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Characterization of Poaceae (grass) species as indicators of the level of degradation in a stretch of riparian forest in Matutina, Brazil

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ABSTRACT

Despite their extreme importance for environmental balance, riparian forests have been severely disturbed over time. This study aimed to identify grass species and determine their distribution in a disturbed stretch of riparian forest along Pimentas creek, in the municipality of Matutina, which is in the state of Minas Gerais, Brazil. Among four plots established within the study area, we recorded *Pennisetum purpureum* Schumach., *Urochloa mutica* (Forssk.) T.Q. Nguyen, *Urochloa decumbens* (Stapf) R.D. Webster, *Paspalum notatum* Flüggé and *Andropogon bicornis* L. The most common species was *Pennisetum purpureum*, which occurred in all of the plots, more frequently in those that had been disturbed. The proportions of exotic and native grasses, as well as their distribution, differed significantly among the plots. The distribution of the grass species varied according to the level of degradation of the creek bank, occurring more frequently where the bank had been disturbed. Therefore, we assume that grasses can be used as indicators of degradation in riparian zones. We also found that grasses are less efficient in preventing erosion than is the typical riparian vegetation.

Key words: riparian zone, perturbation, creek banks, bioindicators

Introduction

The term "forest degradation" can be understood as changes in a forest that affect its composition and function, reducing its ability to provide goods and services (FAO 2001). Forest degradation leads to structural losses, reduced productivity and less native species diversity. Although degraded areas might still contain some trees, they lose their ecological integrity (Lamb & Gilmour 2003).

Riparian forests, defined as areas of woody vegetation along the banks of rivers or other watercourses, constitute one of the most degraded forest ecosystems on the planet. In plant ecology terms, a riparian zone comprises the population of plants surrounding a watercourse, regardless of the principal region of occurrence or floristic composition of that population (Ab'Sáber 2004).

Riparian forests have many functions that are crucial to sustaining the ecosystem, such as protecting water resources; balancing the local flora and fauna; regulating the hydrological cycle of watersheds; maintaining water quality; preventing erosion of the banks and siltation of the bed of the watercourse; and acting as a natural filter for possible contaminants such as chemical residues, pesticides and fertilizers. Bodies of water that are surrounded by preserved riparian forest are less affected by such contaminants and help maintain the stability of ecosystems (Noffs *et al.* 2000; Primo & Vaz 2006). For these and other reasons, it is necessary to preserve the remaining riparian forests and to restore riparian zones that have been degraded.

Certain animals and plants are important allies of humans and nature because they are environmental indicators, providing evidence of various changes occurring in the environment, indicating when it has been contaminated or is being destroyed. Such organisms are designated biomarkers and occur in quantities proportional to the levels of imbalance (Oliveira *et al.* 2004).

Grasses belong to the family Poaceae, which comprises approximately 790 genera and 10.000 species. In Brazil, approximately 200 genera and over 1350 species of Poaceae having been recorded. Poaceae occur mainly in open environments, are generally anemophilous and represent the principal component of grasslands worldwide. Although grasses are less common within forest formations, various species of the subfamily Bambusoideae inhabit forests, as do some species of the subfamily Panicoideae (Boldrini *et al.* 2008; Castro & Lorenzi 2008).

Some studies have addressed the potential role of grass species as bioindicators of atmospheric pollution (Oliva

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& Figueiredo 2005) and of toxic compounds in the soil (Siciliano *et al.* 2009), as well as in the phytoremediation of soils contaminated with heavy metals (Barbosa *et al.* 2005). However, there have been only a few studies of grasses as bioindicators, especially as bioindicators of degradation, and additional studies of the topic are warranted.

In view of the evidence presented above, the objectives of the present study were to identify, characterize and determine the positioning of grasses along a stretch of creek in southeastern Brazil. We hypothesized that the concentration and richness of grass species would be higher in the degraded areas, suggesting that they are indeed bioindicators of such degradation.

Material and methods

Study site

The study site is in the municipality of Matutina, which is within the Alto Paranaíba macro-region of the state of Minas Gerais, located in southeastern Brazil. Matutina occupies an area of approximately 260 km^2 (at 19°13'19.8"S; 45°58'08"W; elevation, 1149 m), 306 km from the state capital of Belo Horizonte, and has a population of 3761. The average annual temperature is 22.1°C (range, 16.4-29.2°C), and the average annual rainfall is 1230.3 mm. Matutina is within the *cerrado* (savanna) biome, with a topography that is 5% flat, 50% undulating and 45% mountainous (IBGE 2010; Minas Gerais 2012).

The São Francisco River Basin comprises the fluvial system of Matutina and those of other municipalities. The principal rivers are the Abaeté and the Borrachudo (Minas Gerais 2012). In the area surrounding Matutina are the creeks Estiva, Martins and Pimentas (Prefeitura Municipal de Matutina 2009).

The study site selected was on Pimentas creek, downstream of Matutina. As shown in Fig. 1, we delineated four plots of 600 m^2 each (200 × 3 m): two on the left bank, designated "riparian" (a remnant of primary forest) and "adjacent" (downstream of the "riparian" plot); and two on the right bank, designated "opposite" (directly across from the "riparian" plot) and "deforested" (downstream of the "opposite" plot). With the exception of the "riparian" plot, all of the plots exhibited degradation, to varying degrees, as quantified by the absence of the native vegetation. For example, the "opposite" plot contained many juvenile trees, as well as some adult individuals, whereas the "adjacent" plot contained only a few trees and two bamboo groves. The "deforested" plot contained no trees or saplings.

To determine the position of the grasses, each plot was divided into 20 quadrants (10 × 3 m each). Each quadrant was further subdivided into three strips (10 × 1 m each), designated positions 1, 2 and 3 (Fig. 2), position 3 being the farthest from the bank.

Procedures

The field work was conducted in 2009, at the end of the dry season (August and September). In each quadrant, we made photographic records and notes of the current status of the watercourse (soil structure, siltation, erosion, etc.), of the grasses present and of their position in relation to the creek bank (position 1, 2 or 3). We collected botanical material for voucher specimens and for taxonomic identification by experts.

To determine whether the proportions of native and exotic grasses differed among the plots, as well as to determine whether their positions differed within plots, we performed statistical analysis using contingency tables and chi-square tests at a 5% level of probability (Zar 2010), together with descriptive statistics such as means, percentages and frequencies (Farias *et al.* 2008).

Results and discussion

Within the study site, we recorded five grass species: *Pennisetum purpureum* Schumach.; *Urochloa mutica* (Forssk.) T.Q. Nguyen; *Urochloa decumbens* (Stapf) R.D. Webster; *Paspalum notatum* Flüggé; and *Andropogon bicornis* L. The first three are exotic (native to Africa and invasive in Brazil), and the last two are native to the Americas, including almost all of Brazil (Lorenzi 2000). The most common species was *Pennisetum purpureum*, which occurred in more than half of the 60 quadrants sampled in the degraded plots, followed by *U. mutica* and *Paspalum notatum*, each of which occurred in approximately 30% of the quadrants, whereas *U. decumbens* occurred in 23%, and *A. bicornis* was the least common species, occurring in only 5% (Fig. 3). Because it had a closed canopy, the "riparian" plot was expected to contain some exotic grasses. However, *Pennisetum purpureum*, which has high photosynthetic efficiency (C_4 metabolism) and is a major invasive exotic species that dominates other species, especially in wet lowlands (Quesada *et al.* 2004), was recorded in five quadrants. In the "opposite" plot, we recorded primarily *A. bicornis* and few of the other species, with the exception of *Pennisetum purpureum*. In the "adjacent" plot, there was a higher number of quadrants containing all of the grass species except (again) *A. bicornis* (Tab. 1).

The "deforested" plot showed the highest species richness, containing all of the grasses sampled, and was the only plot in which *Andropogon bicornis* was recorded, albeit in only a few marshy quadrants (Tab. 1). Such moist locations are preferred by *A. bicornis*, which accepts any type of soil, having an advantage over other species in nutrient-poor, acidic soils (Rondon Neto & Gama 2003), and invades depleted pastures, as well as roadsides and vacant lots (Lorenzi 2000).

Overall, the most frequently recorded species was *Pennisetum purpureum*, which was present in all plots and in approximately half of the quadrants, and the least frequently

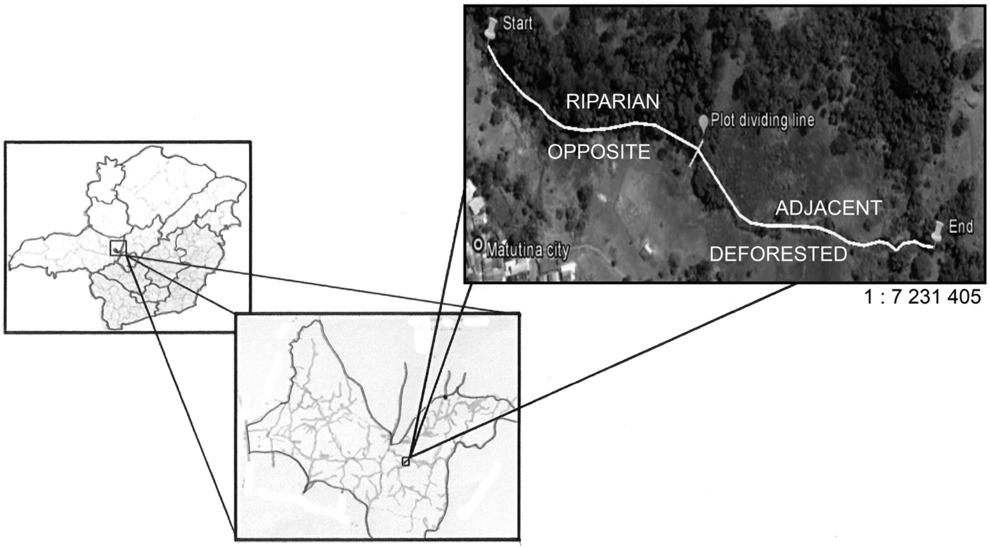

Figure 1. Map of the study site, on which the "start" and "end" points delimit the portion of creek along which the plots "riparian", "opposite", "adjacent" and "deforested" (600 m² each) were established. Pimentas creek, municipality of Matutina, state of Minas Gerais, Brazil.

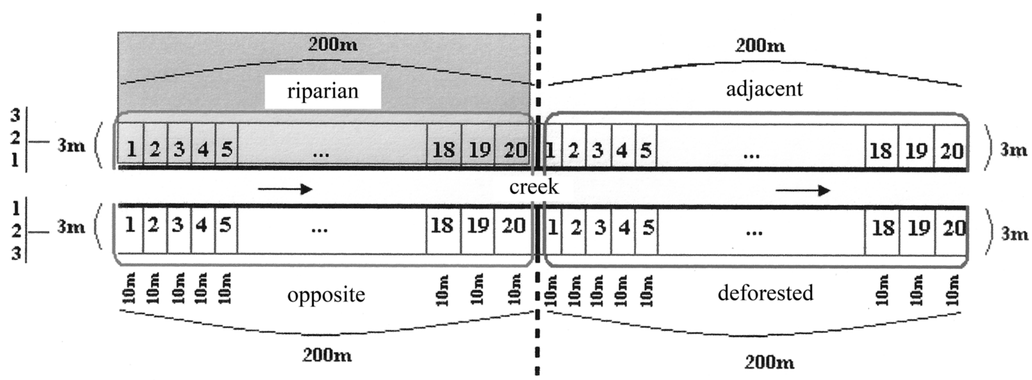

Figure 2. Schematic representation of the experimental design, indicating the four plots established on the right and left banks of Pimentas creek, municipality of Matutina, state of Minas Gerais, Brazil.

Figure 3. Proportional frequency of grass species—*Urochloa decumbens* (Stapf) R.D. Webster; *Pennisetum purpureum* Schumach.; *Urochloa mutica* (Forssk.) T.Q. Nguyen; *Paspalum notatum* Flüggé; and *Andropogon bicornis* L.—in the three degraded plots evaluated. Pimentas creek, municipality of Matutina, state of Minas Gerais, Brazil.

Table 1. Frequency of the grass species sampled in the plots studied along Pimentas creek, municipality of Matutina, state of Minas Gerais, Brazil.

Species*	Plot				Total
	Riparian	Opposite	Adjacent	Deforested	
	n of quadrants	n of quadrants	n of quadrants	n of quadrants	n of quadrants
Urochloa decumbens	-	04	04	06	14
Pennisetum purpureum	05	14	15	05	39
Paspalum notatum	-	01	03	14	18
Andropogon bicornis	-	-	-	03	03
Urochloa mutica	-	01	05	14	20

*Species identified: *Urochloa decumbens* (Stapf) R.D. Webster; *Pennisetum purpureum* Schumach.; *Paspalum notatum* Flüggé; *Andropogon bicornis* L.; and *Urochloa mutica* (Forssk.) T.Q. Nguyen.
Riparian – a remnant of primary forest; Opposite – directly across from the "riparian" plot; Adjacent – downstream of the "riparian" plot; Deforested – downstream of the "opposite" plot.

recorded species was *Andropogon bicornis*. Each of the remaining species occurred in at least 14 of the quadrants sampled. According to Lorenzi (2000), *Pennisetum purpureum* is an aggressive plant that can reach up to 3.5 m in height, produces considerable biomass and is difficult to control, which explains its widespread occurrence in our study site.

The frequency of grasses in the plots sampled within the study area is shown in Tab. 2. We obtained a significant result (χ^2 = 15.471, critical value of $\chi^2_{0.05,\ 3}$ = 7.815). On that basis, we can conclude, with 95% confidence, that the proportion of native and exotic grasses differed among the plots, exotic species being considerably more common than were native species.

The distribution of grasses also differed significantly among the plots (χ^2 = 14.839, critical value, $\chi^2_{0,05,3}$ = 12,592). The grasses occurred most often in position 1 and on a gradient to least often in position 3 (Tab. 3). In riparian forests, clearings favor the approximation of grasses to the banks of a watercourse, because they provide a favorable environment, with higher temperatures and greater light intensity, complimenting the greater availability of water. According to Odum (1988), C_4 plants are adapted to high temperatures and high light intensities, which makes them more productive than are C_3 plants under such conditions. In addition, C_4 plants use water more efficiently, being abundant in warm, tropical regions and rare in forests and regions where the temperature and light intensity are low.

In general, we observed an average of two grass species in each position. Considering only the degraded plots, we found little difference among positions 1, 2 and 3, in terms of the frequencies of grass species (37%, 32% and 31%, respectively). In the "riparian" (undegraded) plot, *Pennisetum purpureum* was noted close to the creek, where there were clearings, favoring its establishment. Because they are C_4 plants, grasses produce greater dry mass under conditions of high temperature and moderate water stress, and, in places with high light intensity, their great carboxylation efficiency gives grasses a competitive advantage (Larcher 2000). Except in such clearings, the forest areas studied had a closed canopy, and, under the shade of large trees, there was no grass.

In the "opposite" plot, the species richness was greatest in position 3 (44%), followed by position 2 (32%) and position 1 (24%). This can be explained by the fact that there are trees present on the slope on that side of the creek (either by natural regeneration or because they had not been selected for harvesting), shading the soil and impeding or preventing the development of grasses. In the deforested areas, grass species were prevalent on the creek bank because of the lack of riparian vegetation. Where the native vegetation has been removed by human activities, secondary vegetation develops. In the state of Minas Gerais, secondary vegetation currently accounts for a large part of the forest cover (Rondon Neto & Gama 2003).

The distribution of each grass species in the various types of plots is noteworthy (Tab. 4). It is clear, for example, that in the "opposite" plot, the frequency of *Pennisetum purpureum* was higher, especially in position 3, and we recorded only one occurrence of *Paspalum notatum* (in position 1). *Pennisetum purpureum* was also more common in the "adjacent" plot, albeit closer to the bank. In the "adjacent" plot, *Urochloa decumbens* was distributed uniformly. In the "deforested" plot, *Paspalum notatum* was most common in position 3; *Andropogon bicornis* was recorded only in positions 2 and 3; and *U. mutica* occurred most often in position 1. Therefore, each species of grass was distributed differently along the creek and in characteristic positions, varying depending on the conditions and environmental resources, as well as the intrinsic aspects of each. *Paspalum notatum* is a species that has better metabolic activity, with greater production of forage in areas with average temperatures above 15°C (Haddad *et al.* 1999). Otero (1961, cited in Rosa *et al.* 1999) concluded that *U. mutica* handles water surpluses well and is particular about soil type, preferring lowland soils that are fertile and have good moisture content. In a study conducted by the Hórus Institute (Instituto Hórus 2009), *U. decumbens* was found to be drought resistant, to

Table 2. Frequency of grasses, by species type, in the plots studied along Pimentas creek, municipality of Matutina, state of Minas Gerais, Brazil.

Species type	Plot				Total
	Riparian	Opposite	Adjacent	Deforested	
	n of quadrants (χ^2)	n of quadrants (χ^2)	n of quadrants (χ^2)	n of quadrants (χ^2)	n of quadrants
Exotic	5 (3.6842)	17 (13.2631)	17 (14.7368)	17 (24.3158)	56
Native	0 (1.3158)	1 (4.7368)	3 (5.2631)	16 (8.6842)	20
Total	5	18	10	33	76

Riparian – a remnant of primary forest; Opposite – directly across from the "riparian" plot; Adjacent – downstream of the "riparian" plot; Deforested – downstream of the "opposite" plot.

Table 3. Distribution of grasses, by proximity to the water, in the plots studied along Pimentas creek, municipality of Matutina, state of Minas Gerais.

Position*	Plot				Total
	Riparian	Opposite	Adjacent	Deforested	
	n of quadrants (χ^2)	n of quadrants (χ^2)	n of quadrants (χ^2)	n of quadrants (χ^2)	n of quadrants
1	5 (3.0734)	10 (15.7514)	26 (19.5932)	27 (29.5819)	68
2	2 (2.5311)	13 (12.9717)	18 (16.1356)	23 (24.3616)	56
3	1 (2.3955)	18 (12.2768)	7 (15.2712)	27 (23.0565)	53
Total	8	41	51	77	177

*Distance from the creek bank: position 1 = 0-1.0 m; position 2 = 1.1-2.0 m; position 3 = 2.1-3.0 m.
Riparian – a remnant of primary forest; Opposite – directly across from the "riparian" plot; Adjacent – downstream of the "riparian" plot; Deforested – downstream of the "opposite" plot.

Table 4. Frequency of each species of grass by position in the four plots sampled Pimentas creek, municipality Matutina / MG.

Plot	Position*	Species**				
		U. decumbens	*P. purpureum*	*P. notatum*	*A. bicornis*	*U. mutica*
	1	-	5	-	-	-
Riparian	2	-	2	-	-	-
	3	-	1	-	-	-
	1	1	8	1	-	-
Opposite	2	1	11	-	-	1
	3	4	16	-	-	1
	1	3	15	3	-	5
Adjacent	2	3	10	2	-	3
	3	3	3	1	-	-
	1	6	5	4	-	12
Deforested	2	3	1	8	1	10
	3	2	-	14	3	8
	1	10	33	8	-	17
Totals	2	7	24	10	1	14
	3	9	17	15	3	8

*Distance from the creek bank: position 1 = 0-1.0 m; position 2 = 1.1-2.0 m; position 3 = 2.1-3.0 m.
**Species identified: *Urochloa decumbens* (Stapf) R.D. Webster; *Pennisetum purpureum* Schumach.; *Paspalum notatum* Flüggé; *Andropogon bicornis* L.; and *Urochloa mutica* (Forssk.) T.Q. Nguyen.
Riparian – a remnant of primary forest; Opposite – directly across from the "riparian" plot; Adjacent – downstream of the "riparian" plot; Deforested – downstream of the "opposite" plot.

adapt well to humid tropical climates, to be somewhat cold tolerant and to grow in various soil types, although requiring soil that has good drainage and is moderately fertile.

Throughout the study site, we found a considerable amount of trash, especially plastic bags, plastic bottles, household items, shoes and even car tires. Thrown from the banks and subsequently carried downstream by floods or by the normal current, trash was found floating in the creek, stuck in branches, at low-water points, in ravines, on rocks and at siltation sites. The accumulation of trash was greatest in the "riparian" plot, litter being found in 15 of its 20 quadrants, probably because the objects get stuck in the branches of trees and shrubs that are in contact with the water. Cunha & Guerra (2002) warned that trash dumped on lots, streets and hillsides, filters into the water supply and increases the danger of contamination, potentially exposing the population to diseases such as hepatitis and typhoid, as well as gastrointestinal diseases.

Within the "deforested" plot, there were nine siltation sites and five erosion points. The "adjacent" and "deforested" plots had four siltation sites each, with two and three erosion points, respectively. Although grasses are not highly efficient in preventing erosion, the creek banks would probably be worse off without them. In a study conducted in an area of *cerrado* within the Federal District of Brasília, Chaves, Rosa & Santos (1997) concluded that the riparian zone that was occupied by pastures or agricultural lands allowed greater runoff and sediment export than did the riparian zone that was occupied by gallery forests, which are more efficiency in retaining sediment.

Forest vegetation controls erosion by acting as a physical barrier against direct effects and by the support provided by the roots, which hold the soil in place along the banks of a watercourse. Forests act as a drain for the deposition of material, capturing sediment from the higher elevations, preventing it from reaching the water and thus preventing siltation (Ferraz 2001). Our data support that assertion because we found no evidence of sedimentation or erosion in the "riparian" plot, indicating that riparian vegetation is more efficient in fixing soil than are grasses.

Another feature of the study area was that the water was a whitish color, with a characteristic odor, due to the release of dairy waste and urban sewage from the town upstream. The dumping of urban sewage, agricultural fertilizers and detergents into watercourses releases large amounts of nitrates and phosphates into fluvial systems, as do industrial processes, the collective result being cultural eutrophication (Primack & Rodrigues 2001).

We also recorded grasses on rocks within the creek, showing the invasion and dispersal potential of grass species, especially *Pennisetum purpureum* and *Urochloa mutica*. According to Matos & Pivello (2009), grasses of African origin, imported in order to create pasture for cattle, have become invasive in Brazil and are serious threats to biodiversity, especially in warm, open environments, where they compete with native populations. The authors stated that such grasses can alter the fire regime of the invaded areas because they increase the amount of flammable biomass during the dry season, as well as because the intense uptake of nutrients during their growth might alter nutrient cycles, such as the nitrogen cycle.

In some quadrants of the degraded areas, we observed no grasses; those sites were occupied by clumps of bamboo (*Bambusa* sp.) several meters high, which shaded but also covered the soil with their litter. Oliveira *et al.* (2008) used bamboo fiber as mulch and noted its potential for inhibiting infestation by spontaneous vegetation. Mulch, in addition to being a mechanical barrier, is capable of changing the humidity, light absorption and surface temperature of the soil, making it difficult for other species to break dormancy and germinate their seeds.

Another plant species that was quite abundant in some quadrants, where the ground was damp, was *Hedychium coronarium* J. König, which was often found in association with *Pennisetum purpureum* in position 3, where there were no trees. *H. coronarium*, a macrophyte native to the Himalayas and Madagascar, was introduced into Latin America over three centuries ago and is now considered an invasive species, thriving in places where the light intensity is high and the soil is humid (Boeger *et al.* 2007). *H. coronarium* belongs to the family Zingiberaceae, and fragments of its rhizomes can be dispersed through watersheds, allowing the species to establish itself in new regions (Santos *et al.* 2005).

Conclusion

The fact that the concentration of grasses on the banks of Pimentas creek was highest in the "adjacent" and "deforested" plots, together with the fact that grass cover diminished where there was tree cover (in the "opposite" plot) and was absent from the "riparian" plot (except in clearings), shows that human intervention has facilitated the establishment of grass species in the study area, and the same probably occurs under similar conditions in other areas of *cerrado*. Whether purposely introduced in order to create pasture for cattle or the product of secondary succession, grasses, especially exotic or invasive species, were found to constitute an indication that the area was affected by some kind of human activity, as well as being a measure of the level of degradation. We found that the richness and frequency of grass species was highest in the totally degraded plots and decreased in parallel with increases in the level of afforestation.

As observed in this study, degraded creek banks that are occupied by grasses are more susceptible to the processes of sedimentation and erosion, because the root systems of grasses do not retain sediment as well as does the native riparian forest vegetation. Likens (1992) described the importance of riparian vegetation and its ecological and hydrological functions, underscoring the idea that the banks of the channel are stabilized by the roots of trees, which also catch and hold the annual inputs of leaves and other debris, an important source of organic matter for the soil and creek bed.

Although invasive exotic grasses were present in areas that were degraded, this phenomenon should not be viewed negatively, but rather as a source of knowledge for the understanding of the effects of human activity and the level of degradation. This knowledge could lead to new strategies for the management and restoration of the site under study and others like it.

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