Litter production by mangroves. III. Wavecrest (Transkei) with predictions for other Transkei estuaries

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Litter fall was measured in a mixed mangrove community in which *Avicennia marina* (Forssk.) Vierh. was dominant over *Bruguiera gymnorrhiza* (L.) Lam. Mean litter production was 1.24 g dry matter m^{-2} day^{-1} or 4.51 tons ha^{-1} yr^{-1} over a 3-year period. Mean annual leaf yield comprised approximately 72% of total litter. Generally greater leaf fall occurred in the summer than in the winter. In both *A. marina* and *B. gymnorrhiza* propagule production was variable from year to year. In both species, reproductive material was present on the trees almost throughout the year. This behaviour and the low litter yields appeared to indicate that the community is approaching its southern limits. From the 14 ha of mangroves in the estuary it is calculated that total litter production is 50.7 tons yr^{-1}, of which approximately 36.8 tons yr^{-1} is leaf litter. The total litter production of the larger stands of mangroves in Transkei's estuaries was calculated. Mangrove litter is considered to provide a significant input to these systems.

Die vorming van afval is gemeet in 'n gemengde manglietgemeenskap waarin *Avicennia marina* (Forssk.) Vierh. dominant oor *Bruguiera gymnorrhiza* is. Gemiddelde afvalproduksie was 1.24 g droë materiaal m^{-2} dag^{-1} of 4.51 ton ha^{-1} jr^{-1} oor 'n tydperk van drie jaar. Gemiddelde jaarlikse blaaropbrengs het ongeveer 72% van al die afval beslaan. In die algemeen het daar meer blaarval in die somer as in die winter plaasgevind. By *A. marina* sowel as *B. gymnorrhiza* het propaguulproduksie van jaar tot jaar varieer. By albei spesies was daar feitlik dwarsdeur die jaar voortplantingsmateriaal aan die bome. Hierdie gedrag en die lae afvalproduksie dui klaarblyklik daarop dat die gemeenskap sy suidelike grense nader. Daar word bereken dat die totale afvalproduksie van die 14 ha mangliete in die riviermonding 50.7 ton jr^{-1} is. Hiervan is ongeveer 36.8 ton jr^{-1} blaarafval. Die totale afvalproduksie van die groter manglietstande in Transkeise riviermondings is bereken. Mangliet-afval lewer 'n betekenisvolle bydrae tot hierdie sisteme.

Keywords: Estuary, litter, mangroves, Transkei

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Introduction

In Florida, U.S.A., the importance of mangrove detritus as the basis for estuarine production was shown (Odum *et al.* 1973; Lugo & Snedaker 1974; Teas 1976). Mangroves are also constituents of many of the estuaries in Transkei and Natal (Ward & Steinke 1982). Although mangroves occur naturally in the south-eastern Cape, these are usually isolated small stands. The more extensive southernmost communities occur at the Nxaxo–Nqusi Rivers (Wavecrest) and the Kobonqaba River. Studies in Natal (Steinke & Charles 1986) and Zululand (Steinke & Ward 1988) indicated that mangroves provided a significant input of litter into these systems. It was considered necessary, therefore, to extend the litter studies to the southern mangrove communities in an attempt to obtain an understanding of their role there as well. For this reason a litter study was initiated at Wavecrest and continued over a period of three years to minimize variations in production which field observations suggested can occur between years.

Study area

The litter studies were conducted in the mangrove community at Wavecrest which is at the confluence of the Nxaxo and Nqusi Rivers (Figure 1). The community was described by Steinke (1972). The only significant changes since that date have been an extension of *Avicennia marina* (Forssk.) Vierh. trees on the islands at the confluence and an

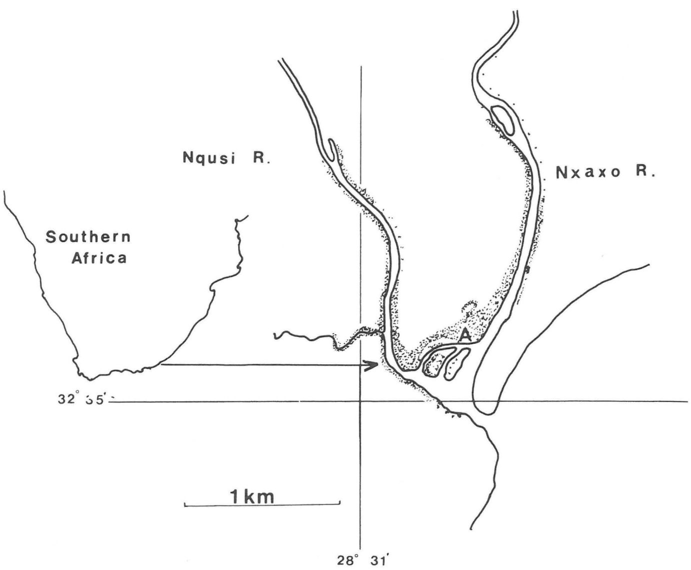

Figure 1 Locality map of Wavecrest, showing the distribution of mangroves along the Nxaxo and Nqusi Rivers. Intensity of dots corresponds with density of mangroves. (A indicates the position of the litter baskets).

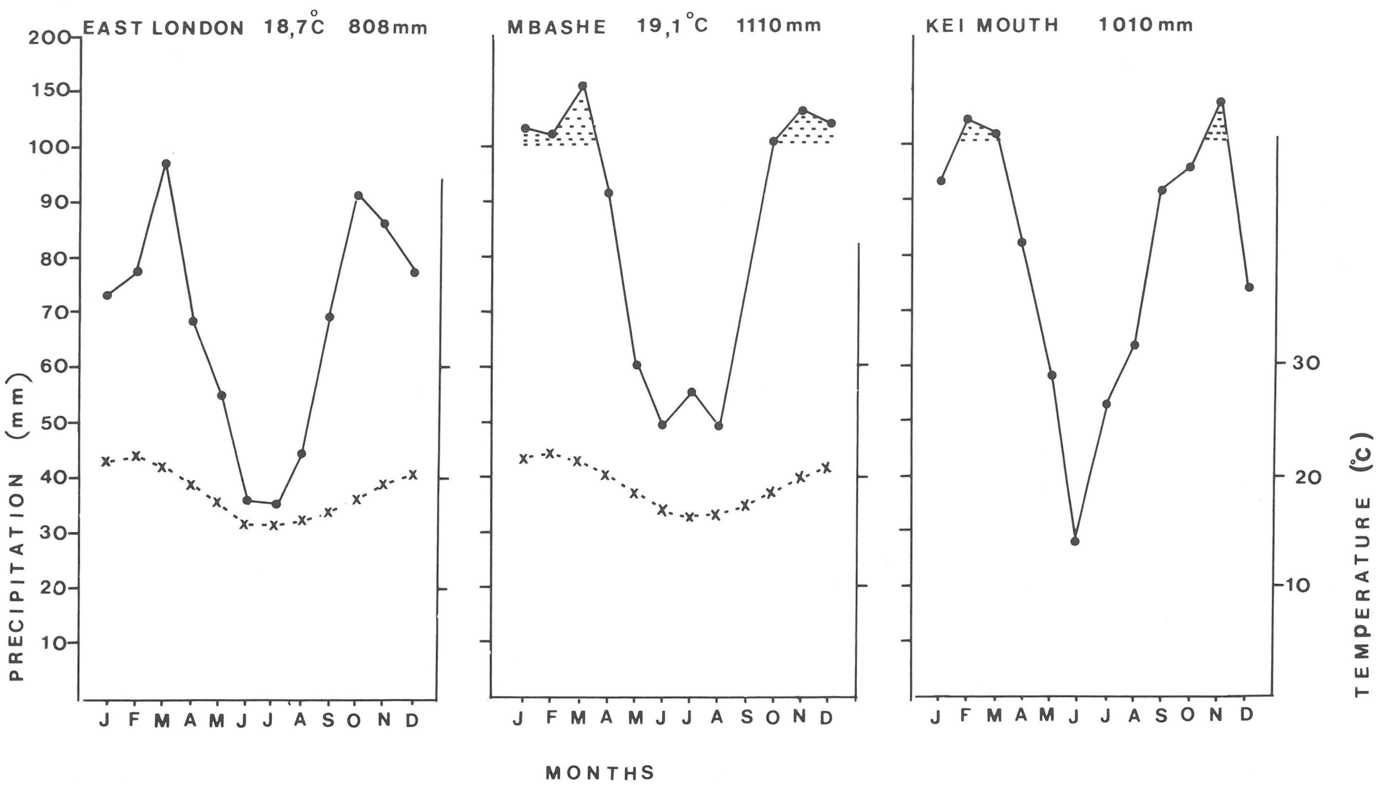

Figure 2 Climate diagrams [East London and Bashee (Mbashe)] and rainfall data (Kei Mouth). S.A. Weather Bureau, Pretoria.

increase in the number and size of *Bruguiera gymnorrhiza* (L.) Lam. individuals, particularly in the areas where this study was conducted.

As the *B. gymnorrhiza* trees are scattered throughout the mainland reach at the confluence, it was not possible to delineate accurately the area occupied by this species. Ward & Steinke (1982) calculated the total area of mangroves in this system to be 14 ha, and it is estimated that of this area approximately 5 ha are occupied by *B. gymnorrhiza*.

While the entire community is usually inundated at high spring tides, only low-lying parts are subjected to tidal coverage at neap high tides.

Materials and Methods

In area A (Figure 1) 14 litter baskets, each measuring 0.25 m^2 in area, were placed in position from the shoreline to the landward edge of the community. To ensure that sampling was representative and without bias due to any possible differences in the community, baskets were positioned using a stratified random technique (Rayner 1969). The distance across the community was divided into 14 strata and one basket positioned by choice of random numbers within each stratum. Five of the baskets were influenced by *B. gymnorrhiza*, while the remainder contained only *A. marina* litter.

The project commenced in July 1982 and was continued for three years. Each year of the study runs from August to July. During the period of this study, because of logistical problems, litter yields were collected monthly. There were no signs of decomposition of litter in the baskets between collections. Following each collection the *A. marina* material was separated into leaves, stems and reproductive material. It was not possible to separate *A. marina* buds, flowers and propagules, which were therefore considered together as reproductive material. The *B. gymnorrhiza* material was separated into leaves, stems, propagules, stipules, flowers and calyces. Because of the relatively low yields, for convenience it was considered necessary to consolidate some of these components of the latter species into a miscellaneous fraction which is defined when the term is used. The leaves and stipules were also counted and the number of stipules used as an indication of leaf emergence after field observations had confirmed the validity of this assumption (Steinke & Charles 1984). The separated material was oven-dried at 70°C for a week and then weighed.

To indicate some of the growing conditions of this southern community, climate diagrams for East London and Bashee, respectively 50 km south and 30 km north, and rainfall data for Kei Mouth, 15 km south of Wavecrest, are given (Figure 2).

Results

The trends in mean daily mass of litterfall and mean numbers of leaves and stipules are presented in Figures 3 and 4 respectively, while the contribution by individual litter components to total litter is shown in Table 1 and Figure 5. Where data do not appear in these Figures, except where stated to the contrary, there were no values recorded for those sampling periods. Because of the relatively low number of baskets containing litter of *B. gymnorrhiza*, the yields of this species were not analysed statistically.

Mean daily mass of fall of total litter showed higher values in the warmer months of the year and generally low values during the cool periods. An exception occurred in August

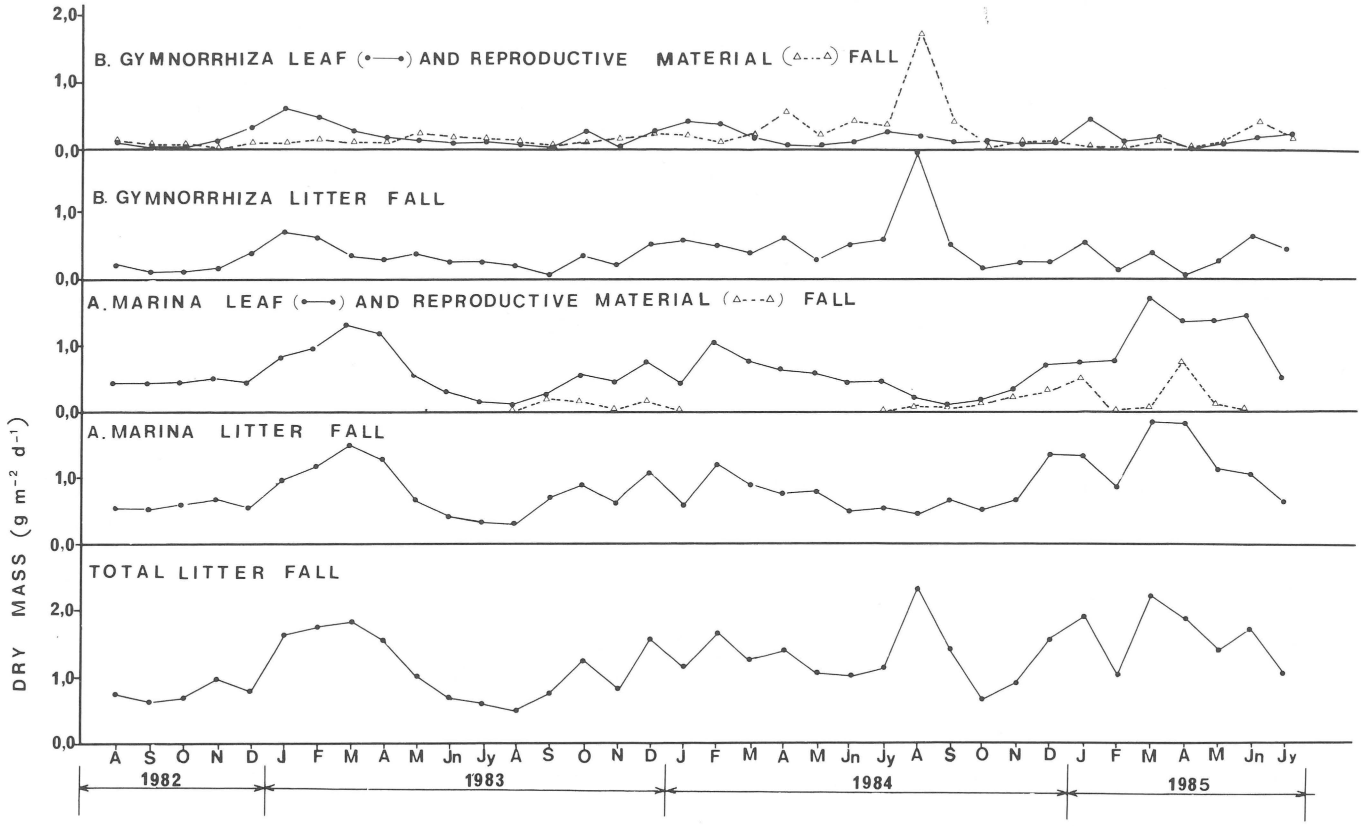

Figure 3 Mean daily litter production for the period 1982 to 1985.

1984 when a sharp peak occurred (see later). The difference between warm and cool seasons was not so marked in 1983/84 when both species produced below average leaf fall in the summer months. Examination of the data from *A. marina* revealed that the above pattern was largely determined by leaf fall of this species. The relationship between total litter fall and leaf fall was not as clear in *B. gymnorrhiza*. The pattern of leaf and stipule fall (Figure 4) is in agreement with trends previously recorded from *B. gymnorrhiza* (Steinke 1988). It is clear that in the 1983/84 and 1984/85 years conditions were more favourable for leaf production than during the previous year.

Stem material made only a small contribution to total litter, *B. gymnorrhiza* contributing a negligible amount while *A. marina* produced more. There was, however, no significant difference in stem production between seasons.

The production of reproductive material showed significant differences among harvest years. In the case of *A. marina* only the third year (1984/85) produced a large yield of propagules. In the initial year of the project the production of reproductive material was too low to be reflected in Figure

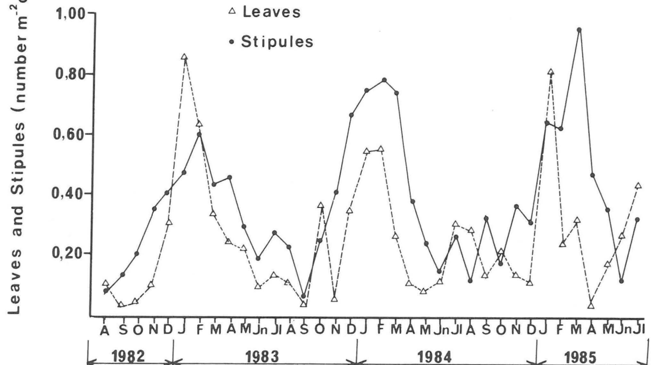

Figure 4 Mean numbers of leaves and stipules of *B. gymnorrhiza* for the period 1982 to 1985.

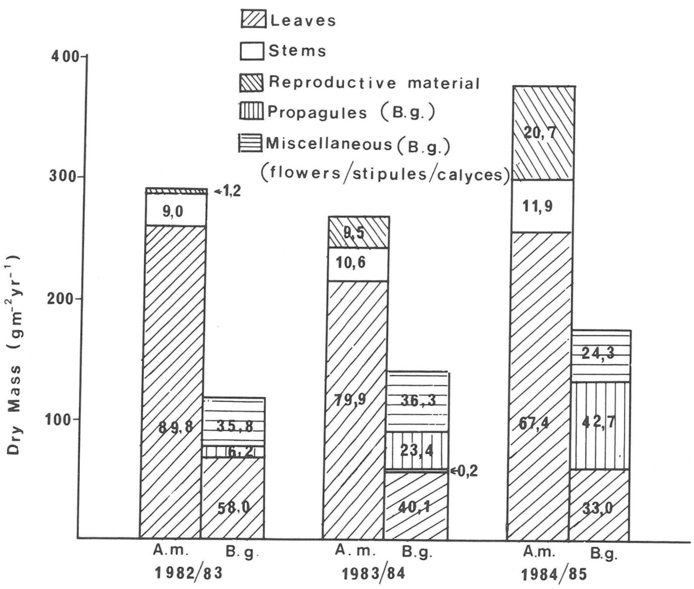

Figure 5 Composition of total litter fall for three consecutive years. Individual components of litter production are given as percentage of total litter fall for each species. (A.m. = *Avicennia marina*; B.g. = *Bruguiera gymnorrhiza*).

Table 1 Mean dry yields of litter components (g m^{-2} d^{-1}) for the period 1982/83 to 1984/85

Harvest years	Species	Leaves	Stems	Stipules	Reproductive material: Calyces + flowers	Reproductive material: Propagules	Total
1982/83	*A. marina*	0.71 A	0.07 N.S.	–	0.01 A		1.10 A
	B. gymnorrhiza	0.18	0.00	0.01	0.10	0.02	
1983/84	*A. marina*	0.58 B	0.08 N.S.	–	0.07 A		1.11 A
	B. gymnorrhiza	0.15	0.00	0.02	0.12	0.09	
1984/85	*A. marina*	0.69 A	0.12 N.S.	–	0.21 B		1.50 B
	B. gymnorrhiza	0.16	0.00	0.02	0.10	0.20	

Any two component values which do not have a letter in common differ significantly ($P < 0.01$). N.S. = not significant

3. In the case of *B. gymnorrhiza* the yields of reproductive material were less variable, although there were large differences from year to year. Propagules were dropped from May to July (3 months), from March to September (7 months), and from March to June (4 months) in the initial, second and third fruiting seasons of the study.

It can be seen from Table 1 that total litter fall showed a significant increase in the 1984/85 harvest year. This was due largely to the higher yield of reproductive material of both species. In the 3 years of the study total litter dry masses were 401.5, 405.2 and 547.5 g m^{-2} yr^{-1} respectively, giving a mean total value of 451.4 g m^{-2} yr^{-1} or 4.51 t ha^{-1} yr^{-1}.

Discussion

Litter yields of reproductive material showed considerable variation among harvest years. Earlier work (Steinke & Charles 1986; Steinke & Ward 1988) to the north revealed a similar cyclical (?) pattern of high and low values of propagule production by *A. marina*. Although the absence of detailed meteorological data for this area makes it impossible to relate behaviour of plants to environment, previous efforts to establish such relationships have proved difficult (Sasekumar & Loi 1983; Leach & Burgin 1985; Lopez-Portillo & Ezcurra 1985). In both species reproductive material was present in the litter baskets (and consequently on the trees) almost throughout the year, although yields of buds and flowers of *A. marina* were too low to be represented in Figure 3. *A. marina* behaves in a similar way towards its southern limit in Australia (A.G. Wells, pers. comm.) and in New Zealand (Crisp *et al.* 1990). The almost continuous production of buds and flowers did not allow us to determine the length of the period required for development of mature propagules of *B. gymnorrhiza*, but field observations indicated a longer period than is necessary to the north (Steinke & Charles 1986; Steinke & Ward 1988). In Natal propagules started falling in November and reached a peak in March/April (Steinke & Charles 1984), while at Wavecrest the earliest recorded falls occurred in March with peaks from May to August.

Greater leaf fall occurred in the warm than in the cool seasons. While it was not possible to correlate leaf abscission with environmental conditions, the climate diagram (Figure 2) indicates that at the time of greater leaf litter production peak rainfall occurs. This is also a time of the year characterized by very strong winds (Heydorn & Tinley 1980). The importance of wet, windy weather in increasing litter fall has been observed by Pool *et al.* (1975).

It is suggested that the markedly lower leaf production by *B. gymnorrhiza* (Figure 4) in the first year of the study could be ascribed to the low rainfall during that period. In 1982/83 rainfall was only 441.6 mm, while in the subsequent two years it almost reached the mean annual figure of 1 010 mm (Figure 2) (S.A. Weather Bureau).

Mean litter yield for this estuary was considered together with yields from *Avicennia* spp. and *B. gymnorrhiza* communities throughout the Indo-Pacific area (Clough & Attiwill 1975; Goulter & Allaway 1979; Ong *et al.* 1980; Duke *et al.* 1981; Woodroffe 1982; Sasekumar & Loi 1983; Steinke & Charles 1986; Steinke & Ward 1988; Woodroffe *et al.* 1988). A linear equation, $y = 14.57 - 0.26x$, was fitted to these data which showed a significant correlation ($r = 0.92$, $P < 0.01$) between litter yields and latitude. Attention had been drawn to the decline in litter yields with increasing distance from the tropics (Leach & Burgin 1985; Steinke & Charles 1986; Woodroffe *et al.* 1988), although it was emphasized that local variations in litter production do occur (Woodroffe *et al.* 1988). It would appear that the low litter yields and erratic reproductive behaviour by the mangroves at Wavecrest can be attributed largely to the fact that they are approaching the southernmost limit of their distribution. The decrease in productivity of mangroves towards their southernmost limits would appear to be largely temperature-related (Oliver 1982). Along our south-eastern coastline this is the environmental factor which shows the greatest variation (S.A. Weather Bureau) and, according to Macnae (1968), a mean annual temperature of approximately 19°C (Figure 2) is probably significant in determining the southern limits of mangroves in this country.

Using the mean litter yields and the mean percentage contributions by individual litter components, total litter production of the mangroves at Wavecrest was estimated to be 50.7 t yr^{-1} (Table 2). Of this output 36.8 t yr^{-1} (or approximately 72%) were made up of leaves. Previous work (Steinke *et al.* 1983) on the degradation of mangrove leaf and stem litter revealed that leaves degraded fairly rapidly. Field observations have indicated that relatively little of the litter is

Table 2 Calculated mean total litter production of mangrove communities at Wavecrest

Community	Total area (ha)	Mean litter yield ($t\ ha^{-1}\ yr^{-1}$)	Litter components ($t\ ha^{-1}\ yr^{-1}$) leaves	stems	reprod. material	miscell-aneous*	Total litter ($t\ yr^{-1}$)
A. marina	9	3.10	21.7	2.9	3.3	–	27.9
Mixed *A. marina–B. gymnorrhiza*	5	4.53	15.1	1.7	3.7	2.3	22.8
Total Wavecrest	14	–	36.8	4.6	7.0	2.3	50.7

*Miscellaneous components comprise stipules, calyces and flowers

lost to the system through tidal export. Degradation can be expected, therefore, to take place largely in the estuary. This is a relatively small estuary and the annual contribution of at least 36 tons of leaf litter probably results in a significant input of nutrients to this system.

Using the data obtained from the litter studies at Wavecrest and the approximate areas of mangroves (Ward & Steinke 1982), it is possible to estimate litter production for other estuaries with mangroves in Transkei (Table 3). All these estuaries have been inspected by boat or on foot to assess their present condition and we are confident that our figures reflect reasonably accurately the productivity of these estuaries. It is conceded that ideally, further litter studies should be undertaken to provide a more accurate representation, and the possibility of extensions to this work is being considered. In some cases there are small differences in areas from those calculated in 1982, but mostly there has been an increase, so these estimates are unlikely to exaggerate litter production. Except in the case of the Mngazana Estuary, *Rhizophora mucronata* Lam. was not common and the contribution of this species would have been negligible in all other estuaries. In the Mngazana Estuary litter production was probably underestimated because the proportion of *B. gymnorrhiza* is greater than in other estuaries and, in the absence of data for *R. mucronata*, figures for *B. gymnorrhiza* were used. With the exception of the Mtata and Mbashe Rivers which have a large catchment area, the rivers are relatively small (Emmerson 1988). Although the southern communities are not as productive as those to the north, mangrove litter production and its subsequent degradation nevertheless probably results in a significant contribution of nutrients to the smaller estuaries. While there are indications that the estuaries in Transkei are being subjected to increased pressures (Steinke 1972; Wallace & van der Elst 1974; Emmerson 1988), the smaller estuaries are still in good condition. To ensure that these estuaries remain productive and do not become degraded like many of those in Natal (Begg 1978), they should be protected from further exploitation.

Table 3 Estimated litter production of mangrove communities in Transkei

Estuary	Latitude	Area of mangroves (ha)	Mangrove species present	Total litter ($t\ yr^{-1}$)
Kobonqaba	32°36′	6.0	A.m.	18.6
Nxaxo–Nqusi (Wavecrest)	32°35′	14.0	A.m. + B.g.	50.7
Nqabara–Nqabarana	32°20′	9.0	A.m.	27.9
Mbasbe	32°15′	12.5	A.m. + B.g.	56.6
Xora	32°10′	16.0	A.m. + B.g.	72.5
Mtata	31°57′	34.0	A.m. + B.g. + R.m.	154.0
Mtakatye	31°51′	7.5	A.m. + B.g. + R.m.	34.0
Mngazana	31°42′	150.0	A.m. + B.g. + R.m.	679.5
Mntafufu	31°34′	10.0	A.m. + B.g. + R.m.	45.3

A.m. = *Avicennia marina*
B.g. = *Bruguiera gymnorrhiza*
R.m. = *Rhizophora mucronata*

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