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Litter Decomposition in a Coastal Dune Slack

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ABSTRACT

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The rates of decomposition of buried and unburied litter of four dominant plants were measured over a 2 year period in coastal dune slacks. The plants were the composites *Gazania rigens* and *Arctotheca populifolia*, the grass *Sporobolus virginicus* and the rush *Juncus krausii*. Decomposition in all cases was faster in buried litter bags than in those on the surface, 50% decomposition taking 40–50 and > 125 weeks, respectively. Further, surface bags with large apertures, to enable the entry of macrofauna, showed the same decomposition rates as bags with small apertures. Exponential decay coefficients were 0.06–0.29y^{-1} above ground and 0.38–0.86y^{-1} below ground. Nitrogen contents of all bags showed increases to peaks of 160–400% initial values at 15–30 weeks. Thereafter nitrogen levels dropped, probably because of the hot dry conditions of summer (40–75 weeks), followed by another increase at 126 weeks to peaks of 140–350%.

ADDITIONAL INDEX WORDS: *Sand, burial, plants, carbon, nitrogen, sand dune.*

INTRODUCTION

Dunes dominate most of the world's inhabited coasts and are severely threatened both by the activities and impacts of man and by a rising sea level. Despite these threats and their great sensitivity, dunes have received limited scientific attention. Geomorphological processes and vegetation have been relatively well studied (HESP, 1990), but fauna and ecological processes are poorly known (McLACHLAN, 1990). Decomposition and litter breakdown rates have never been examined in coastal dunes, despite the importance of decomposition in dunes and other systems (VOSSBRINCK *et al.*, 1979; SANTOS *et al.*, 1981; ELKINS and WHITFORD, 1982; MITCHELL *et al.*, 1986).

A key difference between coastal and desert dunes is that moisture is generally more limiting in the latter. This implies a better developed interstitial fauna involved in decomposition processes in coastal dunes (VAN DER MERWE and McLACHLAN, 1990) as opposed to deserts where surface macroinvertebrates are the main detritivores (CRAWFORD, 1990). However, SANTOS *et al.* (1981) suggested that litter decomposed faster below the surface in desert dunes. In a coastal dune slack in southern Africa McLACHLAN *et al.* (1987) recorded 69% of living plant mass and 97% of detrital mass below ground. Such a high proportion of below ground material would probably favor interstitial activity. The aim of this experiment was to compare above and below ground decomposition rates of litter in a coastal dune slack.

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METHODS

The study area was located in the slacks of the Alexandria dune field on the northern shores of Algoa Bay (33°44'S, 25°51'E) South Africa (McLACHLAN *et al.*, 1987). These are a series of interdune hollows between advancing transverse dunes adjacent to the beach. They average 200 m in length in a shore normal direction and 50 m in width across the floors where the water table is generally within 1 m of the sand surface. The area has a dry temperate climate with an annual rainfall of 250–400 $mm.y^{-1}$, an extreme temperature range of 0–40°C and mean monthly temperatures of 15–21°C.

The area of a typical slack studied by McLACHLAN *et al.* (1987) was 18794 m^2 of which 47% was the vegetated floor with a dry plant biomass of 221 $g.m^{-2}$, dry detrital mass of

43 $g.m^{-2}$ and macrofaunal dry biomass of 0.14 $g.m^{-2}$. VAN DER MERWE and McLACHLAN (1990) recorded a meiofaunal dry biomass of 1.02 $g.m^{-2}$, far above that of the macrofauna. The latter authors provide moisture profiles for the slack sand to 60 cm depth. This study was undertaken in the same slack.

Twelve species of plants commonly occur and exhibit a distinct succession across the slack in response to sand movement. The four dominant plants in the slacks were selected for study: the composites *Gazania rigens* and *Arctotheca populifolia*, the grass *Sporobolus virginicus* and the rush *Juncus krausii*. Standing dead leaves were collected from plants in the dune slacks during February 1986. Sufficient material was collected to give 72 samples of *ca* 10 g dry mass of each species. Samples were shaken clean of adhering sand, oven dried at 60°C for 84 h, weighed to 0.001 g and then placed in litter bags made of nylon mesh with 1.4 mm aperture size and measuring 15 × 15 cm. There were three treatments: (1) 24 samples of each species were buried 10 cm below the sand surface, (2) 24 samples were placed on the sand surface and (3) 24 samples had 0.6 cm diameter holes cut in the bags to allow access to macrofauna and were then placed on the sand surface. Litter bags were attached by nylon cord to 24 stainless steel poles spread out over an area of 10 × 10 m in the center of the slack. At eight intervals over a 126 week period the samples were retrieved in triplicate sets per treatment of each species.

At the start of the experiment, in February 1986, 5 samples of each species were analyzed as follows: after removing excess sand, wet mass was measured to 0.001 g, samples were oven dried for 84 h at 60°C and dry mass taken to 0.001 g; samples were then ground, a subsample ashed at 500°C for 6 h and another subsample analyzed for elemental C and N using a Heraeus rapid analyzer. The latter analysis is accurate to within 1% and 10% of absolute C and N values respectively. Samples were processed within a few days of collection, but C and N analysis only took place within six weeks of subsample preparation. Similar analysis was performed on triplicate samples per treatment retrieved eight times at 4–50 week intervals over 126 weeks. Values were expressed as amounts of C and N as percentages of initial amounts for each species and treatment.

Exponential decay coefficients (k) were calculated for carbon loss using the equation:

$$Q_t = Q_o e^{-kt}$$

where Q_t = carbon at time t, Q_o = initial carbon and k = the annual exponential decay coefficient.

RESULTS

Mean values of the percentage C and N remaining in the 3 replicates of each treatment and species over 126 weeks (Figure 1) indicate a decrease in C levels with time in all cases till the end of the experiment. There were no significant differences between the two above ground treatments, *i.e.* intact bags and bags with holes, but buried bags showed a significantly faster rate of carbon loss than both treatments on the surface over the eight sampling dates (one-way ANOVA, $p < 0.001$). Allowing access to macrofauna does therefore not increase the rates of decomposition, whereas burial does.

The four plant species showed different rates of decomposition; half the original carbon was removed in 45, 30, 50 and 45 weeks in *Gazania, Arctotheca, Sporobolus* and *Juncus* respectively below ground, but only one of the above ground samples had 50% decomposition by the end of the experiment at 126 weeks. The amounts of carbon remaining at the end of the experiment were; 12%, 8%, 15% and 37% in the below ground treatments and 85%, 55%, 67% and 50% in the above ground treatments in the same four species, respectively. These differences between species were not significant for either above or below ground treatments (one-way ANOVA, $p > 0.05$), but differences between above and below ground treatments of each species were significant (one-way ANOVA, $p < 0.001$).

Annual exponential decay coefficients (Table 1) for carbon in combined above ground normal and 'holed' treatments were 0.06–0.29 y^{-1} as opposed to 0.38–0.86 y^{-1} for below ground samples, confirming faster decomposition below ground. Differences between species are also clear, with *Juncus* decomposing fastest above ground and *Arctotheca* fastest below ground.

Nitrogen displayed both increases and decreases with time (Figure 1). Samples of all four species showed a substantial increase above the starting levels by 15–30 weeks. The

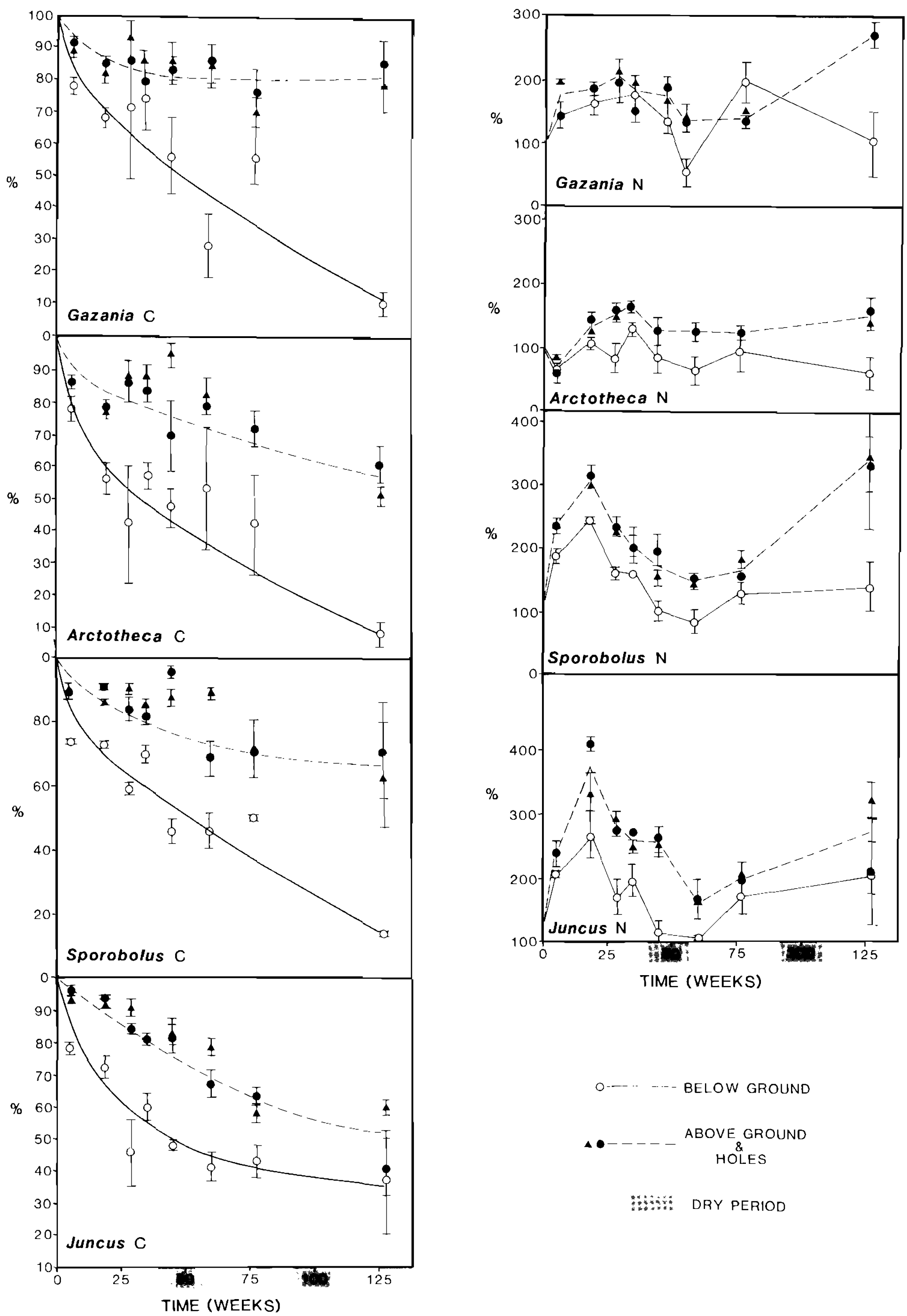

Figure 1. Percentage of initial carbon and nitrogen remaining in litter bags containing four plant species in three treatments over 126 weeks. Lines have been fitted by eye, the two above ground treatments (above and holes) being combined for this.

Table 1. *Annual exponential decay coefficients for litter of four plants above and below ground in a dune slack.*

Treatment	Arctotheca	Gazania	Juncus	Sporobolus	Mean
Above ground	0.19	0.06	0.29	0.15	0.18
Below ground	0.86	0.75	0.38	0.68	0.67
Mean	0.53	0.41	0.34	0.42	0.43

Values are k's (y^{-1}) in the expression e^{-kt}.

two above ground treatments did not differ significantly among themselves, whereas the below ground treatment exhibited significantly less nitrogen enrichment than the above ground treatments (one-way ANOVA, $p < 0.001$). Initial enrichment took 25–30 weeks in *Gazania*, 30–40 weeks in *Arctotheca*, and about 20 weeks in *Sporobolus* and *Juncus*. After this initial enrichment in nitrogen most samples showed a sharp drop, possibly due to dry conditions in the second summer. A second peak was also evident towards the end of the experiment. Nitrogen values differed significantly between species (one-way ANOVA, $p < 0.001$).

Changes in C:N ratios (Figure 2) show a similar trend for all treatments, *i.e.* a rapid initial fall (probably corresponding to microbial colonization) turning at about 20 weeks, followed by a rise during the dry season and finally a decrease until the end of the experiment.

DISCUSSION

Special features of the slack environment include the moist floor, continual sand burial and the limited number of plant species, all dune pioneers. The four species investigated are dominants and thus give a good indication of the general decomposition rates to be expected in this area. Since most litter occurring naturally in the slacks is buried (97%), and >90% of this would consist of the four species investigated (McLACHLAN *et al.*, 1987), about 60% of the detritus in the slacks may be expected to decompose each year. As detritus standing stock was estimated at 43 $g.m^{-2}$, this implies a detrital input of about 26 $g.m^{-2}.y^{-1}$, assuming that standing stock is constant, *i.e.* decomposition balances input. Without burial, decomposition rates on the surface would not equal input and litter would accumulate rapidly.

This study has shown that decomposition of plant material in dune slacks occurs rapidly as buried litter, but slowly as surface litter, which has been demonstrated for deserts (SANTOS *et al.*, 1981). This suggests that decomposition is achieved almost solely by the microfauna. Microfauna was not quantified in this study, but previous work in these slacks (VAN DER MERWE and McLACHLAN, 1990) has shown a rich interstitial biota including nematodes, arthropods and fungi. Their abundance is enhanced by the moist environment and the rapid burial of litter by windblown sand and advancing dunes. Surface litter communities are usually dominated by microarthropods, especially mites (VOSSBRINCK *et al.*, 1979; ELKINS and WHITFORD, 1982).

Decomposition rates were relatively fast, with exponential decay coefficients of 0.38–0.86 y^{-1} below ground and 0.06–0.29 y^{-1} above ground. This is considerably faster than the values of 0.04–0.18 y^{-1} recorded for above ground woody litter in an oak forest by ABBOTT and CROSSLEY (1982), who showed that the annual exponential decay coefficients decreased with increasing size of litter and with drier conditions. The present experiment used relatively fine leaves in a moist environment. There was no clear increase in decomposition rates with decreasing leaf size in the four species examined: *Arctotheca*, with the largest leaves, decomposed fastest and *Sporobolus*, with the finest leaves was intermediate in decomposition rates; *Juncus*, which has woody stems, was slowest. These differences in decomposition rates between species therefore appear to be related to taxonomic position and life form and not leaf size.

MITCHELL *et al.* (1986) recorded turnover times of leaf litter in coastal fynbos (sclerophyllous vegetation) as 14.5 y, with exponential decay coefficients of 0.07 y^{-1} on dry mass and 0.29 y^{-1} on ash free dry mass, highlighting the different exponential decay coefficients obtained using different components of litter, *i.e.* dry mass, organic matter or carbon, the latter giving higher rates. These figures from coastal fynbos are slower than those from the buried

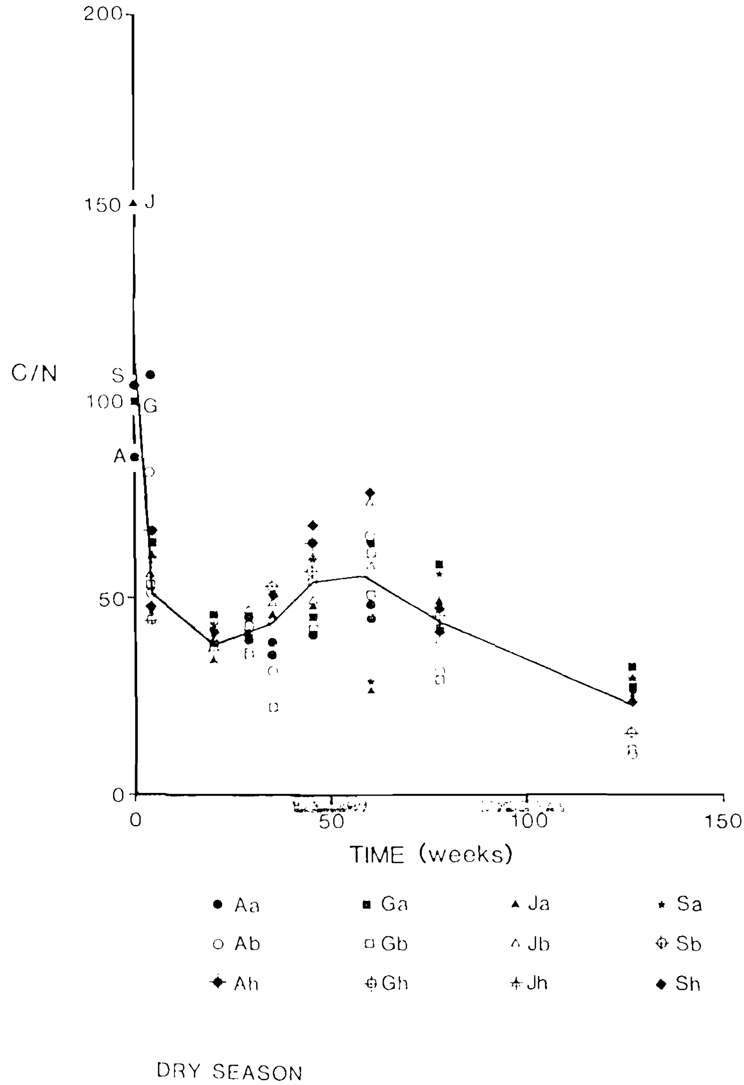

Figure 2. Changes in C/N ratios in litter of four species above (a) and below (b) ground and in treatments with large holes (h) over 126 weeks. Line fitted by eye.

bags in the dune slack, but similar to the faster above ground rates. VOSSBRINCK *et al.* (1979) recorded 29% decomposition in prairie grass in surface litter bags over 9 months and SANTOS *et al.* (1981) found rapid loss of creosote bush litter in buried bags in the Chihuahuan desert, with 29% organic loss in 30 days. The latter figure seems even faster than those recorded here and also indicates the rapid decomposition rates of buried litter.

Nutrients are probably not limiting in the dune slacks where the groundwater is high in nitrogen (McLACHLAN & ILLENBERGER, 1986). The build up of nitrogen may be explained by microbial colonization and nitrogen removal from the interstitial water, rainwater input, penetration of the bags by roots of surrounding vegetation and/or nitrogen fixing bacteria. Nitrogen conservation in this ecosystem is therefore probably not important. In these experiments nitrogen levels were still inflated after 2.4 y in most treatments, thus final organic breakdown and nitrogen removal must take longer than this.

This study has shown a high rate of detrital turnover in a moist dune slack when litter was buried rather than on the surface. It would be useful to conduct experiments of this sort under different conditions along a moisture gradient: a comparison of different coastal and desert dunes would be most illuminating.

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□ RÉSUMÉ □

Pour quatre plantes dominantes (*Gazania rigens*, *Arctotheca populiffolia*, *Sporobolus virginicus* et *Juncus Kransii*) on a étudié la vitesse de décomposition des litières. La décomposition est plus rapide dans les sacs de litière enterrées que dans ceux de surface: 50 % de la décomposition nécessite respectivement 40–50 semaines et plus de 125 semaines. D'autre part, les sacs dont les ouvertures sont larges et permettent l'entrée de la macrofaune présentent le même état de décomposition que ceux dont les ouvertures sont petities. Les coefficients de décroissance exponentielle sont: 0.06–0.29 y^{-1} au dessus du sol et 0.38–0.86 y^{-1} en dessous du sol. Les teneurs en azote de tous les sacs présentent à 15–30 semaines des pics de croissance de 100 à 400% des valeurs initiales. Ensuite, elles chutent, sans doute à cause de l'été chaud et sec (40–75 semaines), puis une autre augmentation se produit à 126 semaines avec des pics de 140–350%.—*Catherine Bressolier-Bousquet, Géomorphologie EPHE, Montrouge, France.*

□ ZUSAMMENFASSUNG □

Die Zersetzungsraten von in Müllbeuteln vergrabener und nicht vergrabener Streu vier vorherrschender Pflanzen wurde über eine zweijährige Periode in Küstendünen gemessen. Die Pflanzen waren die Korbblütler *Gazania rigens* und *Arctotheca populifolia*, das Gras *Sporobolus virginicus* und die Binse *Juncus krausii*. In allen Fällen war die Zersetzung schneller in vergrabenen Müllbeuteln als in jenen an der Oberfläche, nach 40–50, beziehungsweise > 125 Wochen beträgt die Zersetzung 50%. Außerdem zeigten Oberflächen-Müllbeutel mit großen Öffnungen, die den Eintritt der Makrofauna ermöglichen, die gleichen Zersetzungsraten wie Beutel mit kleinen Öffnungen. Exponentielle Zerfallskoeffizienten waren 0.06–0.29 y^{-1} über dem Boden und 0.38–0.86 y^{-1} unter der Erde. Die Stickstoffhehalte aller Müllbeutel zeigten Zuwächse mit Spitzenwerten von 160–400% der Ausgangswerte bei 15–30 Wochen. Danach fielen die Stickstoffwerte, wahrscheinlich aufgrund der heißen, trockenen Sommerbedingungen (40–75 Wochen), gefolgt von einem weiteren Zuwachs nach 126 Wochen zu Spitzenwerten von 140–350%.—*Gabriele Lischewski, Essen, FRG.*