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RESEARCH ARTICLE

Illegal sand mining alters the species composition of ants, beetles, and spiders in a coastal grassland: a case study in Eastern Cape, South Africa

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In the Eastern Cape, natural landscapes that are adjacent to rivers and the sea are threatened by illegal sand mining, which occurs without prior assessment of biodiversity. Sand mining activities lead to the reduction of vegetation cover and plant species richness, which alters microhabitats of epigaeic arthropods. Thus, it is important to assess the effects of sand mining on arthropod diversity. In this study we compared morphospecies richness, abundance, evenness, Shannon-Wiener diversity and composition of functional guilds of ants, beetles and spiders between sand-mined dune and the unmined grassland dune. Arthropods were collected using pitfall traps in the sand-mined and unmined grassland dunes. The sand-mined and unmined grassland dunes supported similar morphospecies richness, evenness and diversity of detritivores, herbivores, omnivores and predators. Sand-mined and unmined grassland dunes had similar abundance of other functional guilds, except for herbivores that were abundant in the unmined grassland. Furthermore, the two types of dunes supported significantly different morphospecies composition of all guilds. Additionally, there were 12 morphospecies that were identified as indicators of the sand-mined dune, and 11 morphospecies that were indicators of the unmined grassland dune, while there was no shared indicator species found between the two dunes. As such, disturbance-tolerant species that prefer open habitats may have replaced specialist arthropods in the sand-mined dune. This study showed that illegal sand mining changes morphospecies composition and reduces the abundance of herbivores, and as such sand mining should be restricted to designated areas as to reduce the impact of mining on arthropods and enhance conservation efforts.

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INTRODUCTION

Assemblages of epigaeic arthropods are shaped by a variety of characteristics, such as percentage of canopy cover and bare ground, leaf litter, grass, forbs, and vegetation height (Lingbeek et al. 2017; Lafage et al. 2019). As such, the alteration of habitats often affects epigaeic arthropods due to their limited dispersal abilities (Perry et al. 2021). Willett (2001) reported a decrease in species richness and abundance of spiders following logging and the loss of herbaceous cover. Additionally, greater species richness and abundance of arthropods are often recorded in less disturbed and/or undisturbed habitats compared to highly disturbed habitats (Lingbeek et al. 2017; Swart et al. 2019). Undisturbed habitats have high species richness of native plants, and according to Botha et al. (2017) and Longcore (2003) a high plant species richness enhances the species richness and diversity of arthropods. For example, both beetles and spiders were found to be more species rich in undisturbed forests than disturbed forests (Uehara-Prada et al. 2009). However, Yekwayo et al. (2017) showed that disturbance does not affect all arthropods because pines reduced abundance of predators only, while species richness and abundance of detritivorous arthropods and ants did not differ between pine plantations and natural forests. Furthermore, in South Africa high species richness of ants and beetles, and high abundance of ants and spiders were recorded in the disturbed savanna compared to the undisturbed savanna (Mavasa et al. 2023). Although some of these studies did not report a decrease in arthropod diversity, disturbed and undisturbed habitats often support different assemblages of arthropods (Uehara-Prada et al. 2009; Lingbeek et al. 2017; Tajthi et al. 2017; Mavasa et al. 2023). This further highlights the sensitivity of arthropods to disturbance, indicating that a disturbance may create microhabitats that are not suitable for some species, while attracting other species. For example, unburned forest plots supported species of ants and spiders that occupy vegetated habitats, while burned forest plots supported species that are associated with open habitats (Vidal-Cordero et al. 2022). In addition, unburned forests supported more web-building spiders than burned plots (Vidal-Cordero et al. 2022), this may have been due to greater availability of web attachment sites.

Sand mining is similar to other disturbances because it is detrimental to the physical structure of the landscape (Rentier and Cammeraat 2022), it may therefore alter microhabitats for arthropods. Legal mining of sand in South Africa contributes towards the country's economy because it provides job opportunities for many people, especially those residing near the mining sites (Naidoo 2008). However, because of the monitory value associated with sand mining, illegal mining has also been reported (Mngeni et al. 2017a). According to Gondo et al. (2019) a total of 11 900 m^3 of sand is mined monthly from the Njelele River in Limpopo, South Africa, which indicates that there is a high demand for sand. This high demand for sand together with a high unemployment rate in South Africa (Francis et al. 2020) are the drivers of illegal mining of sand, which occurs in unregistered mining sites (Chevallier 2014; Amponsah-Dacosta and Mathada 2017; Mngeni et al. 2017a). The impact of sand mining is likely to be greater in unregistered mining sites because it occurs without prior environmental assessment (Amponsah-Dacosta and Mathada 2017) and there is no monitoring by authorities. Additionally, when unregistered mining sites close, they leave open pits, and no rehabilitation of the area occurs (Chevallier 2014; Amponsah-Dacosta and Mathada 2017). In addition to the removal of native vegetation and creation of pits, sand mining leads to soil erosion and landslides (Ako et al. 2014; Mngeni et al. 2017b; Gondo et al. 2019). Furthermore, sand mining activities can enhance the invasion of alien plant species. For example, *Lantana camara* Linnaeus was observed near coastal sand dunes that were being mined in the Eastern Cape, South Africa (Mngeni et al. 2017b). The changes in the natural landscapes that are driven by the extraction of sand also affects animals because their habitats are destroyed or altered (Ako et al. 2014).

An undisturbed dune forest at Richard's Bay in South Africa supported greater diversity of insects compared to postmining rehabilitating dune sites, with the recently rehabilitated site having the lowest diversity (Kumssa et al. 2004). Furthermore, in Uruguay, highly fragmented coastal sand dunes supported low abundance of *Allocosa brasiliensis* Petrunkevitch (Araneae: Lycosidae) than less fragmented dunes (Jorge et al. 2015). Although Damptey et al. (2023) focused on gravel mining, they recorded low density of spiders in a previously mined area compared to natural forests, restored forests and agroforestry plantations. Furthermore, in a checklist of spiders of coastal dune forest at Richard's Bay, Dippenaar-Schoeman and Wassenaar (2002, 2006) recorded a variety of species of web-building and wandering spiders. However, in South Africa, particularly in the Eastern Cape province, there is limited information on the diversity of epigaiec arthropods on dune vegetation or the response of these taxa to sand mining.

Ants, beetles and spiders are usually sampled in large numbers when using the pitfall trapping method, as such this makes each taxon analysable. These arthropod taxa have diverse functional guilds, leading to specialization in habitat requirements within each taxon (Picker et al. 2019; Dippenaar-Schoeman 2023). The sensitivity of ants and beetles to habitat changes, makes these taxa good bioindicators of disturbances (Chowdhurry et al. 2023). As such, understanding how ants, beetles and spiders respond to a disturbance, such as mining of sand, may provide a broader indication of how the entire ecosystem is being affected. Therefore, this study determined if functional guilds of ants, beetles and spiders respond differently to sand mining. This was through comparing morphospecies richness, abundance, evenness, Shannon-Wiener diversity and composition of each guild between the sand-mined and unmined dune grassland. Given that sand mining is an anthropogenic activity, we expected the sand-mined dune to support low species richness, abundance, evenness and diversity compared to the unmined dune grassland. Furthermore, because of vegetation structural differences between the sand-mined and unmined grassland dune, we expect variations in morphospecies composition of arthropods.

MATERIALS AND METHODS

Study area

The study was conducted at Mbolompo (32°4.612' S, 29°5.060' E), located within the Amathole District Municipality, Eastern Cape, South Africa (Figure 1). The Karoo Supergroup covers the Mbolompo area, which consists of a mosaic of a grassland matrix that is dotted with patches of bush clumps and small forests (Mucina and Rutherford 2006). There is also a belt of coastal sand dune thicket (Mucina and Rutherford 2006). The study site has been exposed to illegal sand mining. The sand-mining area is approximately 268 871 m^2 (~27 ha) and is ≥50 m away from the sea. The study area is exposed to subsistence farming through communal cattle grazing. The Mbolompo area experiences about 1 111.64 mm of summer rainfall, while the winter season is dry (NASA POWER Project 2025). The mean maximum summer temperature of the Mbolompo area is 31°C and the mean annual maximum temperature is 29°C (NASA POWER Project 2025).

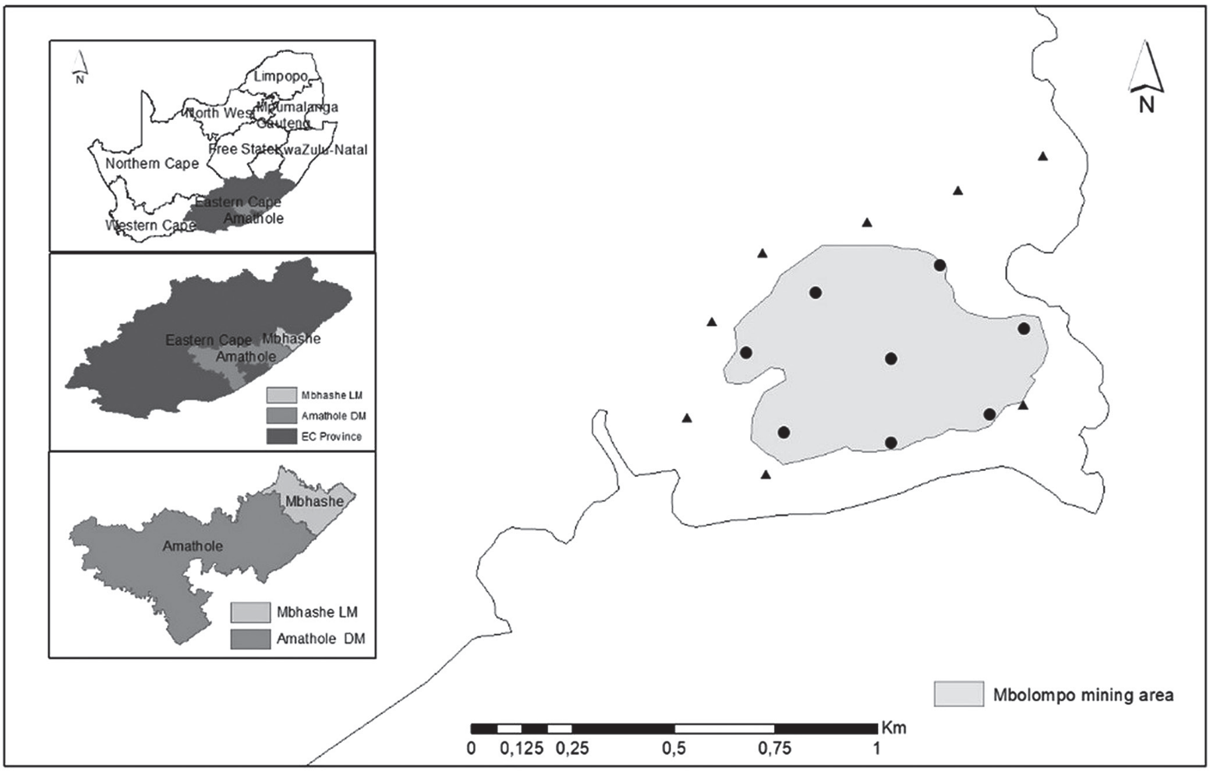

Figure 1: Study site showing plots (circles) on the sand-mined dune and plots (triangles) on the unmined grassland dune within the Mbolompo mining site in Amathole District Municipality, Eastern Cape.

We sampled in summer (late November to December 2021) due to warmer conditions in the Eastern Cape (Nkamisa et al. 2022) offering a greater arthropod activity (Mavasa et al. 2022). Using a distance of ≥200 m between plots within the same category (sand-mined dune or unmined grassland dune), a total of 16 plots were established, eight in each category (Figure 1). We considered these plots to be independent of each other (Samways et al. 2010) as many epigaeic arthropods appear to have limited dispersal abilities (Perry et al. 2021). Establishing all plots in one sand mining site is the limitation of this study. We were unable to avoid this limitation because of the lack of comparable sites within the same area. The altitude of the plots ranged between 12–75 m above sea level.

Sampling design

Each plot was represented by a 5 m × 5 m quadrat. Arthropods were sampled using pitfall traps (6 cm in diameter and 8 cm deep) that were half-filled with 50% ethylene glycol solution, which is not known to attract nor repel arthropods (Gerlach et al. 2009). At each plot six pitfall traps were set out one meter apart in a rectangular shape. To get a more representative sample, we sampled over 28 days, with pitfall traps being emptied on every 7th day after insertion, and this was repeated for a total of four occasions. Data from the six pitfall traps and four sampling times for each plot were pooled to form a single sample. We avoided digging-in effects by leaving pitfall traps uncovered for seven days because Jiménez-Carmona et al. (2019) reported that digging-in effects are more likely to occur within the first 24 hours after setting out traps. The collected specimens were preserved in 70% ethanol. The three studied taxa (ants, beetles, and spiders) were extracted and sorted into morphospecies. Most ants were identified to genus and species levels by the first author and confirmed by Dr Caswell Munyai from the University of KwaZulu-Natal. However, the family level was used for most beetles, and spiders. Various guides were followed when identifying taxa (Dippenaar-Schoeman and Jocqué 1997; White 1998; Davis et al. 2008; Bouchard 2014; Fisher and Bolton 2016; Picker et al. 2019; Dippenaar-Schoeman 2023). Although we acknowledge the limitations of using morphospecies, this is generally acceptable in studies that are focussed on assessing environmental impacts (Derraik et al. 2002; Obrist and Duelli 2010). Classification of arthropods (including ants, beetles and spiders) to morphospecies has been done previously in South Africa (Swart et al. 2019; van Schalkwyk et al. 2021; Geldenhuys et al. 2022). Arthropods were then assigned to functional guilds. Given that some of the specimens (particularly beetles) were identified to family level, for those morphospecies the family was used when assigning guilds. The following guilds were identified, herbivores (ants and beetles), detritivores (beetles), omnivores (ants and beetles), and predators (ants, beetles and spiders) (Fisher and Bolton 2016; Picker et al. 2019; Dippenaar-Schoeman 2023).

Vegetation cover across different plots within each of the two dune types (sand-mined and unmined grassland) appeared similar. As such, at each of the 16 sampling plots a 1 m × 1 m quadrat was used to visually estimate the percentage of vegetation cover. Estimation of vegetation cover was done once during the sampling period. We estimated vegetation cover in the second week of setting out pitfall traps.

Data analyses

Analyses were conducted in R version 4.1.2 (R Core Team) and PRIMER 7 (Anderson et al. 2008). Analyses were conducted separately for each of the four functional guilds (detritivores, herbivores, omnivores and predators). The Shapiro-Wilk test was used to test the data for normality (Rochon et al. 2012). The abundance of detritivores and omnivores, as well as Shannon-Wiener diversity of detritivores and herbivores were normally distributed ($p > 0.05$). The morphospecies richness of herbivores, omnivores and predators, as well as evenness of omnivores were normally distributed. However, morphospecies richness and evenness of detritivores, as well as abundance and morphospecies evenness of herbivores were nonnormal ($p < 0.05$). Similarly, abundance, evenness and Shannon-Wiener diversity of predators were nonnormal. Therefore, to compare these measures of diversity between sand-mined and unmined grassland dunes, linear models were used when datasets were normal, while for nonnormal datasets the generalized linear models were used. Spearman's rank correlation was used to determine if the percentage of vegetation cover correlated with morphospecies richness or abundance of each functional guild. The Spearman's rank correlation was used because the dataset for the vegetation cover was not normally distributed. In addition, the generalized linear model with the negative binomial distribution and the *MASS* package (Venables and Ripley 2002) was used to compare the percentage of vegetation cover between sand-mined dune and unmined grassland dune.

Morphospecies composition of each guild was compared between sand-mined dune and unmined grassland dune using the permutational multivariate analysis of variance (PERMANOVA) in PRIMER. The data were square-root transformed, and the analysis was conducted using the Bray–Curtis similarity measures (Anderson 2001). Principal coordinates analysis in PRIMER (Anderson et al. 2008) was performed to visualize differences in morphospecies composition between the sand-mined dune and the unmined grassland dune. To identify morphospecies that are indicators of the sand-mined dune, unmined grassland dune and shared between these areas, we used the indicator value analysis (De Cáceres and Legendre 2009). The indicator value analysis uses the *Multipatt* function in the *indicpsecies* package (De Cáceres and Legendre 2009). The frequent occurrence and abundance of morphospecies in a habitat type were used in determining indicator morphospecies (Samways et al. 2010).

RESULTS

A total of 6 827 individuals of ants (70.8%), beetles (16.8%) and spiders (12.4%) were collected. Out of a total of 244 morphospecies collected, spiders had the highest percentage (45.1%), followed by beetles (42.2) and ants (12.7). There were more individuals sampled in the sand-mined dune (58.8%) than in the unmined grassland dune (41.2%) (Supplementary Tables S1, S2). However, a slightly greater number of morphospecies (166) was collected from the grassland dune than from the sand-mined dune (146 morphospecies) (Supplementary Tables S1, S2). In both dune types, the most abundant and morphospecies rich subfamilies of ants were the Myrmicinae and Formicinae, while the Dorylinae was least abundant, and the Dolichoderinae was represented by one morphospecies (*Tapinoma* sp.). In the sand-mined dune, families of beetles with the highest abundance were the Cicindelidae, and Scarabaeidae, while families with the highest number of morphospecies were the Scarabaeidae and Staphylinidae (Table S1). In the unmined grassland dune, the most abundant beetle families were the Staphylinidae, Scarabaeidae, Carabidae and Chrysomelidae, while the Staphylinidae, Scarabaeidae and Carabidae had high morphospecies richness (Table S2). Although the Cicindelidae had the highest number of individuals, these were from two morphospecies (Table S1). In the sand-mined dune, the highest number of individuals and morphospecies of spiders were recorded in the Lycosidae, Gnaphosidae, Zodariidae and Theridiidae (Table S1). The families of spiders with the highest abundance in the unmined grassland dune were the Lycosidae, Zodariidae and Theridiidae, whereas the Lycosidae, Zodariidae, Corinnidae and Salticidae were morphospecies rich (Table S2).

Morphospecies richness, evenness, abundance and Shannon-Wiener diversity of detritivores, omnivores and predators were similar between the sand-mined dune and unmined grassland dune (Table 1). Similarly, morphospecies richness, evenness and Shannon-Wiener diversity of herbivores did not differ significantly between the sand-mined dune and unmined grassland dune (Table 1). However, significantly greater abundance of herbivores was recorded in the unmined grassland dune than the sand-mined dune (Table 1, Figure 2). The surrounding grassland had significantly (t = -3.35, p = 0.005) higher percentage of vegetation cover than the sand-mined dune. The percentage of vegetation cover did not correlate with either morphospecies richness of all functional guilds nor abundance of detritivores, omnivores and predators (Table 2). However, the percentage of vegetation cover correlated positively with the abundance of herbivores (Table 2).

There were significant differences in morphospecies composition of all functional guilds between the sand-mined dune and the unmined grassland dune (Table 1). In addition, the principal coordinates analysis separated plots from each dune type, even though the distribution of plots (particularly omnivores) appeared to overlap between dune types (Figure 3). The indicator value analysis identified 12 morphospecies that were associated with the sand-mined dune and 11 morphospecies that were indicators of the unmined grassland dune (Table 3). The indicator ant morphospecies identified in the sand-mined dune represented the Dolichoderinae (*Tapinoma* sp.), Formicinae (*Lepisiota* sp.) and Myrmicinae (*Cardiocondyla* sp., *Crematogaster* sp. and *Tetramorium* sp.) subfamilies (Table 3). However, there were two morphospecies of *Tetramorium* and *Mesoponera caffraria* Smith that occurred frequently in the unmined grassland dune (Table 3). There were five morphospecies of beetles that were indicators of the unmined grassland dune, while the sand-mined dune had *Lophyra* sp. and *Rhyssemus* sp. as indicators (Table 3). Two morphospecies of the Lycosidae (*Foveosa foveolata* Purcell and *Trabea* sp.) and *Hahnia* sp. were indicators of spiders in the unmined grassland dune (Table 3). However, in the sand-mined dune three morphospecies of the Lycosidae (*Pardosa crassipalpis* Purcell, *Pardosa* sp. and *Trabea* sp.), one morphospecies of the Gnaphosidae (*Asemesthes* sp.) and Zodariidae (*Cydrela* sp.) were identified as indicators (Table 3).

DISCUSSION

Our study showed that changes in vegetation cover as a result of sand mining activities do not appear to affect morphospecies richness, evenness and diversity of all functional guilds studied. However, the morphospecies composition of all functional guilds and abundance of herbivores differed between the sand-mined dune and unmined grassland dune. The sand-mined dune had little to no vegetation cover and a greater percentage of bare ground compared with the surrounding unmined grassland dune. As a result, these differences in vegetation cover may have led to differences in microhabitats for arthropods, thus, the sand-mined dune and the surrounding unmined grassland dune supported different morphospecies composition. Although sand mining activities may have provided unsuitable microhabitats for some species of ants, beetles and spiders, the sand-mined dune may have attracted other species. For example, some *Tapinoma* species build their nests in open habitats that are caused by anthropogenic activities (Sharaf et al. 2017; Seifert et al. 2024). Similarly, disturbed habitats tend to support greater abundance of some *Pardosa* species (Liu et al. 2024). This could explain the species of *Tapinoma* and *Pardosa* that we recorded as indicators of the sand-mined dune.

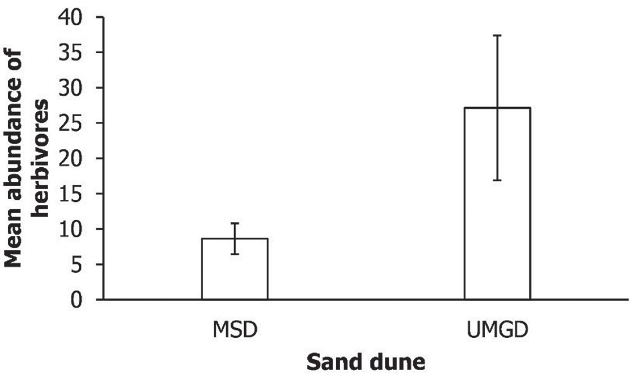

Figure 2: Mean abundance of herbivorous arthropods collected using pitfall traps between the mined-sand dune (MSD) and the unmined grassland dune (UMGD) of Mbolompo, Eastern Cape.

Table 1: Morphospecies richness, abundance, evenness and diversity (represented by z- or t-values and p-values in brackets), as well as morphospecies composition (represented by *Pseudo-F* and p-values in brackets) in the mined-sand and unmined grassland dunes. Significantly different p-values (< 0.05) are bold.

	Detritivores	Herbivores	Omnivores	Predators
Morphospecies richness	-0.69 (0.49)	1.30 (0.21)	1.24 (0.24)	1.14 (0.27)
Abundance	-0.84 (0.41)	2.50 (**0.03**)	-1.43 (0.18)	0.95 (0.36)
Morphospecies evenness	-0.12 (0.91)	-0.36 (0.72)	0.81 (0.43)	1.53 (0.15)
Shannon-Wiener diversity	-0.38 (0.71)	0.32 (0.76)	0.99 (0.34)	1.62 (0.13)
Morphospecies composition	3.12 (**0.0002**)	3.95 (**0.001**)	2.77 (**0.007**)	5,80 (**0.0002**)

Table 2: Correlation (represented by Rho and p-values in brackets) between the percentage of vegetation cover and morphospecies richness and abundance of each functional guild in the mined and unmined grassland dunes. Significantly different p-value (< 0.05) is bold.

	Detritivores	Herbivores	Omnivores	Predators
Morphospecies richness	-0.11 (0.69)	0.44 (0.09)	0.29 (0.28)	0.29 (0.26)
Abundance	-0.11 (0.68)	0.71 (**0.002**)	-0.11 (0.68)	0.15 (0.58)

Table 3: Morphospecies identified by the indicator value analysis (IndVal) as indicators of the sand-mined dune and unmined grassland dune.

Sand-mined dune			**Unmined grassland dune**		
	IndVal	*p*-value		IndVal	*p*-value
Ants			Ants		
Cardiocondyla sp.1	0.78	0.04	*Mesoponera caffraria* Smith	0.85	0.03
Crematogaster sp.1	0.85	0.007	*Tetramorium simillimum* Smith	0.87	0.01
Lepisiota sp.3	0.84	0.03	*Tetramorium* sp.2	0.99	0.002
Tapinoma sp.1	0.90	0.04	Beetles		
Tetramorium sp.1	0.85	0.03	*Stenichus* sp.1	0.87	0.02
Beetles			*Acanthoscelis ruficornis* Fabricius	0.79	0.03
Lophyra sp.1	0.94	0.004	Chrysomelidae 5	0.87	0.007
Rhyssemus sp. 1	0.82	0.03	*Garreta* sp.1	0.79	0.03
Spiders			*Lathrobium* sp.1	0.79	0.02
Asemesthes sp.1	0.82	0.03	Spiders		
Cydrela sp.1	0.79	0.03	*Foveosa foveolate* Purcell	0.94	0.005
Trabea sp.2	0.87	0.009	*Hahnia* sp.1	0.87	0.02
Pardosa sp.1	0.86	0.01	*Trabea* sp.1	0.83	0.02
Pardosa crassipalpis Purcell	0.87	0.01			

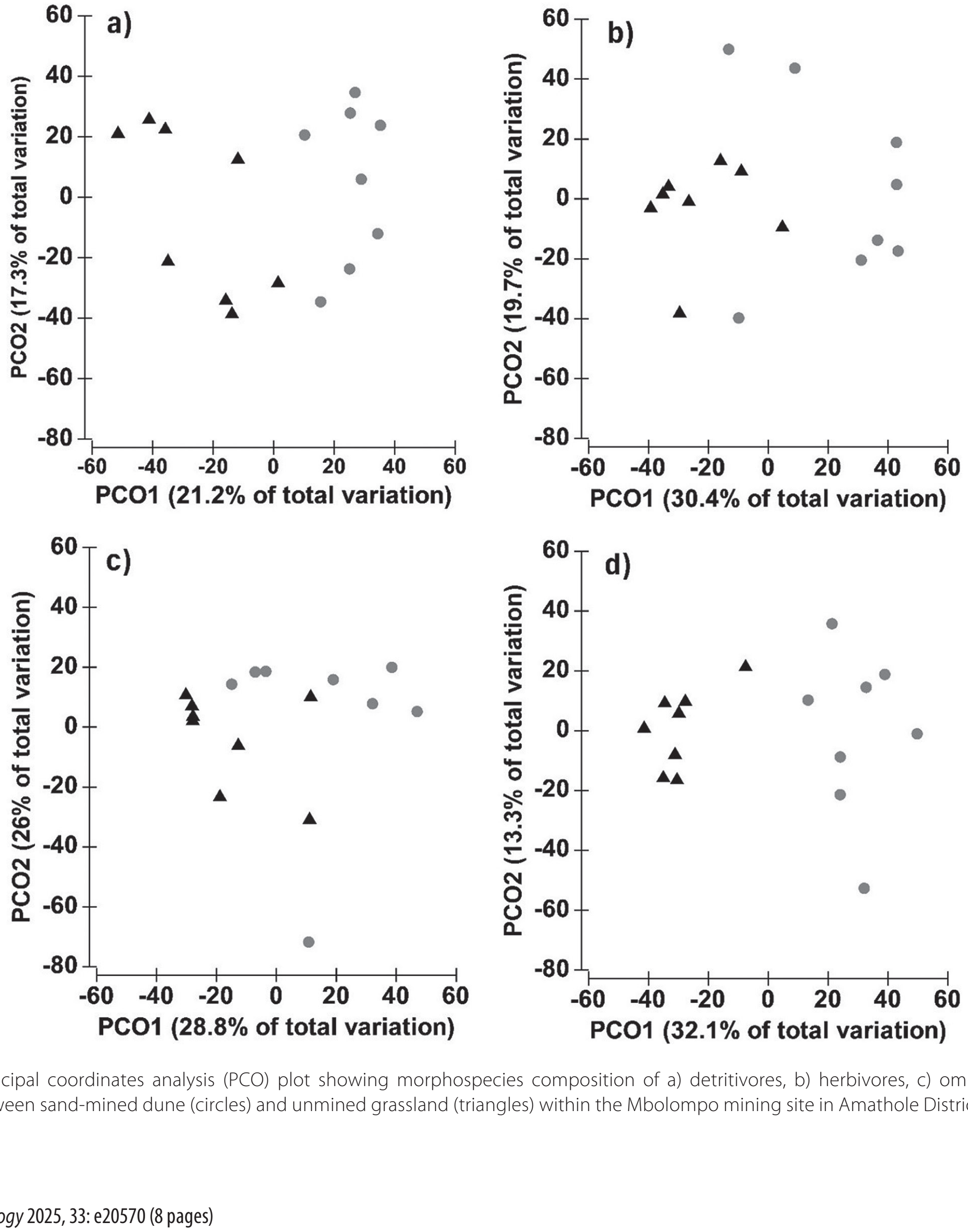

Figure 3: Principal coordinates analysis (PCO) plot showing morphospecies composition of a) detritivores, b) herbivores, c) omnivores and d) predators between sand-mined dune (circles) and unmined grassland (triangles) within the Mbolompo mining site in Amathole District Municipality, Eastern Cape.

Hlongwane et al. (2024) recorded greater abundance of *Pardosa crassipalpis* Purcell in three studied habitat types (sand forest, ecotone and the savanna). However, in our study, *P. crassipalpis* was sampled in the sand-mined dune only, which may indicate that the generalist nature of this species was influenced by vegetation type.

Although sandy soil is dominant in both mined and unmined dune grassland, the frequent occurrence of some species of ants in the sand-mined dune might be due to both the sandy soil and the presence of artificial ponds from the open pits. This is because moist soils from the artificial ponds may have created a conducive environment for some species of *Cardiocondyla*, *Lepisiota* and *Tetramorium* (Sharaf et al. 2017). Similarly, *Lophyra* species, one of the indicators morphospecies of the sand-mined dune, are known to be diverse in sandy areas, especially those near water (Mawdsley and Sithole 2008; Dangalle et al. 2012; Picker et al. 2019). Out of the total abundance of beetles, this tiger beetle was the most abundant morphospecies. Furthermore, identification of a *Rhyssemus* species as an indicator of the sand-mined dune could be because species of this genus prefer sandy areas, including coastal sand dunes (Lim and Bae 2024).

Contrary to our findings, complex habitats support greater species richness and abundance of arthropods than simpler habitats (Gardner et al. 1995). However, when focusing of vegetation presence, according to Sackmann and Farji-Brener (2006) abundance of different arthropod taxa are affected differently by habitat complexity. For example, burnt (simpler) and unburnt (complex) habitats supported similar abundance of beetles, while ant abundance was higher in burnt plots than in the unburnt plots, with the steppe habitat being the most abundant followed by the scrub and then the forest (Sackmann and Farji-Brener 2006). An increase in the percentage of bare ground and simplicity of habitats has been reported to increase abundance (Graham et al. 2004) and species richness (Ossola et al. 2015) of ants compared to complex habitats. According to Gibb and Parr (2010) foraging in ants can be influenced by habitat complexity, because they found that ants detected baits faster in simpler habitats compared to complex habitats. Therefore, the sand-mined dune may not have a decreased morphospecies richness and abundance of ants because of easier foraging. However, in Mexico, ant diversity has been reported to be enhanced by plant species richness and plant cover (Chen et al. 2015). Furthermore, in North Carolina, Menke et al. (2011) recorded low species richness of ants in disturbed open urban areas compared to areas with thick canopy cover.

In Guinea, Yeo et al. (2019) recorded a greater abundance of ant species, such as *M. caffraria* in open habitats (savanna and meadows) compared to the forest habitat. However, in our study, *M. caffraria* was an indicator species of the unmined grassland dune, of which in the context of our study, represented closed habitat. Our study and that of Yeo et al. (2019) defined open and closed habitats differently and focused on different vegetation types (savanna, meadows, forest and grassland). However, in both studies *M. caffraria* was abundant in the habitats dominated by grass. Furthermore, Sharaf et al. (2017) reported that *Tetramorium simillimum* Smith forages on the ground underneath grasses, likely accounting for the sampling in the unmined grassland dune only.

Grazing by cattle took place in our studied areas, however, it was dominant in the unmined grassland dune because of greater vegetation cover compared to the sand-mined dune. According to Wagner et al. (2021) abundance of dung beetles increases in grazed areas compared to ungrazed areas. This is due to the presence of dung from grazers. This can explain the frequent occurrence of a *Garreta* species that was an indicator of the unmined grassland dune. Although abundance of other functional guilds did not differ between the sand-mined and unmined grassland dune, there was greater abundance of herbivorous arthropods in the unmined grassland dune compared to the sand-mined dune. In addition, a Chrysomelidae morphospecies was identified as an indicator of the unmined grassland dune, while no herbivorous morphospecies were indicators of the sand-mined dune. High abundance of herbivores in the unmined grassland dune can be attributed to greater vegetation cover because plant species richness and vegetation cover correlate positively with species richness of arthropods (Diehl et al. 2013; Malumbres-Olarte et al. 2013; Rahman et al. 2015; Gómez et al. 2016). In our study, percentage of vegetation cover did not correlate with abundance nor richness of other functional guilds, however, there was a positive correlation between percentage of vegetation cover and abundance of herbivores. Greater vegetation cover improves arthropod diversity because of increased habitat heterogeneity (Malumbres-Olarte et al. 2013; Rahman et al. 2015). Furthermore, web-building spiders occupy habitats based on prey availability and potential sites for constructing webs, both of which are more available in habitats with high vegetation cover (Roberson et al. 2016). Therefore, the sand-mined dune and the unmined grassland dune that we studied supported different assemblages of predators (which were dominated by spiders) because of differences in habitat requirements. However, Lubin et al. (2020) pointed out that even though most spider species require specific habitats, there are some species that are generalists. Furthermore, predatory arthropods are not influenced by plant species richness (Corcos et al. 2021), and we found no correlation of predatory arthropods with vegetation cover in our study. However, differences in morphospecies composition of all functional guilds between the sand-mined and unmined grassland dunes show that even amongst predatory arthropods, there are specific habitat requirements.

Our study provides evidence that sand mining alters morphospecies compositions due to changes in landscape structure by creating open habitats with limited resources. As a result, the foraging activities of arthropods in the sand-mined dune may have increased, leading to greater catch in pitfall traps. Therefore, similarities in morphospecies richness and abundance between sand-mined and unmined grassland dunes could have been due to resource availability, which may have influenced foraging patterns and the catchability of arthropods. Furthermore, differences in morphospecies composition of arthropod guilds between sand-mined dune and the unmined grassland dune may be because of the limited dispersal abilities and microhabitat specialization of the taxa.

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AUTHORS' CONTRIBUTIONS

IY: conceptualisation, investigation, methodology, data curation, formal analyses and wrote the original draft.
AM: conceptualisation, investigation, methodology, and reviewed and edited the manuscript.

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