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Assessing the Ecological Impact Due to Disc Golf

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Abstract

The aggregate demand for outdoor recreation has increased in recent years, thus presenting managers with the challenge of providing opportunities for outdoor participation and at the same time preserving in a sustainable way the ecosystem in which those activities take place. The identification and assessment of environmental impacts as a result of modern urbanization have become a top priority among conservationists and managers. This study examines the ecological footprint of a popular urban recreational activity: disc golf. Three ecological markers were selected as indicators of ecological degradation: soil erosion, soil compaction and density of vegetation cover. Results indicated that disc golf significantly increases soil compaction, which yields greater soil erosion and a decrease in vegetation cover. The findings of this study call upon managers and professionals to pay closer attention not only to the ecological degradation associated with outdoor recreational activities but also to the solutions that would lead to a long-term sustainable management. Since some of the ecological degradation is caused by human behavior, a focus on behavioral interventions should be an essential component in finding a relatively inexpensive and sustainable solution.

Keywords: disc golf; outdoor recreation; environmental management; urban parks

Assessing the Ecological Impact Due to Disc Golf

Introduction

Disc golf, sometimes known as 'frisbee golf' became a popular leisure time sport in the early 1970s and continues to increase in popularity (Ransdell, Oakland, & Taylor, 2003). Disc golf historians suggest that the sport began with "Steady" Ed Headrick, who is often cited as the "father" of the sport. Headrick was the driving force responsible for the modern era of Frisbee sports and subsequently founded the International Frisbee Association, the Junior Frisbee Championship, and the World Frisbee Championship. The first formal disc golf course was designed and installed in 1975 in Oak Grove Park, (Pasadena, California), by Headrick and was well received by patrons. During that same year Headrick also founded the Professional Disc Golf Association, that later was operated by players (Disc Golf Association, 2011).

Disc golf is a lot like the traditional golf. Players use specially made plastic flying discs instead of balls and clubs, and throw them for 'par' at an above-ground target instead of a hole in the ground. The object of the game is to complete each hole in the fewest number of throws, starting from a tee area and finishing at the disc pole hole. Most disc golf courses consist of 18 or 24 holes, but some nine-hole courses could be found too. Holes lengths vary, but generally fall between 150 and 500 feet each. As a player progresses down the fairway, he or she must make each consecutive shot from the spot where the previous throw has landed. The trees, shrubs, and terrain changes located in and around the fairways provide challenging obstacles for the disc golfer.

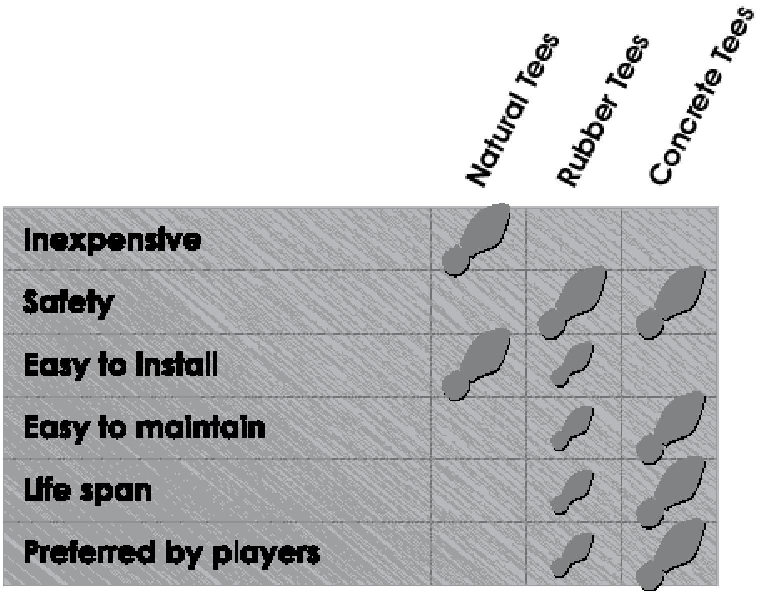
The sport has been steadily increasing in the number of participants but this past decade saw the most phenomenal growth in the sport's history. Disc golf more than doubled in terms of membership (from 6,230 members in 2000 to 14, 326 in 2009) and the number of Professional Disc Golf Association-sanctioned events nearly tripled (from 361 in 2000 to 1,113 in 2009) (Martin, 2011). Some players play for a recreational purpose but others like to compete. There are more than 1,200 events annually in 48 states and 22 countries around the world that provide opportunities for the competitive disc golfers. Much of the appeal of disc golf is that it is an affordable sport that can be played for a lifetime. The vast majority of courses are located in public parks and many do not charge any fees for participation. Over the last ten years a growing number of public golf courses have permitted disc golf to be played on their grounds.

Despite the popularity of the sport, environmentalists have voiced concerns over the environmental impacts (LeClerc, Che, Swaddle, & Cristol, 2005; Lawrence, 2010). In spite of many environmental advantages disc golf seemingly has over traditional golf (e.g., no chemicals needed to keep the field green, no cutting of trees in order to design the course), there have been some recent environmental concerns associated with the sport (Estrella, 2005; Gascoyne, 2005; LeBlanc, 2006; McCaughan, 2004). For instance, some disc golf courses in California have already been closed because of the environmental problems associated with excessive use and lack of a management plan. More specifically, some of the disturbing concerns are destruction of undergrowth plants because of high foot traffic, damage to the bark of the trees from discs, and soil erosion and compaction. These concerns introduce new challenges to sport managers and planners of outdoor sport activities in urban settings.

In recognition of these environmental concerns the Professional Disc Golf Association (PDGA) founded an Environmental Committee in 1998, with members from all over the world. The primary objectives of this committee are (Professional Disc Golf Association, n.d.):

1. To educate players and course designers about the impacts of existing and proposed courses.
2. To provide specific input, advice, and general expertise in specific locations.
3. To store environmental documents and/or data from courses around the country for use by other course designers or operators.

The PDGA acknowledges that a major concern with disc golf courses is soil erosion and the most prevalent type of erosion happens near the tees and baskets. Figure 1 presents information about the different types of tee designs (graded on a 3-level scale) used in the construction of disc golf courses to minimize environmental damage. In addition to soil erosion, trampling is another concern and the PDGA Environmental Committee has proposed several mitigation and maintenance strategies to decrease the impact. For example, some of the strategies call for installing courses in areas with low foot traffic or replanting with some native vegetation areas with serious foot impact.



Big mark – high grade
Small mark – average grade
No mark – low grade

Figure 1. Different types of tee design and their characteristics (Source: http://www.innovadiscs.com).

A secondary concern relative to disk golf is the damage done to trees when they are struck by the disk during the contest. The Environmental Committee suggests using stakes to protect the tree trunks and sensitive trees and shrubs. Although the PDGA and its Environmental Committee recognize the possible environmental problems associated with disc golf, they argue that when regular maintenance is performed, environmental effects are minor and no long-term effects should be expected. Regardless of the optimistic belief of no long-term threats, the challenge is to find ways to determine and monitor the impact to avoid last minute fixes and to promote proactive instead of reactive management.

Previous work in the field of recreation has been focused mostly on golf, rock climbing, or mountain-biking, and their impact on the ecosystem (Geoff & Alder, 2001; McMillan, Nekola, & Larson, 2003; Wheeler & Nauright, 2006). Potentially, the findings of this study will contribute to the existing body of literature on outdoor recreation and human ecology, and may yield practical implications for managers and professionals. The effects of recreation on the ecosystem have been studied in general, but the extent to which an urban sport such as disc golf (easily viewed as eco-friendly) affects the environment remains unexplored. Based on recent concerns that have been raised in relation to disc golf and the ecological degradation associated with this relatively new outdoor recreational activity, the purpose of this study was to assess the environmental impact (if any) from playing disc golf.

Sustainability

Sustainability is a concept that has become ubiquitous in sport and recreation policy and practice. Over the last decade, the interest in examining the impact of sport on the physical environment has remained strong. This interest crosses the multiple domains of recreational, amateur, and professional sport (Falt, 2006; Lindsey, 2008; Smith & Westerbeek, 2007). Falt (2006) brings to bear that many college and professional sport franchises are now incorporating environmental responsibility into their business model. For example, Smith and Westerbeek (2007) in their analysis of sport as a vehicle for corporate social responsibility argued that sport organizations must be compelled to protect the physical environment as a part of exhibiting socially responsible conduct. They further explicate that, "socially responsible sport acknowledges this burden [protecting the environment] and develops policies to avoid environmental damage" (p. 6).

In the last ten years there has been growing international concern relative to sustainability practices in golf course management. For example, authors such as Wheeler and Nauright (2006) and Gössling, Hansson, Hörstmeier, and Saggel (2002) argued that despite the popularity of golf and its tremendous revenue generating potential, golf course owners, operators and developers must be mindful of the negative impacts of poor design and the lack of policies and sound management practices needed to protect and sustain the resource.

Moreover, Gossling et al. (2002) advocated the use of ecological footprint analysis as a tool to assess tourism sustainability of golf resources used by local residents and tourists. Similarly, Woodside (2009) proposed the use of systems thinking, cause mapping, and system dynamics modeling and simulations of golf, recreation/tourism, and environmental relationships to help achieve viable solutions palatable to major stakeholders. Palmer (2002) also urged for continuing discourse between managers and stakeholders to promote sustainability and sound user policies and management practices. Overall, the trend in golf course management focuses on environmental sustainability, protection of the resource and the use of contemporary research methodologies to inform policies and management practices.

Environmental Impact Assessment

Evaluating environmental impact because of outdoor recreational activities is not new to academia (LeClerc, Che, Swaddle, & Cristol, 2005). Based on previous work in the field, there are two possible methods of assessing the environmental impacts – one is through quantitative measurements of the indicative variables and the other is more qualitatively focused and adopts assigning different scores depending on the visual appearance of the particular area of interest. Nevertheless, the reliability of the information obtained through the latter method would likely suffer, especially when data collection is conducted by more than one person. Therefore, to ensure high level of reliability the quantitative approach is more desirable than the qualitative.

Several variables have been used to measure ecological degradation in outdoor recreational activities. A variable often used is human trampling, which is defined as the mechanical destruction of ground level vegetation (Cole, 1995; Liddle, 1991). For example, in a study on sand dune communities Liddle (1991) evaluated the soil and vegetation condition as markers of human trampling. Other variables examined as indicators of environmental damage are soil compaction and change to vegetation cover (Quinn, Morgan, & Smith, 1980; Thurston & Reader, 2001). Measures of soil compaction and change to vegetation cover were used by Sun and Walsh (1998) who presented an overview of the ecological impacts of recreational activities in Australia and they argued that some of the physical degradations include soil loss and compaction as well as vegetation damage. Similar results were found by Goeff and Alder (2001) in their study on mountain biking in Australia, showing that trail erosion, soil compaction and vegetation damage occur on the trails. Although the majority of measures have been focused on soil and vegetation variables, other variables have been used as well. For example, McMillan, Nekola, and Larson (2003) measured the effect of rock climbing on environment by evaluating the density, richness, diversity and composition of the land snail community in Southern Ontario. In another study on rock climbing, Muller, Rusterholz, and Baur (2004) looked at plant cover and species density in order to assess any ecological problems associated with this sport.

Based on the above review, variables used as indicators for ecological degradation in outdoor recreation could be generally grouped into three categories – mechanical (e.g., measuring soil erosion and compaction), flora (e.g., measuring plant cover) and fauna (e.g., measuring a particular land community). To assess the problems associated with disc golf in particular, the following variables were chosen – soil compaction, soil erosion and vegetation density. These three variables are appropriate indicators of ecological degradation because of the nature of disc golf and the environment in which it takes place.

Based on the current literature and the importance of analyzing the impacts of users on the resource, the conceptual framework of this study is based on Stern's (2000) Theory of Environmental Significant Behavior (TESB). This theory focuses on understanding the behaviors of the end-users and how the overuse and abuse of the resource negatively impacts the environment. In essence, TESB can be defined by its impact, the extent to which it alters the structure and dynamics of ecosystems. Most important, this theory provides an understanding of the individual human behaviors that need to be modified in order to minimize environmental degradation. Environmental impact and degradation is usually a bi-product of human behavior and natural processes occurring in the ecosystem. In some instances, the environmental effects of human behavior are unknown to resource users, which in turn makes eradicating the potentially behaviors more challenging. Relatedly, Stern and Gardner (1981) argued that it is necessary to adopt an impact-oriented definition to identify and target behaviors that can make a large difference to the environment. Subsequently, this approach is important for making applied research meaningful. It is necessary to adopt an intent-oriented definition that focuses on people's beliefs, motives, and so forth in order to understand and change the target behaviors. Whereas, theories such as *rationale-choice theory* or the *theory of planned behaviors* focus on the choices of individuals and the benefits and consequences of their actions, neither theory directly emphasizes the impact on the environment. Rational choice theory attempts to explain social phenomena based on individualism, rationality, consequentialism, egoism and maximization (Hardin, 2002). Its main focus is the individual decision-making process, when the individual has a number of alternative options to choose from. According to the theory, an individual will choose the option with the maximum benefits to himself under the existing constraints.

The theory of planned behavior is a theory about the link between attitudes and behavior. The basic premises of the theory are that personal attitude, subjective norms, and perceived behavioral control, together shape an individual's behavioral intentions and behaviors. Accordingly, if people evaluate the suggested behavior as positive (attitude), and if they think their significant others want them to perform the behavior (subjective norm), this results in a higher intention (motivation) and they are more likely to do so (Ajzen, 1991). While the behavioral intention and behavior dimensions of the theory help to understand the end-user, it does not focus on the measurable damage to the resource.

Research Questions

Based on relevant literature, the theoretical framework selected for the study, and the three ecological markers selected as indicators of ecological degradation, the following research questions were formulated: 1) Is there any ecological degradation due to the sport of disc golf? and 2) If so, is there a significant difference in the ecological degradation between areas in the park where disc golf is played when compared to areas in the park used for other recreational activities? Research questions are utilized as opposed to hypotheses due to the descriptive nature of the study (Riddick & Russell, 2008).

Methodology

Site Selection

Three parks in the city of Austin, Texas, with designated disc golf courses were the focus of this study – Pease Park, Zilker Park, and Mary Moore Searight Park. All three parks are located in an urban setting and are managed by the city of Austin Parks and Recreation Department, although maintenance of the disc golf courses is mainly carried out through the volunteer work of the disc golf players themselves.

Pease Park. **The disc golf course in Pease Park was established in** 1989. The course is situated along Shoal Creek and has a scenic trail with many trees as well as some wide open holes and cliffs (see Appendix A). Its length is 1387.75 m (4550 feet) with a total of 18 holes.

Zilker Park. The disc golf course in Zilker Park was established in 1987 (see Appendix B). The course has only 9 holes and its total length is 818.32 m (2683 feet). The baskets at this short and tight course are moved between the North and South site of the park twice a year. When tournaments are organized, the course is expanded to 18 holes.

Mary Moore Searight Park. The disc golf course in Searight Park was established in 1992 (see Appendix C) and it has 18 holes spread throughout a large wooded area. The course is 1446.00 m (4741 feet) in length and has a few long holes that are scattered throughout the course, but there are also many short holes.

Data Collection

Soil compaction, plant density and soil erosion data were collected from two different types of locations at each of the three disc golf courses: off the course path and around the baskets which are on the course path. Soil compaction, plant density and soil erosion are indicators of ecological degradation. The rationale for choosing two different types of locations at each disc golf course was that environmental problems are expected to differ depending on the walking pattern of the disc golf players and other users of the park. The two different types of sampling locations allowed for comparison of the soil and vegetation condition in areas with different foot impact. The time required to collect the data was three weeks for the vegetation density and two days for the soil compaction, while three months were required to collect the soil erosion data.

Variables

Three variables represented onsite land degradation: soil compaction and erosion, and plant density.

Soil compaction. Soil is a natural body comprised of solids (minerals and organic matter), liquids, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter, and the ability to support rooted plants in a natural environment (United States Department of Agriculture, 2008). Soil compaction occurs when soil particles are pressed together, reducing pore space between soil particles and pushing out the air normally located there. Soil compaction reduces the large pore space, restricting air and water movement into and through the soil, thus limiting root growth. Soil compaction is the primary factor limiting plant growth in urban soils. The decrease or loss of biota can cause further impacts on soil and vegetation because organisms are important agents in promoting the development of soil structure and are critical to the process of nutrient cycling (Flink & Searns, 1993).

Traffic over soil is the major contributor to soil compaction. For example, moist soil can reach 75% maximum compaction the first time it is stepped on, and 90% by the fourth time it is stepped on (Whiting, Wilson, & Card, 2006). Compaction results in decreased rates of water infiltration and eventually leads to increased soil erosion. Soil compaction is one consequence of land use practices that involve trampling (see Appendix D). Knowing about soil density on a site is important because increased density will hinder root penetration. The greater the useable soil volume for plant root growth, the greater a plant's growth potential. There are two main effects of soil compaction: increased soil density to potential root growth, which limits growth levels, and decreased soil drainage. Soil compaction prevents seeds from pushing through the soil. Plants will not receive air and water from compacted soil. Also, living organisms in the soil cannot survive without water, air and nutrients.

Soil erosion. Geological soil erosion has been occurring for some 450 million years and is a natural phenomenon, but it becomes a problem when human activity causes it to occur much faster than under natural conditions. For example when large numbers of hikers use trails or extensive off road vehicle use occurs, erosive effects often follow, arising from vegetation removal due to foot traffic and vehicle tires (Dregne, 1983; Misak, Al Awadhi, Omar, & Shahid, 2002). When soil is removed at about the same rate as it is formed, problems rarely occur, but when loss of soil occurs at a much faster rate than its formation, serious problems may arise. Soil erosion can occur incrementally and some of the effects of erosion can be masked for many years, making the evaluation process more difficult and management strategies more complex. The main on-site impact from soil erosion is the reduction in soil quality that results from the loss of the nutrient-rich upper layers of the soil, and the reduced water-holding capacity of the soil.

Plant density. When vegetation declines, a prime source of organic litter is lost and the density of soil biota declines as well. A change in soil biota reduces the availability of nutrients to plants and this can result in further lost of vegetation cover. Therefore, plant density can be used as an indicator of loss of vegetation cover. Plant density is often used for monitoring long-term vegetation changes, because of its sensitivity to changes in the adult population. Plant density is defined as the number of organisms per unit area. Plants in trampled areas usually have reduced density, leaf surface, and flower and seed production. These changes can lead to less successful reproduction and eventually to a decrease in cover.

Instrumentation

The diagnostic tool used to measure compressive strength of soil is the penetrometer (DICKEY-john soil compaction tester). It has a pressure gauge and a probe stick with depth markings at 3-inch intervals. The probe is hand driven into the soil and soil compaction is displayed in 50 psi (pounds per square inch) increments up to 400 psi. The penetrometer is designed with the purpose of mimicking a plant root. This type of soil compactor is the more precise instrument for evaluating soil compaction than the pocket penetrometer, which is designed to measure surface compaction (Amacher & O'Neill, 2004).

Five random numbers, generated using *Femlab,* determined five baskets on each disc golf course around which soil compaction was tested. Measurements were taken at five different spots around each basket. The purpose of this was to ensure that enough directions around the basket were covered, thus averaging out variations due to the players' walking patterns. In addition, soil compaction measures were taken approximately 10 meters away from each basket for the purpose of comparing areas where golfers usually walk with areas where they rarely walk. At each of these comparative locations, five different spots were tested.

Soil erosion was measured by using soil erosion pins inserted into the ground, which is a widely used method for measuring erosion (Hadley & Lusby, 1967; Haigh, 1977; Takei, Kobaski, & Fukushima, 1981). The top of the pin gives a datum from which changes in the soil surface level can be measured. The pins were 20 cm (7.9 in) long and 1 cm (0.4 in) in diameter so that they would not interfere with the surface flow. A metal washer was placed over the pin to ensure a better base from which to measure to the top of the pin. Prior to recording the eroded soil level, the washer was lowered over the erosion pin and down to the ground surface. The function of the washer was to even out irregularities in the ground surface surrounding the pin. The difference in elevation between the washer's surface and the head of the erosion pin was recorded by a ruler. Measurements were collected 3 months after the initial time of pin placement. Pins were randomly placed within a radius of about 1 m (40 in) around the baskets. The number of the basket where each pin was nailed into the ground was selected by using *Femlab* to generate random numbers. A total of 10 baskets were selected at each of the three disc golf courses. In addition to that, soil erosion pins were placed in approximately 10 meters away from each basket for the purpose of comparing erosion level. A total of 20 pins were placed on each disc golf course, 10 of which were close to the baskets and 10 away from the baskets. Each pin was stamped with a number from 1 to 20.

A common method for evaluating land plant density is the plot method (Brower, Zar, & Von Ende, 1998). A *plot* is generally a rectangle or a square, but circles and other shapes can be used as well. For the sampling of vegetation cover and density, rectangular plots were used, since they yield better results than the other shapes (Doolittle, 2004). Rectangular sample areas are more accurate than square or circular ones, because of the general tendency of vegetation to clump. A plot with a rectangular shape with sides in a 1:2 ratio (0.71 m X 1.42 m) was constructed. The size of the plot in relation to the size of the plants measured is a critical consideration because it can affect the precision and accuracy of the measurements. When determining the appropriate plot size needed to sample the vegetation, the goal was to select a minimum area that would fully represent the species composition of the community. The dimensions of the plot generally depend on the nature of the vegetation, and for the purpose of evaluating grassland, the dimensions of 0.71 m by 1.42 m (sampling area of 1 m^2) are desirable (Barbour, Burk, Pitts, Schwartz, & Gilliam, 1998).

The location of the center of each plot was determined by randomly choosing a number that represented a basket number on the disc golf course. Random selection minimizes bias by purposefully ignoring the nature of the vegetation and terrain. The random numbers were generated using *Femlab*. The center of the plot was placed at 0, 3, 6, and 9 m away from the basket in two randomly chosen directions. A compass was used to determine the directions. The rationale for choosing two random directions was to eliminate the effect of sunlight on the growth pattern of vegetation. After the plots were marked out, each species was counted within each plot. A substantial amount of time was required for the accurate counting of all plants in each plot. Plots were placed around the basket areas and off the course path. Since the purpose of measuring plant density was to estimate the vegetation cover and not to identify the individual species, monocots and dicots were combined when counted. Species that were touching the edges of the plot were counted as belonging to the sampled area. After collecting the data, plant density was calculated using the equation:

$$D_i = n_i / A$$

Where D_i is the density for species *i*, n_i is the total number of individuals counted for species *i*, and A is the total area sampled.

Results

Statistical analysis of the collected ecological data was performed using SPSS 18.0. A *t*-test (independent) was used to analyze the soil compaction data. Results indicated that the degree of soil compaction differs significantly between areas around the disc golf baskets and areas away from the baskets. This statistically significant difference was noted in all three sites of study. Results are presented in Table 1 below.

Table 1. Results for soil compaction.

Park	Mean value in close proximity to disc golf baskets	Mean value away from disc golf baskets	*t* - test
Mary Moore Searight	6.78 cm (2.67 in)	14.12 cm (5.56 in)	$t(10) = 2.31$ $p = 0.04$
Zilker	4.62 cm (1.82 in)	9.83 cm (3.87 in)	$t(10) = 3.15$ $p = 0.01$
Pease	2.79 cm (1.10 in)	7.54 cm (2.97 in)	$t(10) = 3.91$ $p = 0.003$

All soil penetration readings were taken by inserting the penetrometer until the level of compaction reached 300 psi, which is the level at which it is believed that root growth is greatly inhibited (Penn State - Department of Crop and Soil Science, 2002). Although there is no established precise threshold level for soil compaction which precludes plant growth, a significant increase in the level of soil compaction should be viewed with concern; smaller numbers mean higher levels of soil compaction. This is explained by the fact that the penetrometer used to measure soil compaction does not go deep into the soil when the compaction is high and leads to low reading numbers.

Not all erosion pins originally placed into the ground were found at the time of collecting the data. At Zilker and Mary Moore Searight Parks 50% of the originally placed pins were found, while in Pease Park 80% of the pins were located. This is an expected rate of recovery, because of some of the problems usually encountered with this method of measuring soil erosion (Hudson, 1993). First, a few baskets were removed from their original location, which served the purpose of a land mark for the location of the pins. Second, during some of the volunteer days a large amount of mulch was spread out throughout Pease and May Moore Searight Parks, thus covering some of the areas where pins were originally placed. Third, some pins may have been simply removed by park visitors. This common problem occurs at times because park users sometimes tend to be curious and are likely to remove some of the pins.

A *t*-test was used to compare soil erosion data collected in close proximity to the disc golf baskets with erosion away from the baskets. Results indicated a significant difference in the level of soil erosion between the two locations, with erosion being at much higher level close to the baskets than away (the higher the number, the worse the level of erosion).

Table 2. Results for soil erosion.

Park	Mean value in close proximity to disc golf baskets	Mean value away from disc golf baskets	*t* - test
Mary Moore Searight	0.31 cm (0.12 in)	0.16 cm (0.06 in)	$t(8) = 2.89$ $p = 0.020$
Zilker	0.24 cm (0.09 in)	0.16 cm (0.06 in)	$t(8) = 4.03$ $p = 0.004$
Pease	0.24 cm (0.09 in)	0.08 cm (0.03 in)	$t(14) = 4.32$ $p = 0.001$

Although there is no established precise rate for soil erosion, which inhibits vegetation cover (consequences from soil erosion depend on the specific site characteristics), an elevated rate of soil erosion should be viewed with concern.

The vegetation cover data collected in each park were analyzed visually using a bar graph. Figures 2, 3, and 4 represent the data collected in Pease Park, Zilker Park, and Mary Moore Searight Park respectively:

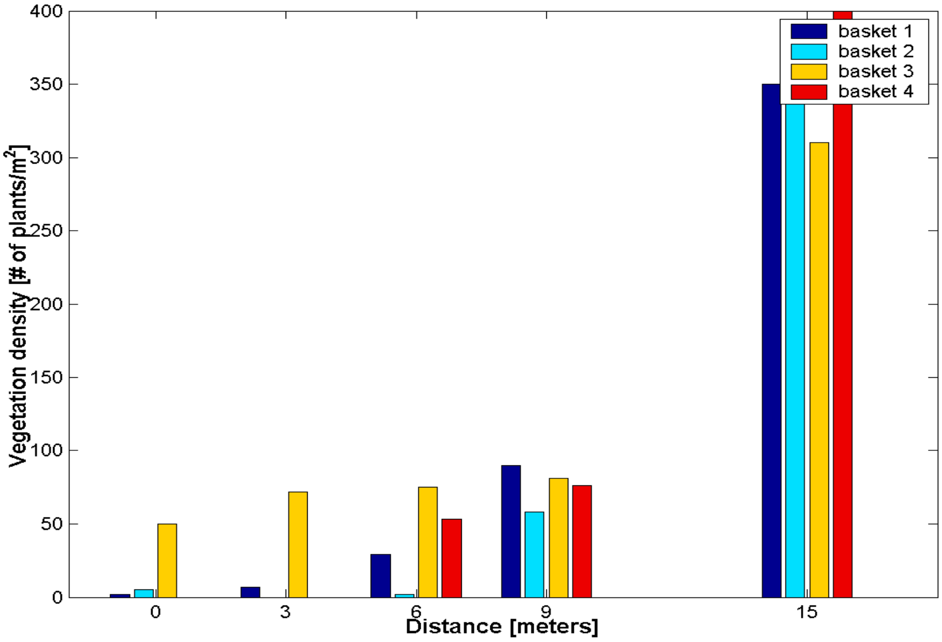


Figure 2. Vegetation cover in Pease Park.

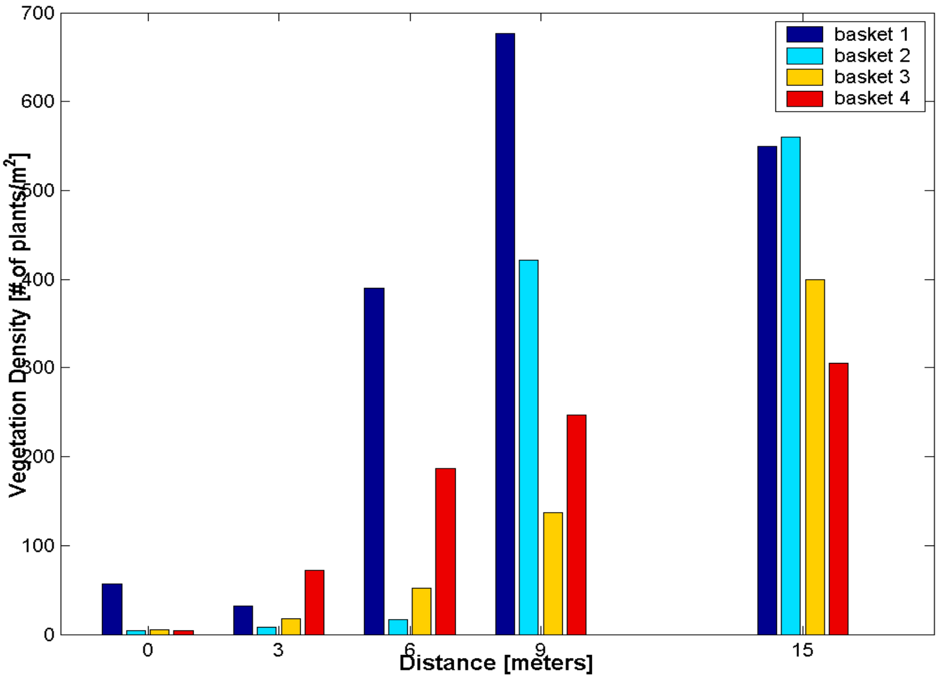


Figure 3. Vegetation cover in Zilker Park.

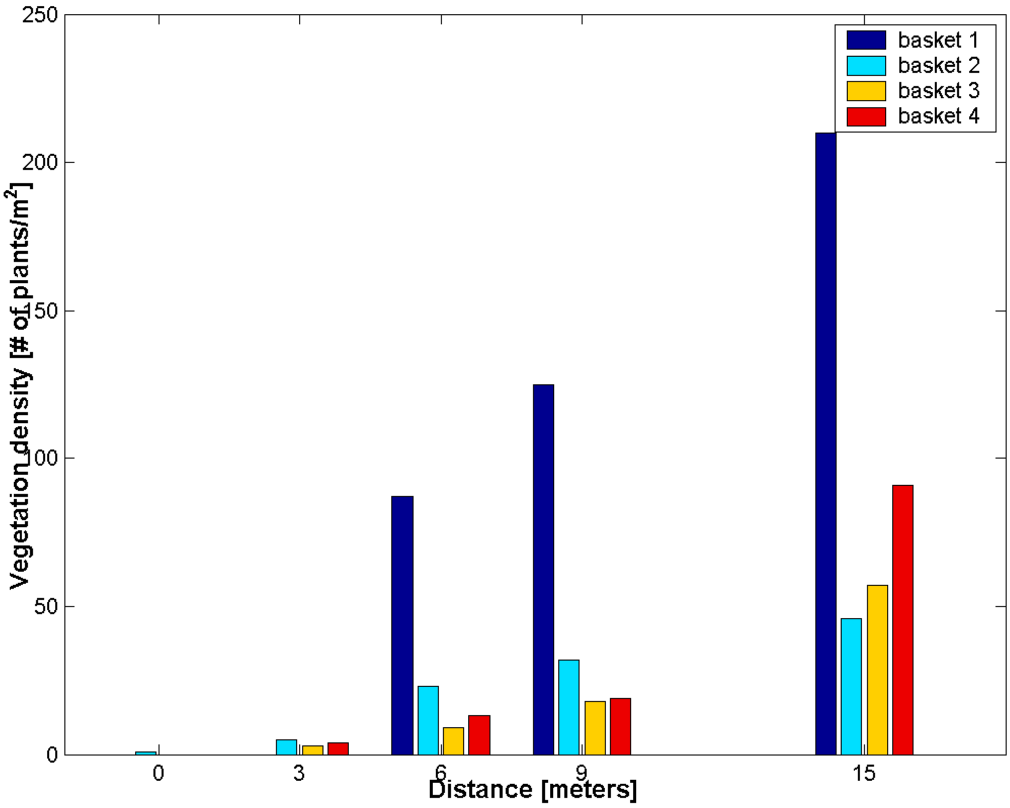


Figure 4. Vegetation cover in Mary Moore Searight Park.

The visual representation of the vegetation cover indicates the large difference in vegetation density between the areas located in close proximity to the disc golf baskets and these located farther out. The lack of vegetation cover around the baskets is evident on all three disc golf courses.

Discussion and Conclusion

The results of the soil compaction analysis indicate that the soil in areas where disc golf baskets are placed is highly compacted when compared to areas not on the disc golf course. This could be explained by the heavy foot traffic around and in close proximity to the baskets. Regardless of whether disc golfers manage to get the disc into the basket or not, they have to walk to the basket and pick up their discs. Also, some of the baskets are used as a practice basket, which implies that an enormous number of steps are taken around the baskets. This results in damaging the vegetation cover and compressing the soil upper layers.

Soil compaction due to human trampling is a problem with some severe consequences. Most of the organic material in soil is concentrated in the upper layers and this organic horizon promotes water circulation by increasing the absorptive capacity of the soil and by increasing moisture retention. If soil compaction in the surface layer develops it can increase runoff, which in turn causes increasing soil and water losses. Also, excessive soil compaction impedes root growth and therefore limits the amount of soil explored by roots and results in decreased plant ability to take up nutrients and water.

Similar conclusions have been reported in other studies on outdoor recreational activities. Recreational trampling leads to increase in soil compaction and a decrease in soil organic matter as well as a decrease in plant cover (Cole, 1995; Hylgaard & Liddle, 1981; Kuss, 1986; Sun & Liddle, 1993). More recently, in a study on the effects of experimental trampling on soil and vegetation, Kutiel, Eden, and Zhevelev (2000) showed that only 71 days after they started their experimental treatment of trampling, the depth of soil penetration decreased with increasing trampling intensity. A possible solution to the soil compaction problem could be to relocate the baskets every few months (depending on intensity of usage and geographical conditions) to allow for the soil and vegetation to recover.

Although a natural process affected by heavy rainfall and strong winds, soil erosion is also affected by soil compaction. Soil compaction leads to a decrease in vegetation cover, which eventually leads to an increase in the level of erosion. Based on the results from the soil erosion analysis on the three disc golf courses it is evident that areas in close proximity to the baskets are more susceptible to soil erosion than areas farther away from the baskets. This could be explained by the heavy foot trampling associated with disc golf, which is especially concentrated around the baskets. The effect is exacerbated because baskets are rarely moved around the course path, thus not allowing for sufficient recovery time and causing soil conditions to worsen. The consequences of soil compaction and erosion are reduced plant density and less successful reproduction of grass species, which can lead to less biomass and sparser cover. The danger is in reaching the carrying capacity of the ecosystem before tangible damages are detected and some mitigating measures are taken.

The analysis of the vegetation cover clearly indicated that areas in close proximity to the disc golf baskets were lacking vegetation cover. This could be explained by the fact that excessive walking takes place around the baskets and in close proximity. Excessive walking leads to soil compaction, which in turn slows down the process of vegetation growth. Soil compaction impedes the process of plants absorbing nutrients from the soil, therefore causing a decrease in vegetation cover. The condition of the vegetation cover away from the path of the disc golf courses was much better when compared to the locations around the baskets. Although recreationists still walk in these areas, foot traffic is not as heavy as on the disc golf course.

The relationship between soil and vegetation is reciprocal. In other words, reduction in vegetation makes the soil more susceptible to erosion but at the same time soil erosion leads to a decrease in plant cover. The severity of the problems arises from the fact that park usage due to disc golf is highly concentrated in nature, which leads to both soil and vegetation impacts. These effects are confined to the specific area where disc golf is played. A few meters away from the walking path of the disc golfers, soil and vegetation are likely to be less affected.

Disc golf continues to emerge as a popular sport pastime in the United States. As the critical mass of players increases recreation and park management agencies must balance ecological and community objectives without compromising the environment. Knowledge about the ecological conditions of the area where recreational activities are taking place is the cornerstone to developing an effective intervention program for behavioral change. Organizations such as the PDGA can play a major role in educating its members who are users about the environmental impacts of the sport. Concurrently, managers must promulgate policies and implement management practices that protect and sustain park resources without radically impinging upon the interests of disc golfers. With collaborative efforts to educate and protect the park resource, sustainability is a realistic endeavor.

Management Implications

The results of this study point to some of the negative effects the sport of disc golf has on the surrounding environment and in particular on the soil and vegetation cover. This, however, does not imply that we are advocating a solution of the environmental problems through eliminating the sport of disc golf altogether. The challenge is to keep the effects within boundaries that do not surpass the carrying capacity of the specific ecosystem. Understanding the factors (e.g., foot traffic, local geological and geographical conditions) influencing the amount of impact can assist in the design of preventive measures with the focus being on the factors having the greatest potential to affect the site. Most importantly we need to focus on eliminating the causes rather than the symptoms of the problems.

In order to decrease and minimize some of the negative effects due to disc golf we would like to recommend some specific measures that could be easily implemented. A possible solution to the soil compaction problem could be the application of six inches of woodchip mulch which significantly reduces soil compaction. A benefit of mulch application would be to increase the level of organic matter in the soil areas where, due to foot traffic and lack of vegetation growth, the organic matter has been decreasing. In addition, breaking up the soil (tilling or subsoiling) is an effective means of ameliorating compacted soils (Harris, Matheny, & Clark, 2004). The soil could be broken up effectively with minimal damage to tree roots utilizing a pneumatic excavator.

In order to decrease the impact of foot traffic and trampling, courses could use concrete tees and define pathways down the fairway as well as between holes. This would allow for minimizing the spread of traffic and the area affected by trampling. In addition, pathways could be covered with mulch. Depending on the local characteristics and the natural setting of the parks where disc golf is played, a solution to minimize foot traffic, soil compaction and erosion could be to move the baskets around the park every few months. This would allow for the vegetation to recover and grow back and for the players to experience a different course layout, thus preventing the boredom of playing all over again the same holes. However, local conditions need to be taken into account. For example, if there is a creek running through the park, moving the baskets around the park could be limited.

Additionally, we highly suggest that disc golf course managers take their cues from turf managers that work at golf courses and professional associations such as the United States Golf Association (USGA). Practices such as rotating the positions of tee boxes, pins and cups on golf courses are similar to changing the layout of holes (where possible), rotating baskets and using more resilient turf on disc golf courses. Sharing knowledge of the state-of-the-art in course management can be a boon for disc golf course managers.

In general, managerial practices for solving environmental problems used in the past have been focused on restoration and preservation efforts. Although a necessary measure, restoration and preservation practices are rather a short-term solution. Other strategies should be aimed at achieving a long-term solution that will provide for sustainable sport. This long-term solution should be sought in the area of human behavior, since human behavior is what mainly causes the ecological degradation. Therefore, investigating the golfers' behaviors could assist in the identification of problem behaviors linked to the environmental problems. It may be that disc golf players are unaware of the existing problems. In addition, the time lag between the impact and the identification of its consequences might impede the perception golfers have about the impact of their sport. As the principals of TESB suggest, environmentally significant behavior changes could be achieved by education and by supplying information about the impact disc golf has on the surrounding environment. In addition, community management that involves the establishment of shared values and expectations could assist in those efforts.

Park managers must seek to balance the appropriate use of park facilities to accommodate the sport while maintaining a commitment to protect the resource. Moreover, managers must consider both the operational and policy impacts of permitting disc golf. In addition, the principals developed by Gardner and Stern (1996) could provide some guidance for park managers when designing interventions for behavioral modifications since those principals specifically focus on behavioral approaches to environmental protection. The recommended steps are:

- Identify target behaviors that are environmentally significant.
- Analyze the behaviors to identify the responsible actors and actions.
- Consider the full range of casual variables and explore their possible relevance to the target behavior.

Finally, as Lindsey (2008) argues, both the community of facility users [disc golfers] and the parent organization of the sport must be active participants in promoting environmentally sustainable practices toward the end of protecting the resource. Individual, community, and organizational sustainability practices are essential to the vibrancy of the facility (pp. 281-283). In essence, there must be an active level of "self-policing" to ensure that disc golf players are abiding by not only the rules and etiquette of the sport but also the policies related to sustainability as promulgated by organizations such as the Professional Disc Golf Association (PDGA). For example, one of PDGA's policy statements indicates the following,

The relationship that the sport of disc golf has with the environment is an integral part of the golfing experience and is one of the core reasons we develop satisfaction from playing … As the sport continues to grow, environmental concerns such as erosion, soil compaction, and impact on flora and fauna will become more prevalent and will need to be properly addressed (PDGA.com., para. 1-2).

Withstanding the mandate to players, another strategic action that managers can take is to enlist the active support of the PDGA to train players, employees and develop management plans to protect the resource. On the organizations' website they extend the professional courtesy of "working with local parks departments to answer questions about environmental issues and course maintenance, and be a general contact for these issues" (PDGA.com, para. 2). In summary protecting the golf course as resources is a direct responsibility of players (individually and the community of players), course operators, and professional associations that promote and govern the sport of disc golf. Collaborative efforts can lead to improved management practices and a synchronized effort to protect the physical environment.

Future Research

In light of the results of the present study and the small body of knowledge related to this area of park management two areas for future research surface. First, there is a need to study the leisure behavior of disc golfers and general park users relative to the environment and sustainability efforts. In some instances park users may inherently be unaware of the consequences of their actions in relationship to the local ecosystem. Exploring the factors impacting this type of rational decision could contribute to the design of intervention programs for behavioral modifications among outdoor sport participants. Second, a comprehensive examination of management practices instituted by recreation and park organizations to limit/eliminate the ecological degradation is in order. Of particular interest are agencies that have disc golf courses in their park inventories. Currently, strategies such as moving/relocating disc golf baskets and active activity areas on a scheduled basis are employed to aid in sustainability efforts. Strategies such as these allow for recovery time of the ecosystem and limit the number of users to promote environmental sustainability. A clear understanding of "best practices" among park agencies relative to disc golf courses will provide invaluable information to park managers to improve resource management practices.

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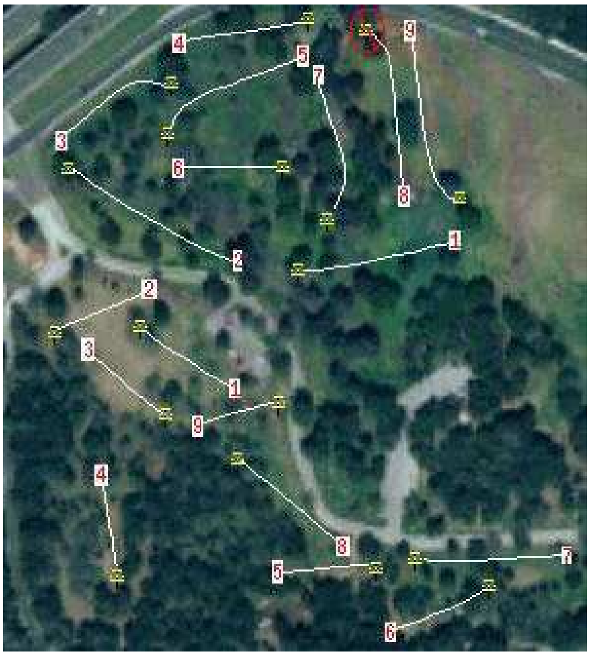
Appendix A

Disc Golf Course in Pease Park

Appendix B

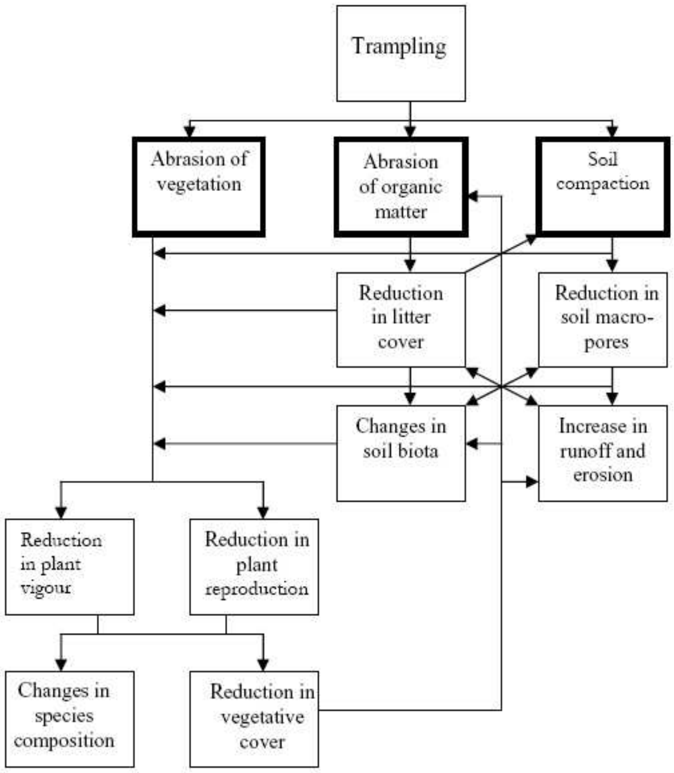
Disc Golf Course in Zilker Park



Appendix C

Disc Golf Course in Mary Moore Searight Park

Appendix D



Trampling effects on vegetation and soil. Borrowed from Smith and Hellmund (1993) "Ecology of Greenways: Design and function of linear conservation areas".