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Response and Simulation of Vegetation in Desert Scenic Spot to Tourists' Trampling Disturbance

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Abstract

A large number of tourists had a devastating effect to the scenic area. Shapotou and Huangshagudu scenic spots in Ningxia were selected as the research areas. The fait accompli method was used to investigate the response of footpath in the above scenic spots to tourists' stampede interference. Three different angles and different vegetation types of quadrats were set up to simulate tourists' stampede mode and observe the vegetation recovery after stampede. The results showed that: (1) The tourist trampling disturbance mainly were limited 0-4 meters distance from the tourist trails, but there was difference for different tourist trails. (2) The index of land cover impact (*ILCI*) of the investigating sections indicated the 1 meter distance from tourist trail is seriously disturbed; Because of the palisade on both sides of the plank road, the average value of *ILCI* in north of Shapotou (investigating section 4) is less than 44.9%.(3)With the increase of tourist activity,the coverage of vegetation decline, the height of plant reduce, the quantity and kinds decrease,soil crust fragmentation increase.(4)Because of different angle of sand dune, the impact of tourist activity to vegetation and soil is different.Vegetation and biological crust of sample C which is the biggest angle suffer from the devastation.(5)Based on limits of acceptable change (*LAC*) visitor questionnaires, the limit of acceptable change in ground coverage was 16.4%. The vegetation coverage should be below this level at desert scenic spots. It shows that there is natural incompatible relationship between tourist demand to the empty and desolate desert and desert ecological management. The results also indicated that the current tourism disturbance had some negative effect on the tourist experience and ecosystem.

Key words: Desert scenic spot; Trampling disturbance; Response; Simulation

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As the scope of tourism activities expands and its intensity increases, its role and influence on the ecological environment become more obvious. With the rapid development of desert tourism in China, the ecological environment, resources and society brought about by it are becoming more obvious (Mi and Liao, 2005). Ningxia is a region rich in desert tourism resources. The desert-type tourist areas represented by Shapotou, Shahu and Huangshagudu are the most characteristic tourist spots in Ningxia and Northwest China.

When the number of tourists exceeds the environmental capacity of the desert tourist area, it will bring damage even destructive effects to the scenic spot, which will bring great negative impact on the ecological environment of the scenic spot, the protection of desert resources and the psychological feelings of tourists. As the impact deepens, it will also have serious consequences. The interference of human tourism activities has become one of the most important factors affecting the stability of ecosystems in desert scenic spots.

The impact of tourism activities on the ecological environment is inevitable (Dong, et al, 2013). The research on the impact of tourism activities on the ecological environment can be traced back to the European and American countries in the 1930s (Bates, 1935; Bates, 1938). For more than 80 years, the impact of tourism activities on vegetation has always been the focus of research. Scholars have summarized the impact of tourism development on the natural environment from five aspects: soil, animal, vegetation, water and noise, and realized the dialectical view of the impact of tourism development on the environment (Smith, 1992). The researches focused on the impact of tourism activities, especially natural tourism activities, on soil and on vegetation (Spink, 1994; Cole, 1990; Kuss, Graef, & Vaske, 1990; Hammitt & Cole, 1987). In recent years, European and American countries have been theoreticalized and systematic in the study of tourism environment, forming a more systematic evaluation method of tourism environmental impact (Kim, Borges, & Chon, 2005; Ballantyne, Packer, & Falk, 2010; Carić & Mackelworth, 2014; Michailidou, et al, 2016; Tan, et al, 2017; Jeyhun, et al, 2019; Pope, et al, 2019). China's research started relatively late. After the 1990s, many scholars have studied the quality of tourism environment, the study of tourism environmental carrying capacity, the study of tourism on environmental forms, and the countermeasures of tourism environmental protection on the basis of extensively absorbing foreign research results. A wide range of theoretical discussions have been made in research and other aspects, and a series of theoretical discussions have been published (Liu & Bao, 1996; Bao, Wu, & Lu, 1999; Lu, 1996; Cui, 1995). In addition, many scholars have also done some detailed and in-depth work in empirical research. They have explored tourism in terms of population, vegetation landscape, animal, water quality and soil characteristics in Emei Mountain, Mount Huangshan, Zhangjiajie Forest Park and other places. The relationship between the intensity of interference and various environmental factors, different tourism development strategies for different types of natural tourist attractions, and protection measures for resources and environmental problems in tourism development (Jiang, et al., 1996; Lu, 1996; Deng, et al, 2000). These studies show that the natural ecological environment of China's tourist attractions is seriously affected by tourism development and tourism activities, which are highlighted by the effects on vegetation, soil, water, biodiversity and the atmosphere.

In recent years, the rapid development of tourism based on natural resources has become the most important form of tourism in the world. Scholars have carried out a lot of research on environmental response under tourism interference, but there are fewer studies on ecosystem details and landscape diversity, and there is also a lack of response to desert ecosystems. Tourism activities are selectively affected by tourists and visitors and tourists such as camels and horses as tourist tools interfere with the desert ecological environment, and the community structure and diversity of desert crusts and desert vegetation are affected to varying degrees. Activities such as the construction of a large number of tourist facilities and the rolling of vehicles have also destroyed the landscape, community structure and diversity of vegetation.

Some scholars have done a lot of work on the tourism environment impacts of ecologically sensitive areas such as nature reserves and forest parks, and have achieved many effective results. However, the desert scenic spot is not the same as the ecological environment, resource endowment and tourism products of the above-mentioned scenic spots. The mechanism of influence of tourists' behavior on the scenic spot is also very different. Through the monitoring of the impact of tourism activities on the desert ecological environment, the evaluation of the response of the footpath to the tourists' activities, and the simulation experiment of the desert vegetation trampling on the tourists, this study attempts to seek the tourism development and management mode suitable for the desert scenic spot, so as to make the sustainable use of the desert tourism resources.

1. SURVEY OF RESEARCH AREAS

This study selects two unique desert scenic spots in Ningxia,the 5A Shapotou Scenic Area and the 4A Grade Huangshagudu Scenic Area as the study area, mainly considering that the tourism resources of the two scenic spots belong to the typical landscape type of the arid area, and reflects the environmental impact mechanism of scenic spots in different stages of development. Shapotou Scenic Spot is an early scenic spot for desert tourism in China. As the first national desert nature reserve and tourist area in China, it attracts a large number of Chinese and foreign tourists and is relatively mature. As an emerging force in Ningxia desert tourism, Huangshagudu Scenic Area has developed strongly in recent years and is a potential desert tourism hotspot. Shapotou and Huangshagudu were selected as research objects, because they have certain typicality and representativeness in the development of desert tourism in Ningxia; exploring their tourist behavior characteristics and environmental response can represent the general situat of Ningxia desert scenic spot to a certain extent.

Shapotou Scenic Area (37°27′16″-37°29′5″N,104°57′58″-105°1′16″E) is located in the southeastern edge of Tenggeri Desert, 20 km west of Zhongwei City, Ningxia Hui Autonomous Region, with an elevation of 1230-1569m, bordering on the Yellow River. It is a scenic area integrating desert, Yellow River, oasis and alpine mountains. It is known as "Desert Park on New Continental Bridge".Situated in the transitional zone between desert and grassland, desert and oasis, the scenic spot is famous for its large and dense grid-shaped crescent dune chain.

Huangshagudu Scenic Area (38°32′58″-38°34′21″N, 106°31′42″-106°33′22″E) is located in Yueya Lake Township, Xingqing District, Yinchuan City, 52 km away from Yinchuan, surrounded by Mu Us Sandy Land and Ordos Platform. It is one of the eight scenic spots in Ningxia during the Ming and Qing Dynasties. The scenic spot combines the natural landscape of Changhe desert, wetland lakes and rural villages. The restoration of wetland and the prevention and control of desert in Huangshagudu are closely related to the ecological security of Yinchuan City, the capital of Ningxia.

2. RESEARCH METHOD

2.1 Selection of Observation Transect

According to the tourist volume distribution data of the Three Desert scenic spots (Shahu, Shapotou and Huangshagudu) in the past five years, the peak season of Ningxia desert tourism is from May Day Holiday to Corban Festival. After the end of September, the tourist volume distribution shows obvious node polarization. Most of the tourists are concentrated in the Mid-Autumn Festival, the National Day holiday and the Corban Festival. The number of tourists in other periods is very small. Walkway Survey and Research Selected in August 2012.At this time,the desert tourism in Ningxia is in the peak period of tourists, and the instantaneous pressure of tourism activities on the environment is also in a high value period.

According to the principles of representativeness, typicality, uniformity and matrix stability of desert biology survey sample selection, this study chose the scenic spots of Shapotou and Huangshagudu to investigate the walkway. The survey site was selected to be about 100 m north of the ticket office of Huangshagudu Wetland Park (sample belt 1), east of the tourist service center (sample belt 2), and surfing. Car Lane (sample belt 3) and boardwalk (sample belt 4) in northern Shapotou District are the only way to enter desert scenic spots. Sample belt 3 is the natural lane of desert recreation project surfing car.Sample belt 1 at 38°33′10″N, 106°32′24″E,is the only way for tourists to transfer from surfing cars to enter desert scenic spots. More than 80% of tourists pass through the scenic spots, which is typical of tourists' activities. The walkway is a wooden trestle, consisting of sleepers about 82cm in length and 30cm in width. About 20-30 cm above the surface, with shrub-grass complex ecosystem on both sides, visitors can walk down the trestle to exert influence on the surrounding vegetation of the trail, such as climbing flowers and trees, taking pictures, resting, etc. The second sample belt is located at 38°33′28″N, 106°31′58″E, which is a mixed public trail for tourists, surfing bicycles and camel riders. Influencing mechanism is restricted by many factors. Walkway is formed naturally with a width of 3.54m, sandy road and shrub-grass ecosystem on both sides. The three sample belts are at 38°33′57″N, 106°32′12″E. They are natural lanes of surfing car entertainment projects in scenic spots, and have typical effects of entertainment projects. Tourists seldom involve in them. There are many wheel marks on the surface with a width of 5.6m and grass cover ecosystem on both sides. The four transect belts are located at 37°28′4″N, 104°59′43″E. They are the walkway leading to the northern area of Shapotou. The wooden walkway is 1.8m wide and 30-40cm above the surface. There are fences on both sides of the walkway. The fence is composed of wooden piles and cables with a height of about 1.2m. The walkway is separated from the sand control area, which is an ideal sample for studying the obstacle mechanism of tourists'activities. In the survey sample area, the center is the walking path, the outside of the walking path is taken as the beginning, extending to both sides,Five 1*1m quadrats are set up (the number of quadrats is reduced appropriately when encountering steep slopes or riverbanks). In the homogeneous area 5 meters away from the edge of the sample area, tourists have no influence or less influence. A 1*1m control quadrat is set up (Figure 1).

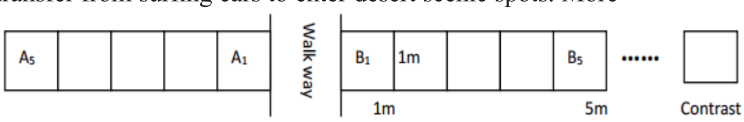

Figure 1
The design of investigating sections

The observation results of plant species and vegetation height were recorded respectively. The survey items include the width of the walking path, plant species, the slope of the walking path, the slope of the walking path, the soil crust fragmentati, the type and quantity of garbage. The response of vegetation and soil to disturbance was estimated by the method of fait accompli analysis and data comparison and statistics between disturbed sample area and control sample area.

2.2 Selection of Experimental Transect

The experimental area is located in the northeast side of the main footpath adjacent to the surfer interchange of Huangshagudu scenic spot, a homogeneous area rarely affected by tourism activities, about 50-100m away from the footpath, which is a potential tourist activity area. After nearly ten years of management by the scenic spot company, the sand dunes in the sample area have been gradually fixed, and the vegetation type has changed from desert to desert grassland. The average vegetation coverage is more than 40%, and the growth thickness of desert crust is 0.3cm.

Sample A (1m×3m) contains 5 experimental plates (1m × 0.5m) and 1 contrast plate (1m × 0.5m). All plates are set parallel to the contour of sand dune (Figure 2), and the trampling treatment of 25, 75, 150, 300 and 700 steps are respectively tested; sample B experiments the trampling treatment of 25, 50, 100, 200 and 500 steps respectively; sample C contains 4 experimental plates and 1 control plate 10 steps, 20 steps, 30 steps and 50 steps of trampling were tested respectively. The Experimenter (weighing about 83kg) trampled once in the investigation sample with natural gait as one step.

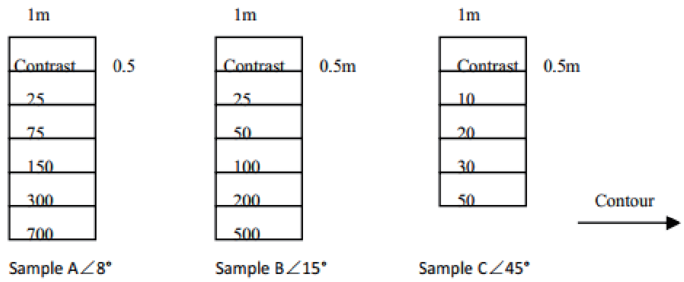

Figure 2
Experiment sample area design

2.3 Index Selection

On the basis of previous studies, the change degree of vegetation and desert epidermis after disturbance can be obtained by comparing the data obtained from the sample area survey with the unaffected control area.

2.3.1 Cover Reduction and Floristic Dissimilarity

Cover Reduction (*CR*, %) and Floristic Dissimilarity (*FD*,%) parameters proposed by Cole were used to calculate vegetation coverage and species interference index (Cole, 1990).

$CR=(C_2-C_1)\times 100/C_2$ (1)

In the formula, C_1 is the vegetation coverage of the affected sample area, C_2 is the vegetation coverage of the undisturbed control sample area.

$FD=\sum|Pi_1-Pi_2|/2$ (2)

In the formula, P_{i1} is the number of a plant in the affected area and P_{i2} is the number of the plant in the unaffected sample area.

2.3.2 Height Reducation (*HR*, %)

$HR=(H_2-H_1)\times 100/H_2$

In the formula, H_1 was the average plant height in the measured area, and H_2 was the average vegetation height in the undisturbed control area.

2.3.3 Soil Crust Fragmentation (*SCF*, %)

The average crust fragmentation of desert crust was obtained by averaging the crust fragmentation measurements at each survey site in the sample area. The crust fragmentation degree of desert affected by tourists can reflect the response degree of disturbance on the surface of desert, especially fixed and semi-fixed dunes.

$SCF=(SCF_1-SCF_2)/SCF_2\times 100$

In the formula, SCF_1 is the desert crust fragmentation degree in the affected sample area and SCF_2 is the desert crust fragmentation degree in the unaffected control area.

2.3.4 Index of Land Cover Impact (*ILCI*, %)

By averaging *CR*, *FD* and *HR* of each sample area, the comprehensive response degree of each sample area can be obtained.

$ILCI=|CR+FD+HR|/3$

According to the level of surface response, it can be divided into five levels: level 1 - *ILCI* value below 20%, indicating that the degree of surface interference is very slight; Level 2 - *ILCI* value between 20% and 40%, indicating that the degree of surface interference is slight; Level 3 - *ILCI* value between 40% and 60%, indicating that the level of surface interference is moderate; level 4 - *ILCI* value between 60% and 80%, indicates that the surface is seriously disturbed, and the level 5 - *ILCI* value is over 80%, indicating that the surface is extremely disturbed.

2.3.5 Limits of Acceptable Change (*LAC*, %)

As long as there are tourism activities, it will affect the surrounding ecological environment, whether it is beneficial or harmful, the key is to what extent the impact is unacceptable. In order to judge the acceptability of the disturbance of tourists' activities on the ecological environment of the scenic spot, vegetation coverage within 5 meters of the scenic spot's roadside was selected as the index and graded. It can be divided into six vegetation coverage levels, the first level is 0; the second level is 0-20%; the third level is 20-40%; the fourth level is 40-60%; the fifth level is 60-80%; the sixth level is 80-100% (100% of the desert is completely covered by vegetation without any bare sand). Random questionnaires were conducted to investigate the degree of unacceptability of vegetation coverage in the desert near the roadside, and to determine the *LAC* value of the survey area.

3. RESULT ANALYSES

3.1 Tourist Tread Disturbance Response of Observation Transect

3.1.1 Comparing the Disturbance Range of Tourists' Stamping

Usually, the impact of tourists on the scenic spots along the trail is gradually weakened from the edge of the trail to both sides. However, due to the sparse vegetation and the mobility of sand dunes in desert scenic spots, the rule of trampling along the trails is not obvious. From Figure 3 and Figure 4, it can be seen that the impacts of trampling disturbance in both desert scenic spots are within the range of 4m on both sides of the walkway. The changes of the Index of Land Cover Impact (*ILCI*) and the increase rate of Soil Crust Fragmentation (*SCF*) are the strongest in the 1-3m sample area, while the trampling disturbance in the 4th, 5th and other sample areas is relatively stable. From the response of specific scenic spots to trampling disturbance, the increase rate of Soil Crust Fragmentation (*SCF*) was the most dramatic change in the shrub-grass composite system of Huangshagudu scenic spot, the smallest change in the periphery of surfing car lane (the crust around lane was weak); The response Index of Land Cover Impact (*ILCI*) is the most severe in Huangshagudu Trestle Road and Surfing Vehicle Lane, while the desert trestle in northern Shapotou District is relatively weak.

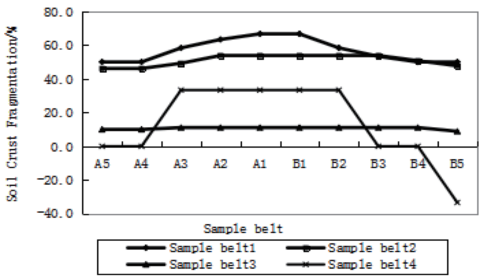

Figure 3
The soil crust fragmentation at four investigation sections

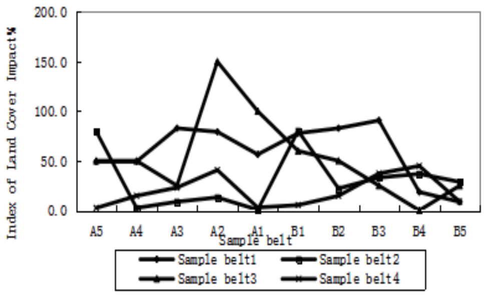

Figure 4
The index of land cover impact at four investigation sections

3.1.2 Response of Visitors to Tread Disturbance on Plant Population and Soil Crust Change

Sample belt 1 (north side of ticket office of Huangshagudu Wetland Park): Wooden Trestle Road extends along the Yellow River bank basically, and it is an onshore trestle road that tourists must pass after surfing trucks unload passengers in scenic spots. The width of the trestle is 82 cm and the slope is about 4-6°. Most of the trestle is 10-30 cm away from the ground. Some of the trestles are submerged by drifting sand. Because of the narrow wooden trestle road, the original grass cover on both sides, such as sand plants such as Artemisia desterorum, Hedysarum laeve, Stipa bungeana and litter layer, disappeared after trampling by tourists, causing the desert to be completely bare and crust unable to form. From the main indicators, the increase rate of Soil Crust Fragmentation (*SCF*) is the largest among the four transects, with 66.67% of the sample within 1 m on both sides and 50% of the sample within 5 m distance. This is due to the sand-fixing vegetation outside the sample area of wooden trestle road and mainly Hedysarum scoparium. When tourists are sightseeing, they tend to stop taking pictures when there are landscape trees on both sides of the trail, resulting in bare soil between the trestle road and landscape trees (such as *Hedysarum scoparium*), and almost zero desert crust. The reduction rate of Cover Reduction (*CR*) was 88.6% in the range of 3 m. The vegetation coverage decreased sharply, the species of vegetation decreased, and the Floristic Dissimilarity (*FD*) reached 80% (Table 1).

Table 1
The Index at 1-4 Meter Distance at Four Investigation Sections (unit: %)

Index	Sample belt	A4	A3	A2	A1	B1	B2	B3	B4
CR	1	28.6	85.7	88.6	42.9	85.7	85.7	91.4	-42.9
	2	5.0	-22.5	-6.3	-18.8	72.5	6.3	6.3	-6.3
	3	0.0	-50.0	-400.0	-300.0	20.0	0.0	-150.0	-100.0
	4	0.0	16.7	16.7	0.0	-16.7	0.0	33.3	25.0
FD	1	20.0	60.0	60.0	40.0	80.0	80.0	80.0	40.0
	2	17.0	33.0	33.0	33.0	50.0	50.0	50.0	33.0
	3	25.0	50.0	75.0	50.0	50.0	50.0	50.0	25.0
	4	50.0	50.0	50.0	50.0	50.0	50.0	25.0	25.0
HR	1	11.0	42.0	32.0	55.0	53.0	39.0	53.0	26.0
	2	69.0	6.3	6.3	0.0	93.0	79.0	65.0	69.0
	3	30.0	23.0	53.0	29.0	65.0	56.0	-6.0	6.1
	4	46.0	51.0	62.0	18.0	0.0	56.0	58.0	53.0
SCF	1	50.0	58.3	63.3	66.7	66.7	58.3	53.3	50.0
	2	46.2	49.2	53.8	53.8	53.8	53.8	53.8	50.8
	3	10.0	11.1	11.1	11.1	11.1	11.1	11.1	11.1
	4	0.0	33.3	33.3	33.3	33.3	33.3	0.0	0.0

Sample belt 2 (east side of Tourist Service Center in Huangshagudu): The walking path is 3.54M wide and the slope is 0-3 degrees. It is a mixed drifting sand road. Located below the tourist service center, this area is a branch of the diversion direction of tourists (the rest of the tourists flow to camel farms and continue to walk along wooden trestles). There are fewer tourists and more desert off-road vehicles. The Floristic Dissimilarity (*FD*) of this section ranges from 20% to 50%, and the change of surface vegetation is gentle. However, the vegetation Height Reduction rate (*HR*) varies greatly, and the vegetation height on both sides varies greatly. The *HR* of the sample in the left side of the trail varies from 0 to 6.3% within 3 m, and the *HR* of the right side varies from 65% to 93% (Table 1), which is due to the large slope on the left side (10-30°) and the small slope on the right side (2-3°).

Sample belt 3 (Huangshagudu Surfing Vehicle Lane): Walk 5.6m wide, slope 0-3°, drifting sand lane. This area is located in the deep desert, with few tourists (only a small number of tourists walking through the desert), the lowest increase rate of Soil Crust Fragmentation (*SCF*), the sample on both sides of the lane is between 8.89% and 11.11%. Desert crust is seriously damaged. While the lane destroys crust, the lane also rolls over the sand body in the lane. Surfing wheels press to 1 m on both sides of the sample, and the vegetation increases, which is much more than the reference sample, resulting in the extreme situation of reducing vegetation coverage (*CR*) to - 400% and - 300%.

Sample belt 4 (desert trestle road in northern Shapotou area): desert trestle road is wooden, 1.8m wide, with a slope of about 3-8°,30-40cm away from the ground. There are fences at 70cm on both sides of the trestle road, separating the walkway from the desert control area. The height of the fence is about 1 m, which effectively prevents visitors from entering the desert control area to play, and prompts visitors to quickly pass the trestle road to the desert recreation zone in the northern region. This area is the area with the lowest change of Coverage Reduction rate (*CR*) and Index of Land Cover Impact (*ILCI*). The change of vegetation coverage is small (-16.7%～33.3%) and the area of residual litter on the surface is significant.

3.1.3 Tourists' Response to Trampling Disturbance

Table 2 shows the difference of *ILCI* degree in four sample areas. Overall, three of the four transect belts had serious or very serious extremely disturbance in the 1m sample area at the edge of the runway. Among them, Huangshagudu Wetland Park Ticket Office survey section (sample belt 1) has the most serious interference. There are three samples at the edge of the walkway which reach extremely standards. The average *ILCI* is 78.3%. The 1m sample area on the edge of the track of the East survey section (sample zone 2) and the surfing car lane survey section (sample zone 3) of the tourist service center also reached a seriously level. The *ILCI* value of desert trestle road survey section (sample belt 4) in northern Shapotou District is all below 44.9%, which belongs to moderate to very slight disturbance, because the wooden fence on both sides of the trestle road plays an obvious role. The other three zones showed low values in the 3-4 m sample area from the main runway, and high values in the 5 m sample area, which showed high-low-high changes from the edge of the runway to the distal sample area.

Table 2
The Index of Land Cover Impact (*ILCI*) of Three Tourism Spots (unit: %)

Sample belt	A5	A4	A3	A2	A1	B1	B2	B3	B4	B5
1	49.3 c	49.3 c	82.9 e	79.3 d	56.4 c	77.9 d	82.9 e	90.7 e	18.6 a	8.6 a
2	79.8 d	2.5 a	8.8 a	13.1 a	0.6 a	80.3 e	22.1 b	33.1 b	36.9 b	28.8 b
3	50.0 c	50.0 c	25.0 b	150.0 e	100.0 e	60.0 c	50.0 c	25.0 b	0.0 a	25.0 b
4	2.5 a	14.7 a	23.0 b	40.7 c	2.9 a	5.4 a	14.7 a	37.3 b	44.9 c	8.8 a

Note: "a" stands for level 1, "b" stands for level 2, "c" stands for level 3, "d" stands for level 4, and "e" stands for level 5.

3.2 Investigation Results of Simulated Stampede Interference

3.2.1 Cover Reduction and Floristic Dissimilarity

After 25 and 75 times of trampling for 1 hour, the vegetation coverage of sample A did not change; after 700 times of trampling for 1 hour, the vegetation coverage response index reached 85.0%, and the vegetation coverage decreased sharply. Half a month later, the *CR* value of 700 times of trampling was 85.0%, which increased to 90.0% after one month, indicating that the vegetation did not recover under heavy trampling (Figure 5). The vegetation coverage of sample B changed little (11.1%) after 100 times of trampling for 1 hour, and reached 72.2% after 500 times of trampling for 1 hour. After half a month, the *CR* value of 50 times of trampling was stable at 16.7%, and it also reached 83.3% under 500 times of trampling, and it continued to increase to 88.9% after one month. The vegetation coverage of sample C desert is small (15%), after 50 times of trampling, the vegetation coverage is reduced (2%), *CR* value reaches 86.7%, and still can not be restored (0%) after one month.

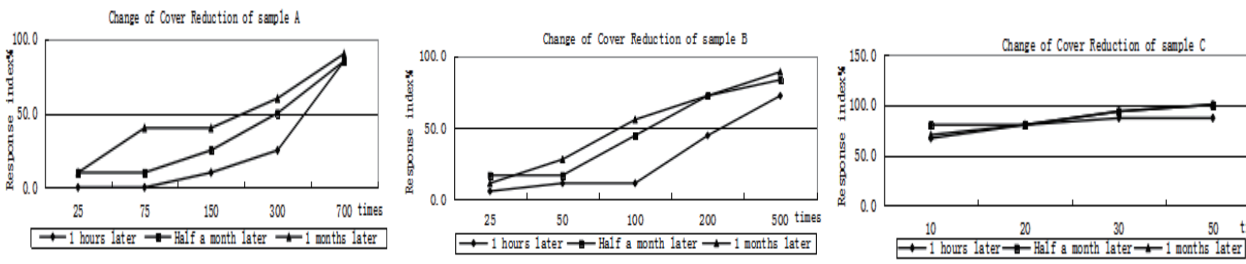

Figure 5
The dynamic response of CR change under different intensity trample of samples A, B, C (%)

The resistance of vegetation in sample A is the strongest. The *FD* value of 700 times of trampling is almost three times that of 25 times of trampling (Table 1), and after one month, the condition of vegetation restoration is not ideal. There are five kinds of original vegetation in the quadrat: *Kalidium foliatum* (*Pall.*) Moq., *Agriophyllum squarrosum* (*L.*) Moq., *Artemisia desterorum Spreng*, *Festuca* L., *Leymus secalinus* (*Georgi*) Tzvel . the species that disappeared after a month's trampling are *Festuca* and *Leymus secalinus*. There are few vegetation left in the sample. The original vegetation in sample B is the same as that in sample A. after one month, the *FD* value of vegetation only trampled 50 times recovers below 50%; the vegetation in the 500 times trampled sample decreases 71.5%, and the species disappeared are *Artemisia desterorum Spreng*, *Festuca* and *Leymus secalinus*. After one month, 50 steps of sample C, all species disappeared (Table 3).

Table 3
The Trampled Change of *FD* Responding After Half Month and a Month (%)

Sample A			Sample B			Sample C		
Times	**Half a month**	**A month later**	**Times**	**Half a month**	**A month later**	**Times**	**Half a month**	**A month later**
25	28.7	26.5	25	29.5	27.0	10	39.1	36.4
75	37.8	38.1	50	42.2	42.0	20	56.5	67.6
150	46.5	43.7	100	56.3	59.0	30	73.9	75.4
300	73.9	69.9	200	80.0	67.6	50	100.0	100.0
700	85.7	87.1	500	82.6	71.5			

3.2.2 Height Reducation

(1) There was a positive correlation between the vegetation height of sample A and the increase of trampling times; after 700 steps of trampling, the vegetation height was 0, all of them were buried. One month later, the recovery rate was 15.8% in 25 steps, and the degree of recovery was negatively correlated with the degree of trampling.

(2) After 500 times of trampling for 1 hour, the response index of sample B vegetation height reached 93.8%, and the vegetation height decreased from 16cm to 1cm. After half a month, HR value still reached 68.8%.

(3) Under the influence of 30 times of trampling, the height of sample B desert vegetation is reduced to 0. One month later, the vegetation restoration in the quadrat was still unsatisfactory, and 50 times of trampling on the vegetation died (Table 4).

Table 4
The Dynamic Response of HR Change Under Different Intensity Trample of Samples A, B, C (%)

Sample A				Sample B				Sample C			
Times	**1 hours later**	**Half a month**	**A month later**	**Times**	**1 hours later**	**Half a month**	**A month later**	**Times**	**1 hours later**	**Half a month**	**A month later**
25	0.0	5.3	15.8	25	0.0	18.8	-6.3	10	21.4	78.6	14.3
75	21.1	5.3	36.8	50	56.3	6.3	6.3	20	85.7	85.7	71.4
150	52.6	36.8	42.1	100	68.8	37.5	31.3	30	100.0	92.9	78.6
300	78.9	36.8	47.4	200	81.3	62.5	56.3	50	100.0	100.0	100.0
700	100.0	78.9	68.4	500	93.8	68.8	68.8		21.4	78.6	14.3

3.2.3 Soil Crust Fragmentation

(1) The degree of crust damage of sample A is serious, because the original biological crust area is large and the fragmentation is small; the *SCF* value reaches 500.0% after 150 times of treading; the crust is completely damaged after 700 times of treading. Even after one month, the SCF value was 233.3%, which was not due to the restoration of desert crust, but due to the slight damage of water erosion, wind erosion and desert animal activities.

(2) The crusts of sample B were all damaged after 200 times of trampling; after one month, the inner crusts of sample B were slightly recovered after less than 100 times of trampling, and the crushing degree of crusts was still 100.0% after more than 100 times of trampling.

(3) The *SCF* value of sample C is the smallest, because the desert crust area of sample C is small and the inclination angle is large, a little human activity interference will cause destructive damage to the crust, and 10 times of trampling will destroy 90.0% of the crust in the sample (Table 5).

Table 5
The Trampled Change of Desert Crust Responding After Half Month and a Month (%)

Sample A			Sample B			Sample C		
Times	**Half a month**	**A month later**	**Times**	**Half a month**	**A month later**	**Times**	**Half a month**	**A month later**
25	166.7	33.3	25	150.0	0.0	10	58.3	28.6
75	366.7	166.7	50	200.0	66.7	20	65.0	28.6
150	500.0	200.0	100	375.0	100.0	30	66.7	42.9
300	533.3	233.3	200	400.0	200.0	50	66.7	42.9
700	566.7	233.3	500	400.0	233.3			

3.3 Main Influencing Factors of Tourists' Stamping Disturbance

Different attractiveness of tourism resources, different behavior of tourists, and construction and management of scenic spots all affect the impact of recreational behavior on the environment, and there are complex interactions among various factors. Under the natural development situation of desert scenic spots, the impact degree of the walkway system is closely related to the number, distribution, trend of tourists passing through and the types of recreational activities, but there is no unified evaluation standard for this, so this study does not give quantitative analysis and discussion. Pearson correlation test analysis method was used to select and study the four influencing factors of elevation, walking path width, slope and slope gradient of each survey sample area, and the correlation between vegetation and soil disturbance effect on both sides of the scenic area walking path, so as to determine the influence degree of each parameter of the walking path on tourism disturbance. As can be seen from Table 6, there is no significant correlation between the survey items and elevation; *FD*, *HR*, *CR* and *SCF* are all correlated with the slope, width and slope gradient of the walking track; *FD* is only correlated with the width of the walking track; The negative correlation between *SCF* and the gradient of walking path and slope is very significant, which indicates that the gradient of walking path is large, tourists tend to walk on the trestle rather than climb the sand slope, and the fragmentation of soil crust is small.

Table 6
The Correlative Analysis Result of Different Impact Factors

Parameter	(FD)	(HR)	(CR)	(SCF)
Altitude	-0.334，p=0.837	0.354，p=0.789	0.563，p=0.894	-0.326，p=0.673
Walkway width	3.466，p=0.032	5.873，p=0.014	3.748，p=0.043	2.593，p=0.031
Walkway gradient	-0.895，p=0.342	-5.231，p=0.032	-2.432，p=0.016	-3.576，p=0.009
Slope gradient	-1.890，p=0.056	-3.238，p=0.028	-3.947，p=0.010	-5.873，p=0.004

3.4 Limits of Acceptable Change of Tourist Stamping Disturbance

A questionnaire survey was conducted on the acceptable limits of environmental shocks along the tourist trails. Visitors are invited to choose the level (pictures of typical scenic spots) that they deem unacceptable and to determine the Limits of Acceptable Change for the area. The results of the questionnaire for 156 visitors are shown in Table 4. The highest proportion of desert vegetation was found in grade 2 (0-20%), followed by grade 3 (33.3%). Another 12.8% thought that desert scenic areas should not be covered by vegetation in order to highlight the rudeness and vigor of the desert. No one asked for 100% vegetation coverage at the edge of the walkway. Therefore, it can be preliminarily judged that the acceptable change limit is that the vegetation coverage at the roadside should not be higher than 16.4%. Compared with the field survey, the vegetation coverage of each survey sample area is greater than LAC except Huangshagudu Wetland Park, which exceeds the acceptable change limit. The vegetation coverage on both sides of desert trestle road in northern Shapotou area is unacceptable. It shows that tourists'empty and desolate experience in desert is a natural and irreconcilable opposition to desert ecological management.

Table 7
The Limits of Interviewer's Acceptable Vegetation Coverage Near the Trail

Interviewee	Desert vegetation coverage（0%）	（0～20%）	（20～40%）	（40～60%）	（60～80%）	（80～100%）	Average 16.4%
Number	20	64	52	8	12	0	-
Percentage	12.8	41.0	33.3	5.1	7.7	0	-

3.5 Relationship Between Vegetation Response and *LAC* in Different Periods

According to the survey and statistics, the acceptable limit of desert vegetation coverage for tourists is 16.4%. Most of the tourists think that they will lose the original vigorous, primitive and rough desert. According to the survey results of each experimental area in each period, the more serious the stampede is, the more acceptable it will be to tourists. As shown in Table 4, only the observation of vegetation coverage of four quadrats is higher than the lac threshold of tourists (16.4%); the more trampling times, the smaller vegetation coverage, the closer to the experience demands of "non modern", "primitive", "passionate exploration" and "rough and vigorous" required by tourists(table 8).

Table 8
The *LAC* Changes During Different Periods

Sample A			Sample B			Sample C		
Times	**Half a month**	**A month later**	**Times**	**Half a month**	**A month later**	**Times**	**Half a month**	**A month later**
25	18◆	18◆	25	15	16◆	10	3	3
75	18◆	12	50	15	13	20	3	3
150	15	12	100	10	8	30	1	1
300	10	8	200	5	5	50	0	0
700	3	2	500	3	2			

Note: "◆" means vegetation coverage exceeds LAC (16.4%)

CONCLUSION

The disturbance of tourism activities to desert natural environment is most easily reflected in the changes of plant population and desert crust, and affects tourists'experience.

Taking Shapotou and Huangsha ancient ferry scenic spots in Ningxia as study areas, the response of footpath in the above scenic spots to tourists' trampling interference was investigated by the fait accompli method, and three different angles and different vegetation types were set up to simulate the way of tourists' trampling and observe the vegetation recovery after trampling. The results show that:

(1) Generally speaking, the influence of tourists on the scenic spots along the walkway is gradually weakened from the edge of the walkway to both sides. However, the rule of trampling along the tourist trails in desert scenic spots is not obvious. Through the analysis, it can be concluded that the impacts of trampling disturbance in both desert scenic spots are within the range of 4m at the edge of the walkway, but the desert trestle in northern Shapotou District is obviously benefiting from the barrier effect of wooden bars, and the impacts of vegetation and desert crust on tourism activities are less than those in the other three sample belts.

(2) *ILCI* and *LAC* are used to comprehensively measure the impact of tourism activities on the ecological environment. Among them, the polling section of Huangshagudu Wetland Park Ticket Office (sample zone 1) has the most serious disturbance, reaching the extremely serious standard, with an average ILCI value of 74%. It is also one of the most visited walking paths in Huangshagudu Scenic Area (1800-2200 people per day); The *ILCI* value of desert trestle survey section (sample belt 4) in northern Shapotou District is all below 44.9%, which belongs to the moderate-very slight degree of interference. Although the number of tourists passing through the trestle reaches 6000-12000 per day, due to the obvious role of wooden railings on both sides of the trestle, the interference degree is obviously lighter than that of Huangshagudu Scenic Area. The influence degree of the three transects of Huangshagudu showed a "high-low-high" change from the edge of the walking path to the distal transect.

(3) The impact on the environment can be observed by simulating the behavior of tourists. Due to the particularity of desert ecological environment, it is very sensitive to the behavior of tourists. Once the sand fixation vegetation and biological crust are destroyed, the sand dunes will be activated. Although stampede experiment cannot accurately simulate the impact of tourists' activities, the effect of the method is obvious, which can provide an effective reference for the management and decision-making of desert scenic spots. The results show that with the increase of the intensity of tourists' activities, the vegetation in the quadrat shows the decrease of coverage, height, number and species of plants, and the increase of the fragmentation of desert crust. Different intensity of trampling has different effects on sand dunes. Within the range of desert ecosystem, the system can recover itself. Once it exceeds its regulating capacity, it will be difficult to recover to the original ecological type. The main reasons for the differences in biodiversity change may be the over exploitation of tourism, the over trampling of tourists and the uncivilized behaviors of tourists. Therefore, it is necessary to control the development of tourism, regulate tourists' behavior and protect the biodiversity of desert scenic spots.

(4) Visitors should not exceed 16.4% of the acceptable change in vegetation coverage by the roadside. The vegetation coverage on both sides of desert trestle road in northern Shapotou area reached an unacceptable level (grade 5). It shows that tourists' empty and desolate experience in desert is a natural and irreconcilable opposition to desert ecological management. The study on tourist experience in desert scenic spots should be further strengthened.

This study has some similarities with previous research results, but it also shows the irregularity of tourist activities and the randomness of environmental impact in desert scenic spots. What is insufficient is that the detailed study on desert ecosystem by tourism activities in this study does not reflect enough ecological characteristics.

Ningxia is one of the mature desert tourism areas in China, and the environmental impact of its tourism activities has begun to show. In other desert scenic spots in China, the decrease of vegetation coverage and crust fragmentation on both sides of the walkway caused by trampling disturbance have begun to affect ecosystem succession (dune movement, soil development, vegetation restoration) and tourists' recreational experience along the route, and have a tendency to further endanger the achievements of desert control. Therefore, it is imperative to curb the chaotic state of unrestrained development and management system of desert scenic spots in China. Desert scenic spots should strengthen the planning and design of walking paths and protective fences, improve the scenic spot identification system, standardize tourist behavior, strengthen tourists' environmental awareness, Establish a long-term environmental monitoring and early warning mechanism system to promote the sustainable development of desert scenic spots in China.

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