Both the adults and larvae prey on the larvae of other insects.
Carabidae	SOWD	Predaceous with some noted to live in decaying plant material such as logs and leaf litter
Aradidae	SOWD	Mycetophagous, found under loose bark of dead branches feeding on fungi.
Elteridae	SOWD	Adults feed on vegetable matter such as leaves, flower petals or pollen.
Chrysididae	SOWD	Larvae are external parasites of the fully fed or immature insects.
Chalcididae	SOWD	Secondary parasitoids, which attck larvae or pupae of large variety of insects.
Chalcidoidae	SOWD	Some parasitic, others phytophagous and others hyperprasitoids.
Curculionidae	SOWD	Most are phytophagous
Gasteruptidae	SOWD	Parasitic in the nest of solitary wasps and bees, especially those that nest on dead wood.
Pseudoscorpionida	SOWD	Widely distributed in various habitats, commonly under the bark of deadwood.
Sphecidae	SOWD	Most are predators and prey on a variety of insects
Lepistmatidae	SOWD	Occupy a variety of habitats including houses.
Megachilidae	AODW	Pollen collecting. Nest in burrows excavated by larvae of wood boring beetles.
Colletidae	AODW	Nest on pithy plant stems or in existing burrows in wood excavated by larvae of wood boring beetles.
Coreidae	AODW	Phytophagous, attack young plant shoots.
Gryllidae	AODW	Most species are omnivorous and nocturnal.
Colletidae	AODW	Their nests are usually made wither burrowing into the ground or utilizing existing burrows in wood such as those made by wood boring beetle larvae.
Pyrrhocoridae	AODW	Phytophagous. They are the main transmitters of nematospora fungi.
Galleriidae	AODW	Larvae feed on a variety of dried substances.
Chrysomelidae	AODW	Adults feed on plants but are also adapted to different types of life.
Cicadellidae	AODW	Most types of vegetation serve as a host, often abundant on shrubs and trees.
Tenebrionidae	AODW	Some are phytophagous with larvae living in decaying wood and plant litter.
Blattidae	AODW	Often found around areas where humans live.
Lepidoptera	AODW	Adult feed entirely on nectar, over ripe fruit and other liquid substances.
Montodea	AODW	Often solitary, occurring mostly on vegetation and use deadwood as hunting grounds.
Pentatomidea	AODW	Include a number of pests that are of economic importance. Use deadwood for refuges.
Phasmatidae	AODW	May be common in dry grass, which they resemble. Use deadwood as refuges.

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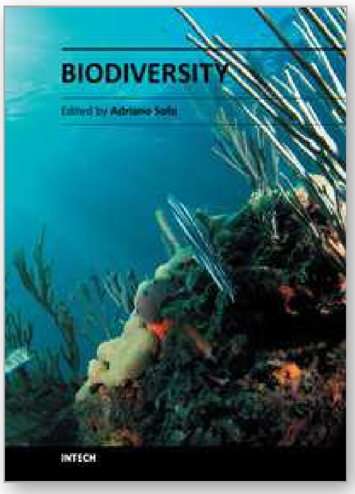

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Biodiversity is strongly affected by the rapid and accelerating changes in the global climate, which largely stem from human activity. Anthropogenic activities are causing highly influential impacts on species persistence. The sustained environmental change wildlife is experiencing may surpass the capacity of developmental, genetic, and demographic mechanisms that populations have developed to deal with these alterations. How biodiversity is perceived and maintained affects ecosystem functioning as well as how the goods and services that ecosystems provide to humans can be used. Recognizing biodiversity is essential to preserve wildlife. Furthermore, the measure, management and protection of ecosystem biodiversity requires different and innovative approaches. For all these reasons, the aim of the present book is to give an up-to-date overview of the studies on biodiversity at all levels, in order to better understand the dynamics and the mechanisms at the basis of the richness of life forms both in terrestrial (including agro-ecosystems) and marine environments.

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