Greener Golf:

An Ecological, Behavioral, and Communal Study of the University of Michigan Golf Courses

Radrick Farms Golf Course, Hole 12 (Image courtesy of Radrick Farms Historical Archive)

Project Team:	Parker Anderson, MS/MLA Rachel Chalat, MS/MAE Emily Gehle, MLA Ian Makowske, MS/MBA Kimberly Martin, MS
Advisors:	Andrew Horning, Graham Institute for Sustainability Jeff Plakke, Matthaei Botanical Gardens and Nichols Arboretum Ray De Young, School of Natural Resources and Environment
Client:	Corbin Todd, University of Michigan Athletics Department

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Greener Golf Master's Project Team, Streamsong Resort, Streamsong, FL (Image courtesy of Ian Makowske)

1) Abstract

As one of the leading public universities in the world, the University of Michigan, owns two 18-hole golf courses: Radrick Farms Golf Course (RFGC) and the University of Michigan Golf Course, also known as the Blue Course. The land on which RFGC is situated has a long and diverse history. Over 18,000 years ago, the area was covered by the Wisconsin glacier, the recession of which left a unique till mix and geological features, including Fleming Creek and deposits of sand and gravel. The presence of these resources led to the transformation of the landscape into a gravel mine, which functioned through the 1920s. In the early 1930s, University of Michigan alumnus Fredrick C. Matthaei, Sr., purchased the land from Cadillac Sand and Gravel, along with additional acreage surrounding the mine, and began the process of restoring the gravel pit by re-grading the area, planting alfalfa and red clover, and converting portions of the area to farmland. Following its donation to the University in 1957, the land was converted into a championship 18-hole golf course designed by world-renowned golf course architect Pete Dye.

From its beginning, environmental considerations have been a priority at the RFGC. In 2001, the management of RFGC committed to the Michigan Turfgrass Environmental Stewardship Program (MTESP), initiating a series of strong sustainability objectives. Since 2001, RFGC has received special recognition from the Washtenaw County Pollution Prevention Program, in addition to becoming "one of only four courses in the state [of Michigan] with both MTESP and Audubon Cooperative Sanctuary certifications."[1] Radrick Farms Golf Course is also the only club in the state to become a Groundwater Guardian Green Site; in 2012, Washtenaw County presented RFGC with the 2012 Washtenaw County Environmental Excellence Award for Water Quality Protection, and in 2014, RFGC was recognized by the Department of Environmental Quality of the State of Michigan as a Clean Corporate Citizen (C3), the first golf course in the state to receive this recognition.

The Blue Course, is located near the iconic Michigan football stadium, south of Central Campus. Prior to becoming a golf course, the area was used for farmland. In 1929, the Blue Course was designed by Dr. Alister Mackenzie, now revered as one of the greatest golf architects. The course officially opened in the spring of 1931 and immediately drew praise as one of the finest in America. At the time of its opening, the Blue Course was only the fourth course to be located on a college campus. In the mid-1990s, a multi-million dollar renovation was completed to restore the prestige of the Blue Course to the ranks of Mackenzie's other classics. A new practice range was added to assist Michigan's golf squads, as well as a number of practice greens and bunkers. The popularity of golf carts necessitated large stretches of cart paths that partition landscaped medians around the course.

The unique combination of such a highly regarded and historic golf campus with a strong research university presented an opportunity to conduct a holistic exploration into the benefits that golf courses offer to the ecological, social, economic, and cultural health of the communities that contain them, as well as the opportunity to identify potential recommendations to enhance these benefits. The project team utilized an exploration of current trends in the golf industry, specifically the growing movement for integration of sustainability management techniques, in conjunction with a broader multi-disciplinary focus to inform a working definition of sustainable golf. This definition correlated with the three tenets of permaculture: care for the land, care for the people, and the concept of fair share. The project team assessed the current state of the Blue Course and RFGC in research designed around these three tenets. Specific research included an ecological inventory and site analysis, community perception survey and a study of pre- and post-test

cognitive function in golfers, and a high-level, qualitative analysis of economic implications. Using the findings and results from this research, the project team provided recommendations informed by the tenets of sustainable golf. The recommendations presented by the Greener Golf Master's Project Team highlight three approaches to pushing the boundaries of what it means to be a sustainable golf course. The Greener Golf Master's Project Team has broadly labeled these three recommendations as engagement, accessibility, and innovation.

In addition to the recommendations provided, the Greener Golf Master's Project Team provided the design for a golf course and event space at RFGC that would provide multiple beneficial functions; one of them being the creation of a "living laboratory" where innovations in sustainable golf course management can be tested prior to implementation on the 18-hole golf courses. The team has preliminarily recommended the site be named the Gateway Course due its proximity to the entrance to RFGC as well as its mission to open a new door to how golf courses can play a role in society in the future.

Appendix I is a project summary that includes further discussion of the team's recommendations. This summary is intended for those who wish to learn more about the project, but cannot read the full report below. In addition, the project summary can be used in public distribution for press and other media opportunities.

2) Why Golf?

Introduction

This project was born from a partnership between the University of Michigan Golf Courses and the University of Michigan School of Natural Resources and the Environment. The client aimed to assess the current holistic benefits and implications of the University of Michigan's two golf courses on the surrounding community and ecosystems. This assessment served to inform further recommendations for deepening and broadening these benefits with the intent of improving the University of Michigan Golf Courses' already exemplary sustainability initiatives. In doing so, this paper and the myriad of multi-disciplinary research which informs it, aims more broadly to push the boundaries of what it means for a golf course to be "sustainable." Prior to evaluating the courses specifically, we considered how sustainability is being considered in the golf industry as a whole. With an understanding of the industry history and trends we then aimed to provide an informed analysis of the University's courses.

Industry Trends

The golf industry is at a critical point in its history. With more and more golfers leaving the game and a golf course closing every 48 hours[2], a paradigm shift in how a golf course is created, operated, and presented to the public is necessary. Mark King, President of Taylor Made Adidas Golf, echoed this statement by saying, "In the world today, if things aren't progressing, they eventually die. And I think that's the mentality that we have to have about our game and our industry. If we don't find how to progress it will die."[2]

Increasing demand on land and natural resources, in addition to the increasing threat of volatile weather patterns due to a changing climate, will bring additional pressure from regulators, municipalities, and the public to improve the efficiency of land use. Further, water issues are also at the forefront of concerns for the industry. As the Intergovernmental Panel on Climate Change (IPCC) states in their 2014 report, "Climate change will amplify risks to water resources already affected by non-climatic stressors, with potential impacts associated with decreased snowpack, decreased water quality, urban flooding, and decreased water supplies for urban areas and irrigation."[3]

Golf courses are currently perceived by the majority of the public as a resource-intensive land use that provides minimal benefit to the surrounding community. Those within the industry know that many of these allegations of waste are not valid. However, some are justified. The golf industry has historically fought regulation and scrutiny, believing that increased regulation on a facility will increase operation costs. In order to shift the perception of the public and halt the downward trajectory on which the golf industry currently finds itself, innovative approaches to golf course management and operation need to be adopted.

Talks of implementing sustainable operations are often thought of as austerity measures that will compromise the product, but that is often far from the truth: golf and sustainability are not mutually exclusive. In fact, the future prosperity of the golf industry depends on the ability of the industry to adapt to the challenges that the earth is facing with a growing human population and increasing demand for natural resources. Perceived as a resource intensive land use, golf is

experiencing dramatic decreases in the number of players who participate in the sport despite a growing population. Great potential exists to showcase golf courses as necessary components of the human-created urban and suburban landscapes because of their ability to serve as green spaces that mitigate stormwater concerns and pollution factors, provide habitat to beneficial species, grow food for local communities, demonstrate responsible use of natural resources, and encourage the growth and development of the community through youth programs and game-growing recreational opportunities. It has become clear that golf courses can have a positive social impact on the community and are closely connected with the surrounding population. Indeed, golf courses are "tightly and reciprocally tied ecologically with their surroundings."[4] Technology in monitoring turf conditions using GIS (geographic information systems/science) and sensors provides additional ways for facilities to develop "precision management"[5] plans for their irrigation and nutrient application programs to significantly reduce the need for these required resources.

Renowned golf course architect Dr. Alister Mackenzie stated, "The chief object of every golf architect and green-keeper worth his salt is to imitate the beauties of nature so closely as to make his work indistinguishable from nature itself."[6] This statement was directed towards golf course architecture and management. However, with the additional knowledge and technology of the current time, it also applies to the ecological processes and interactions of a golf course. It is important to manage and construct golf courses to be "indistinguishable from nature"[6] with regard to the role they have in ecosystems.

The golf industry must also respect what is, as indicated by the USGA motto, the "Spirit of the Game," and show integrity for other members of the ecological community, abiding by rules that demonstrate that, like the game of golf, there is no need for "supervision of a referee;" in this way, golf can progress as a champion of environmental stewardship.[7] Managing rough areas on the golf course is one of the most resource intensive practices for a golf facility. *Table 1* shows the significant amount of water required to maintain these areas.

Table 1. **Number of irrigated acres and percentage of total irrigated acres by golf course component for an average 18-hole golf facility in the USA.**

Component	Irrigated acres	% total irrigated acres
Greens	3.7	4.6
Tees	3.4	4.2
Fairways	30.7	38.0
Rough	33.8	41.9
Practice area	5.6	6.9
Clubhouse grounds	3.5	4.3
Total	80.7	99.9

USGA

Golf's Use of Water: Solutions for a More Sustainable Game
USGA Turfgrass and Environmental Research Online
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The 2014 United States Open Tournament at Pinehurst Country Club demonstrated and showcased an alternative to maintained rough with a restoration of those areas to naturalized areas that required less water and considerably less maintenance. Water usage at Pinehurst No. 2 went from a typical 55 million gallons per year to 15 million gallons per year.[8] Saving water that dramatic have great positive implications for the future of the golf industry, especially when future projections see "evapotranspiration over most land areas…to increase in a warmer climate, thereby accelerating the hydrologic cycle."[9] The USGA received significant positive, as well as negative feedback, regarding this change, but overall a great benefit of the change was introducing golf's potential for sustainability and its impact on the environment to common conversation. This dramatic demonstration of practical architectural design that continues to challenge the golfer while minimizing water consumption and other inputs should provide a model of things to come. In other regions of the country, the use of warm season grasses help to mitigate the effect of drought or near drought conditions.

One of the most important and challenging obstacles to a successful future for golf is the public perception of the industry. David Chernushenko, president of a sports sustainability consulting firm, states that golf is "heavily impacted by degraded environments, and that's important…to those in the golf industry who get told they can't build a new course because bad practices have tarred their image."[10] Past poor environmental stewardship in this way limits the industry's potential. It is clear that the marketing of golf courses' environmental stewardship needs to be a prominent initiative. However, changing people's perceptions is a time-intensive and difficult challenge. Current world-renowned golf course architect Tom Doak adds that the "political reality is that for the 90 to 95 percent of the public who are not golfers, the use of pesticides and fertilizers on a golf course carries absolutely no benefit, so why should they be willing to tolerate any risk, actual or perceived?"[11] and "as long as potentially lethal chemicals are used on golf courses, no amount of research will eliminate the potential risk to the satisfaction of the non-golfer."[11] By highlighting the value added to communities, golf courses can demonstrate to golfers, and more importantly to non-golfers, that their local facility is a benefit to their area and a welcome partner in the betterment of their community.

Trends in Sustainability in the Golf Industry

At the beginning of August 2014, the Greener Golf Master's Project Team made a trip to Florida to visit Streamsong Resort, a unique course and resort owned by Mosaic Mining Company (a subsidiary of Cargill). Having extracted phosphate from the area, Mosaic chose to take a step beyond traditional reclamation projects and add value back to the environment and the neighboring community by constructing two courses by top designers and more recently, a resort. It was a valuable opportunity to see the power of resourceful implementation of non-traditional golf course management.

Along with the visit to Streamsong, additional field research visits were conducted and are listed below along with the name(s) of the contacts of each course and any unique features of the course.

Case Study: Golf Course as Part of a Reclamation Project

Streamsong Resort, Streamsong, FL – Rusty Mercer, Superintendent; and Rich Mack, Owner

Streamsong Resort is located in central Florida, a region primarily used for phosphate mining. The golf courses were constructed as an alternative to traditional reclamation of a degraded mining site. Considerable research and environmental science was used to rebuild the soil and restore many of the natural features of the area while providing travelers with a world-class golf experience. (Photo: Ian Makowske. Caption: Streamsong superintendent Rusty Mercer shows the results of the Streamsong Soil-building Program).

Case Study: Golf Course Potential for Urban Stormwater Management and Water Filtration
Oak Meadows Golf Course, Chicago, IL – Greg Martin, Architect

Greg Martin of Greg Martin Designs LLC has engaged the community and created a mutually beneficial design of the Oak Meadows Golf Course to address current issues of flooding and stormwater management. The stakeholders include the local subdivision and a wastewater treatment plant. The proposed design and renovation of the existing golf course provide significant improvements to the management and filtration of stormwater. (Photo source[12]).

Case Study: Golf Courses Promoting Native Areas While Limiting Water Use
The Kingsley Club, Traverse City, MI – Mike DeVries, Architect

Mike DeVries and Golf Course Superintendent Dan Lucas have developed a championship caliber golf course that uses water extremely efficiently while also promoting native plant species for aesthetics, ease of management, and the creation of wildlife habitats. The management strategy of "stressing" the grass by minimally watering and taking a long-term approach to the management of the turf has resulted in a resilient and low-input turfgrass with a high level of playability. (Photo: Parker Anderson).

Case Study: Sustainable Golf Course Construction
*Sand Hills Golf Club, Mullen, NE – Dick Youngscap, Owner/Founde*r

Golf course architecture firm Coore and Crenshaw designed 137 holes on the property that is now the site of the Sand Hills Golf Club. Of the 137 designed holes, 18 were selected based on the efficiency and interest of the routing of the holes, as well as construction needs. The minimalist design technique used on this site utilized the natural features and resources of the site and accentuated existing terrain in the design. This form of design saves significant financial resources in construction, but it requires more hours on the ground understanding the land features.

Case Study: Golf Courses Promoting Native Areas While Limiting Water Use

Poppy Hills Golf Club, Monterey, CA – Matt Muhlenbruch, Superintendent

Poppy Hills Golf Club, home of the Northern California Golf Association, has recently been renovated to reduce the amount of managed turfgrass areas, create additional native areas, as well as reconstruct the greens to increase efficiency of water-use and drainage. A significant amount of the managed turfgrass was removed and replaced with native sand areas that are planted with native grass and tree species. This renovation significantly reduced the requirements of water and chemicals. In addition to the savings from the reduction in resource use, the aesthetic qualities of the golf course have been enhanced by the contrast of the sandy native areas with the managed turf areas. (Photo: Parker Anderson. Caption: Restored native grasses and waste areas reduce water consumption at Poppy Hills).

Case Study: Ecological Renovation with Economic Incentives

Olympic Hills Golf Club, Eden Prairie, MN – Tom Mead, Sustainability Consultant

The owners of the Olympic Hills Golf Club have undertaken a renovation project for their course that promotes a more positive relationship between the golf course and the surrounding ecosystems. The course layout has been upgraded to create a longer and more challenging golf course as well as update the irrigation technology of the site. The original design created barriers between the golf course and the surrounding wetland areas. However, the new design embraces that interface and promotes a healthy, mutually beneficial relationship between the golf course and the surrounding wetlands.

3) Definition of Sustainable Golf

Introduction

Having explored the current trends in the golf industry, the growing impacts of global climate change, and the resulting movement for increased incorporation of sustainability practices in golf course management, the Greener Golf Master's Project Team next set out to create a working definition of sustainable golf around which to frame our specific research and eventual recommendations for the University of Michigan's golf courses. As a multidisciplinary team, our interests in sustainability ranged from environmental to social to economic, and therefore our definition required an equally holistic approach. After much deliberation, we selected the ethics of permaculture[13] as guiding parameters for our definition of sustainable golf. The permaculture movement includes the integration of three main tenets: "care for the earth," which for our considerations encompassed the ecological and environmental benefits and implications of incorporating potential multi-use spaces and native ecosystems in golf courses; "care for the people," which encompassed the individual and communal benefits of restorative green space offered by golf courses; and "fair share," which encompassed the trade-offs in economic growth and sustainability at the golf courses. Having decided upon a working definition for sustainable golf, we next conducted literature reviews of relevant studies relating to each of the three components.

Care for the Earth: Ecological Benefits of Golf Courses on Ecosystem Health

The paradigm of human domination and control of nature is beginning to wane. Our society is shifting to an understanding that the health of the environment and economic stability are deeply connected. "Our ultimate economic fate is based on the state of the ecological processes around us," states author Ronald Dodson, who goes on to say, "Our economic health is based on a system, and that economic system is directly connected to an ecological system."[14] Developing an understanding of the ecological processes at work on the site of the golf course allows for opportunities for managers to partner with these systems in the management of golf courses, rather than impose a program upon the land.

Countless articles have emerged, especially in the last decade, regarding the value of ecosystem services. We are now just beginning to understand the potential for green spaces and green infrastructure to provide anthropogenic benefits as well as benefits to a wide variety of species. The literature suggests that golf courses are ideal locations to incorporate strategic management of ecosystems to not only provide an exceptional recreational experience, but also to provide significant values to society. In the book *Urban Ecology*, Richard Forman states, "Golf courses are tightly and reciprocally tied ecologically with their surroundings."[4] A few examples of these opportunities for golf courses to provide additional values to society are the development of habitats for endangered and threatened species, the creation of complex biological stormwater retention and water filtration systems, the restoration of degraded sites and remediation of contamination, the mitigation of impacts from invasive species, the conversion of waste sites to productive land uses, and the potential to sequester greenhouse gases and reduce the effect of climate change.

Regarding the need to consider golf courses as water filters in urban settings, Richard Forman states, "Constructed wetlands on a golf course can reduce stormwater runoff and treat (i.e., clean) stormwater pollutants. Stormwater basins, ponds, and wetlands often support rich biodiversity. Indeed, golf courses could be extremely valuable by absorbing the piped-in stormwater and treating its pollutants, from surrounding residential and commercial land uses."[4] Often golf courses can manage a significant amount of stormwater and urban runoff and can be of great value to the surrounding community as a filter for large rain events.

The American Society of Golf Course Architects have numerous case studies in which the importance of understanding and designing with the ecology of the golf course site in mind is critical. One specific case regards the design and construction of the Nantucket Golf Club, located on Nantucket Island, Massachusetts. "[A design team] undertook a comprehensive site analysis study to identify the location's numerous environmental attributes, and this in turn influenced the final routing of the golf course and the location and design of the course's facilities…The final plan for the Nantucket Golf Club harmoniously blended the architect's desired golf experience with the site's unique environmental characteristics, therefore minimizing, and even avoiding, impacts on plant and animal species. The site maintained 98 percent of its acreage as…open space, and rare plant species and grassland communities were actually enhanced, thereby improving the overall animal habitat."[15]

Additionally, the Golf Environment Organization (GEO), "the international non-profit dedicated entirely to providing a credible and accessible system of sustainability standards, support programs, recognition, and capacity building for the golf industry,"[16] highlights several international case studies and research showing the importance of ecological considerations in the design, construction, and management of golf facilities. A few highlights of these considerations demonstrate that "the best designed and maintained courses boast a combined landscape and ecological value" and that "factors including the positioning, shape, structure and maturity of habitats can significantly affect the size and viability of a species population…Habitat patches, edges and corridors are the very building blocks of golf courses - with forests, grasslands and wetlands regularly recurring as havens of biodiversity."[16]

Machrihanish Dunes Golf Club in Scotland is an example of a golf course that focuses on the care of the earth by not using any irrigation or chemicals on the fairways, while employing the use of sheep in the off-season to manage the turfgrass. In golf's early history, courses relied on grazing animals to manage the turfgrass. This concept is beginning to return as a viable solution to many problems occurring at golf facilities. Particularly in addressing problems with invasive species, goats are being used to "clear brush, remove invasive species, and manage weeds."[17] The concept of using grazers, especially goats, as managers of invasive species has significant environmental benefits. They remove the need for the use of chemical herbicides and also close an "input loop" through the provision of naturally fertilized areas. There is great potential for using goats on golf courses because "goats will eat more broadleaf plants than grasses" and "for goats, weeds are a resource."[17] This is an example of partnering with natural processes and understanding the characteristics of plants and animals to develop a win-win relationship.

Golf "can become a sport defined by harmony with nature, working responsibly with landscape and environment to create courses that are exciting to play and sustainable in the long-term. The alternatives are no longer viable. Replacing natural ecosystems with heavily modified and unnatural environments, creating artificial landscapes is simply counterproductive. It harms the industry's reputation and challenges its future). Golf has unrivalled potential to…create dynamic ecosystems from degraded landscapes and protect valuable habitats where they already

exist. Almost every single course can enrich its local ecosystem. This makes sense environmentally, commercially and in terms of public relations."[18]

The literature continues to suggest that not only do golf courses have the potential to reduce their negative environmental impact, but they have the opportunity to create significant positive environmental benefits. For example, golf courses today can be constructed on heavily degraded landscapes ranging "from sand and gravel quarries to landfill and superfund sites, to places that have been used to deposit fill and other inert waste materials."[19] Golf courses have the opportunity to "breathe new life" into disturbed sites, thus promoting the return of valuable ecosystem functions.

A final example of the potential partnership between golf courses and the care for the earth is honeybees. Honeybees are currently in a worldwide decline. This is a significant problem because of the pollination services that honeybees provide. A 2014 article in *Superintendent* highlights a few cases of golf course superintendents adding beekeeping programs, developing bee-friendly habitats, and being considerate of pollinators when considering the use of chemicals on the golf course. The honeybees that are being managed on these golf courses "are so intimately connected to the ecosystem that they provide a barometer to the health of the environment, including that of the golf course."[20] The benefits of golf course managers basing their management strategies with the careful consideration of honeybees in mind has significant environmental benefits and additionally creates other opportunities for environmental education, outreach, and investment in environmental programs. Golf course superintendent Scott Witte, who has a beekeeping program at his facility, sells the honey and beeswax in the golf shop, reinvesting the earnings in environmental programs for the golf course. "Because of the [honeybee] hives, he's talking more with golfers about the topic of golf and the environment."[20]

Care for the People: Benefits of Green Space on Community Health

Next in our considerations was the importance of green space to the health of communities and the potential for golf courses to provide this green space to their neighboring communities. Numerous studies have documented the importance of green space for effective cognitive function as facilitated by directed attention restoration. Additional studies have also chronicled the positive effects of nature in addressing childhood attention deficit hyperactivity disorder (ADHD), improved healing, addressing issues of environmental justice, motivating ecological behavior, and ultimately reducing healthcare costs as a proverbial "ounce of prevention." In an attempt to more fully understand the benefits golf courses provide their host communities, this literature review briefly summarizes these various findings.

At the end of the nineteenth century, William James first classified the two types of attention employed in human consciousness: voluntary and involuntary attention; these terms have since been renamed "directed attention" and "fascination" by Rachel and Steven Kaplan for ease of distinction.[21,22] Directed attention allows the human mind to inhibit more interesting stimuli in order to focus on what is important in the moment; this inhibition requires effort. Over the latter half of the century following James' discoveries regarding these two types of attention, the Kaplans' work at the University of Michigan School of Natural Resources and the Environment has shown directed attention to be a finite resource—one that fatigues due to the effort involved in inhibiting other stimuli, but one that can be restored through access to fascinating stimuli, including evolutionarily fascinating objects, including fast things, shiny things, bloody things, etc.[21,29]

Baumeister has shown that directed attention is necessary for self-regulation in its provision of the capability to inhibit other stimuli, be them internal or external.[23] This self-regulation is related to people's ability to control their thoughts, their emotions, their impulses, and to regulate their performance; in short, it is necessary for most higher-order executive function that allows humans to prosper in advanced and civil societies.[23] Berman, Jonides, and Kaplan expanded the study of directed attention's necessity for personal health to interpersonal health, noting that "directed attention involves resolving conflict, when one needs to suppress distracting stimulation," indicating that directed attention is important in maintaining harmony in a community as well.[24]

With directed attention playing such a paramount role in allowing for human interaction and cognitive function, the parallel ability to restore said directed attention is therefore equally important. Much of the Kaplans' research has shown that natural settings are among those most conducive to attention restoration; indeed, their research highlights some of the sources of soft fascination such as "clouds, sunsets…the motion of leaves in the breeze."[25,27] Indeed, in Tenessen's study of the effects of various degrees of natural views from a college dormitory window on associated students' performance, he found, "Those who had natural views from their dormitory windows were better able to direct attention than those with less natural views on some of the measures used to test the capacity to direct attention."[26] It seems that even a view of green space is enough to restore directed attention. These findings were bolstered by Rachel Kaplan in her study regarding the positive effects of natural elements or settings in views from a window in their home on their satisfaction with their neighborhood and their overall sense of health.[27] Wells found that these effects are not unique to adults either; in her study of relocated children, those whose new homes were "greener" tended "to have the highest level of cognitive functioning following the move."[28] Further, Sullivan and Kuo found that residents in urban Chicago who lived in homes with nearby trees reported a greater sense of community connectedness and also fewer violent crimes.[29]

Given the results of these studies, it seems that in an urban setting that is highly demanding of directed attention, the availability of green space, including that potentially provided by golf courses, is necessary for the promotion of personal and interpersonal health in the community. Golf courses therefore can play a positive role in preserving relatively undeveloped, natural, green spaces to provide opportunity for attention restoration.

The importance of green space does not end with the opportunity for directed attention restoration and the improved cognitive function it provides, however. Kuo has applied this notion of the importance of green space to underserved inner cities and found that in a study of 145 residents of urban public housing, those living in comparatively more "built" environments without trees and grass nearby reported "more procrastination in facing their major issues" and further viewed them as "more severe…less soluble" than those living with greener surroundings.[37] The wide availability of green space is therefore also an environmental justice issue, further informed by the following section regarding "fair share."[30]

Hartig, Kaiser, and Strumse's study of 1,413 Norwegian adults also found that use of green space for recreation and restoration was a strong indicator of ecological behavior.[31] In short, those with access to green space are more likely to act in environmentally-friendly, pro-sustainability ways. This appears to indicate an important feedback mechanism; as increasing development and urbanization contribute to global climate change, the behaviors necessary for preserving environmental health are in fact linked to availability and use of green space.

Taylor and Faber's study of children with ADHD found that subjects were able to focus better after a walk in nature than one in an urban setting.[32] This led them to note that "doses of nature might serve as a safe, inexpensive, widely accessible new tool in the toolkit for managing ADHD symptoms."[32] Individuals with ADHD appear to not be the only medical patients who benefit from access to green spaces either; in his study of patients recovering from surgery in a suburban Pennsylvania hospital, Ulrich found that those whose recovery rooms had a window with a view of a natural setting had "shorter post-operative stays" and took "fewer potent analgesics" than those whose windows faced a built environment.[33] In both these studies, green space, whether walked in or viewed through a window, had significant positive impact on documented mental conditions.

Finally, Maller, Townsend, Pryor, Brown, and St. Leger offer a compilation of many of the additional studies linking human health benefits with contact with nature. They posit that given these linkages, contact with nature could provide "an effective, population-wide strategy in prevention of mental ill health" and even as complementary treatment for other ailments and could therefore serve as a sort of "upstream health promotion intervention."[34] Indeed Dr. Alister Mackenzie himself commented on these benefits, writing, "Golf is a recreation and a means for giving us health and pleasure…..One of the reasons why I, a medical man, decided to give up medicine and take up golf architecture was my firm conviction of the extraordinary influence on the health of pleasurable excitement, especially when combined with fresh air and exercise. How frequently have I, with great difficulty, persuaded patients who were never off my doorstep to take up golf, and how rarely, if ever, have I seen them in my consulting room again."[35]

Taken together, these studies present a strong case for the importance of green space in a community. While quantification of savings to a community through reduction of healthcare expenditures on ADHD care, postoperative days in hospital and postoperative prescriptions, and decreased law enforcement and judiciary fees through reduction of violent crime is well-beyond the scope of this project, all items appear to include material value. There are further indirect positive effects to consider—community connectedness, improved personal and interpersonal functioning and the promotion of pro-environmental behavior all of which the literature also indicates green space to support. Golf courses, through the preservation of this green space and the access to nature, by extension provide many of these same important benefits and services to their host communities.

Fair Share: Economics

When considering the future of the golf courses and changes in practice to promote sustainability, we cannot overlook the financial implications of these activities. For decades, a dichotomy appeared to exist between sustainable practices and profitability. This conflict lead to corporations and big business being framed as the antagonist to environment. However, in recent years, it has become apparent that not only do sustainability and business need to work in unison, but sustainable practices can be good for a business' bottom-line. A study from the Massachusetts Institute of Technology surveyed executives across the country about their business's sustainable practices. Thirty-seven percent of companies reported increased profits due to their sustainability efforts.[36] Another recent study found that "S&P 500 companies that build sustainability into their core strategies are outperforming" those who are not planning.[37] In particular, corporations that

were actively planning and managing for climate change accrue an 18% higher return on investment compared to companies who are not planning ahead.

As discussed, the golf industry is especially vulnerable to changes in weather severity, climate change, and degradation of the environment. With this vulnerability and the industry's economy suffering in recent years, it is evident that next steps need to consider both economic growth and sustainable viability.

Currently, the golf industry generates about $70 billion in revenue each year. If one considers the spillover effects, incorporating tourism, this number can exceed $150 billion. With continued financial strain in a struggling market, golf courses are constantly searching for cost-control and reduction strategies. Unfortunately, today's trends suggest that environmental initiatives and golf course sustainability improvements are often overlooked when making operations and design decisions because of the higher short-term costs. However, there are studies emerging that highlight the need for a new way of thought within the industry.

The most significant "sustainability versus profit" choices tend to arise during project conceptualization and master planning in integrated golf, leisure, and residential developments. In such projects, the predominant model has often been to develop as much land into real estate as possible, reducing that which is available for golf and other landscape and ecosystem features. While such projects might bring higher short term returns on investment, a weaker golfing product, expensive maintenance of engineered fixes, and degraded residential views will all inhibit these projects' enduring success.[38]

Trends showing that this perspective is growing can be seen in several case studies. A 2012 periodical highlights the Broken Sound Club in Boca Raton, FL, and how their change in golf course management practices, especially with their composting program, has paid significant dividends for them since their initial investment. The club's general manager was skeptical that the $450,000 investment in a compost digester able to handle the amount of organic material produced on the golf course and in the four restaurants of the facility's dining operation would be able to provide a return on the investment. Not only has the initial investment been recovered, but the Broken Sound Club facility is experiencing significant savings with their new program. The facility has reduced its "landfill hauling fees by $100,000, its fertilizer costs by $35,000, and its pesticide costs by about $8,000. Also, it is shredding palm waste to make its own mulch instead of buying about $30,000 worth of pine straw."[39] Additionally, the course superintendent found that with the addition of the locally generated compost, he was able to reduce the need to apply fertilizer and pesticides to the turfgrass, thus lowering the maintenance requirements for the course and lowering costs. This case study demonstrates the benefit of taking a long-term perspective on golf course operations and demonstrates the potential for solutions that not only benefit the bottom-line, but benefit the environment as well.

In Vero Beach, FL, Orchid Island Golf and Beach Club has made sustainable enhancements to the maintenance facility that helped conserve resources as well as reduce maintenance costs. The course's proximity to the ocean posed a unique problem for the course in that the salt air was deteriorating their maintenance equipment. To be able to combat this detrition, the course designed a new facility with stations to rinse off the equipment each day. The rinse facility recycles the water daily, conserving resources while minimizing the water bill and future maintenance repairs and replacements.[40]

Similarly, the golf industry has the potential to be a leader in the arena of sustainable design and management. As shown with case studies by the American Society of Golf Course Architects (ASGCA), golf courses have the potential to become valuable sites for research. The ASGCA

highlighted cases such as FarmLinks Golf Course, where the design "integrates as many ecosystems and ecotones as practical" to be used as research plots on the property.[41]

The ASGCA also extols the Arbor Links Golf Course in Nebraska City, NE. The golf course has partnered with the National Arbor Day Foundation to develop an "educational model for a sustainable and affordable course."[42] The goals of the project include "conservation of wildlife habitat, protection and improvement of water quality in creeks and watersheds, and restoration of degraded prairie."[42] The designers developed a planting plan for the course that promoted the "restoration of prairie, wetland, and forest…by planting varieties of native tree species, which reestablished a natural wind screen and provided habitat."[42] In conjunction with this planting plan, the management of this facility is "provid[ing] opportunities for education and research sharing on the course [with the] agronomic staff [to] stud[y] turf characteristics, rate of growth, and playing conditions of the greens to detect performance differences and effects. A golf course pocket guide was also developed to educate golfers on the conservation methods employed during the design and construction and to provide information regarding sustainable maintenance techniques."[42]

It is our intention to demonstrate the long-term financial viability and value of adoption of a variety of sustainable management practices. Sustainable golf course management encompasses a broad range of techniques and methods to reduce costs as well as promote the evolution of an operating plan that has positive impacts on the environment. The strategies that this management plan will adopt will vary based on several factors, including, but not limited to regional location, seasonality, water availability, local restrictions/regulations, soil quality, neighboring ecology, and the type of golf facility. In our analysis, we take a more broad approach to the opportunities sustainable practices can have for both the bottom-line and the environment.

Sustainable Golf

Figure 1 demonstrates the three tenants of sustainable golf and their intersections. The intersection of all three tenets indicates true sustainability at a golf course. The remainder of this report will consider the three tenets of sustainable golf in the context of the two University of Michigan courses and highlight examples of the intersections of the three tenants.

Figure 1: Venn Diagram image showing "triple bottom line" intersections. (Images: Radrick;[1] Fair Share;[43] Care for the Earth;[44] Care for the People[45]).

4) Michigan's Courses: Past and Present

Applying Our Definition to the University of Michigan Blue Course and Radrick Farms Golf Course

Having structured this working definition for sustainable golf, the project team narrowed its scope to the application of this definition to inform research on the history of the University of Michigan Blue Course and Radrick Farms Golf Course (RFGC) to better understand how this history affects the current ecosystems of the courses, community perception of the area, and development of the surrounding land, as well as conduct a present-day assessment of their current state. To be able to provide recommendations and advice about the future practices of the golf courses, it is not only necessary to understand the current state of the courses, but their past as well.

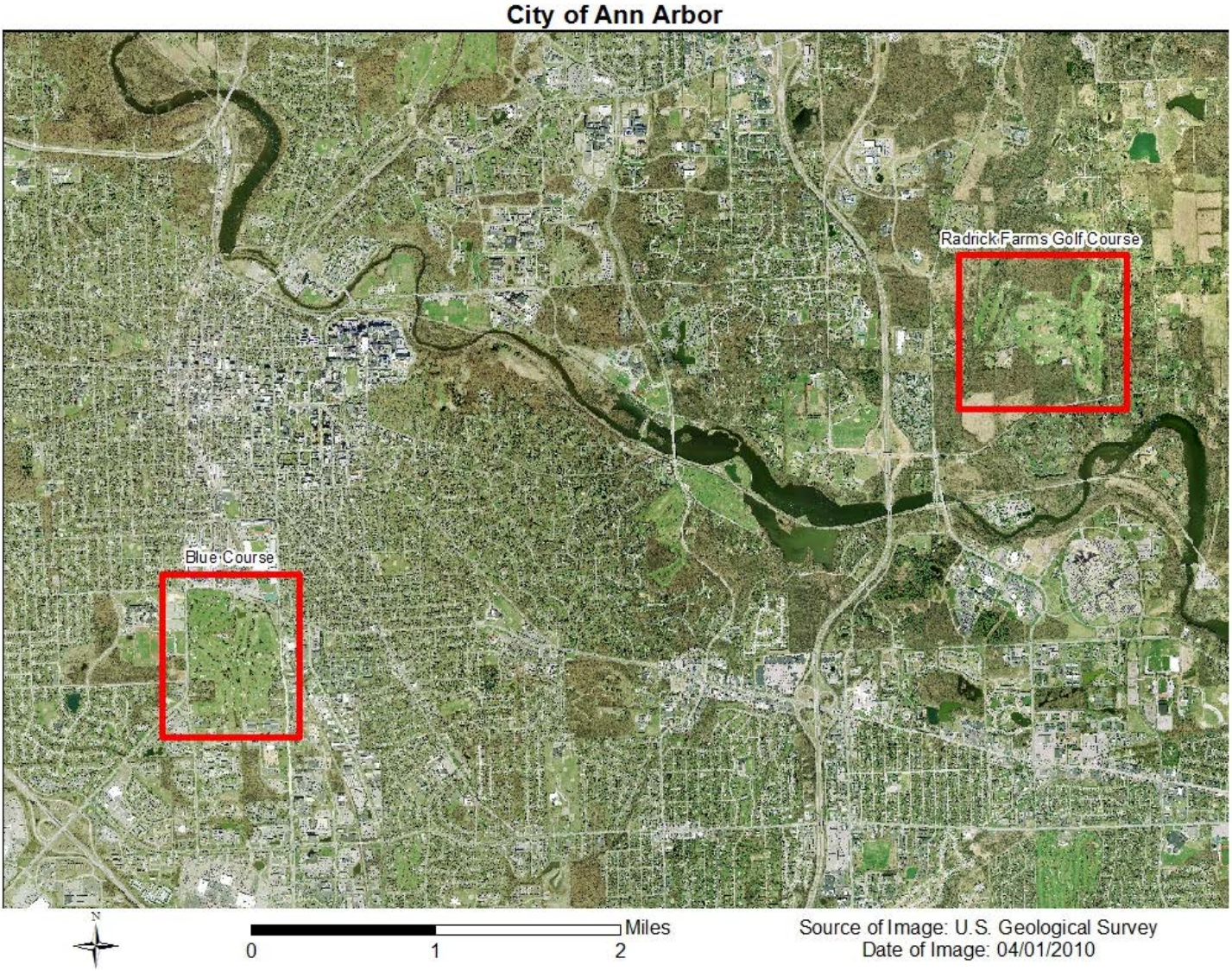


Figure 2: Radrick Farms Golf Course and the Blue Course are located in Ann Arbor, MI.

Radrick Farms Golf Course, 1965, Pete Dye

The land on which RFGC is situated has a long and diverse history. Over 18,000 years ago, the area was covered by the Wisconsin glacier, which was a layer of ice measuring up to two miles thick in some locations. As the glacier receded, it left diverse landscapes with a unique till mix and geologic features, such as Fleming Creek. There is little evidence of Native American habitation of the Radrick Farms area, although artifacts have been found in other parts of Ann Arbor. In the late 1800s, settlers began to come to the area, most of whom purchased land for lumber, which was probably milled by one of the two sawmills along Fleming Creek.[46] By 1912, the Concrete Supply Company owned part of the land that would become the golf course. The glacial activity from over 1,000 years ago had created deposits of sand and gravel, which led to the transformation of the landscape into a gravel mine. Cadillac Sand and Gravel took over the gravel pit and continued mining the area through the 1920s. In the early 1930s, University of Michigan alumnus Fredrick C. Matthaei, Sr., purchased the land from Cadillac Sand and Gravel, along with additional acreage surrounding the mine. Matthaei began the process of restoring the gravel pit by regrading the area and planting alfalfa and red clover to restore the viability of the land.[46] After these restoration efforts, Matthaei moved his family from Detroit to the Radrick Farms property. They lived in an existing white farmhouse, now the Radrick Farms Caretaker house, and built another home on site, now the Radrick Farms Golf Clubhouse. Matthaei converted portions of the land to farmland. Matthaei kept very close ties to the University of Michigan and often hosted social events at his residence.

In 1965, Frederick C. Matthaei, Sr., donated Radrick Farms. It is named in honor of his sons, Konrad and Frederick. Currently owned and operated by the University of Michigan, RFGC is an 18-hole championship course designed by world-renowned golf course architect Pete Dye. In addition to the golf course, Matthaei donated 200 acres of land to the University to develop Matthaei Botanical Gardens.

Since 2001, Radrick Farms has received special recognition from the Washtenaw County Pollution Prevention Program, in addition to becoming "one of only four courses in the state [of Michigan] with both MTESP and Audubon Cooperative Sanctuary certifications."[1] Radrick Farms Golf Course is also the only club in the state to become a Groundwater Guardian Green Site, in 2012, Washtenaw County presented RFGC with the 2012 Washtenaw County Environmental Excellence Award for Water Quality Protection, and in 2014, RFGC was recognized by the Department of Environmental Quality of the State of Michigan as a Clean Corporate Citizen (C3), the first golf course of the state to receive this recognition.

University of Michigan Golf Course, 1929, Alister Mackenzie

The 146 acre University of Michigan Golf Course (Blue Course) is located near the iconic Michigan football stadium, to the south of downtown Ann Arbor and the University of Michigan Central Campus. Prior to the construction of the course, the area was used for farmland. In 1929, the Blue Course was designed by Dr. Alister Mackenzie. Mackenzie is revered as one of the greatest golf architects. He has many award-winning courses around the world, including the Augusta National Golf Course, where the Masters Tournament, the PGA Tour's first major tournament of the year, is played annually. It is believed that Perry Maxwell drew at least two maps of the golf course, one in 1929 that was included in the 1929 Football Program and a later version that is the routing of the course today. The first iteration is very similar to the existing

layout with the exception of holes two through five, which were routed differently, with a large open space in the middle of them. The second routing, true to the layout of the golf course today, was signed by Maxwell.

The regents unofficially opened the course in the fall of 1930, and the course officially opened in the spring of 1931, immediately drawing praise as one of the finest in America. At the time of its opening, the Blue Course became just the fourth course to be located on a college campus. The Blue Course is also part of the legacy of legendary athletic director Fielding H. Yost's "Athletics for All" program and, from the time of its inception, has been the home of the University's golf teams, including the NCAA team champions in 1934 and 1935 and individual NCAA champions John Fischer (1932), Chuck Kocsis (1936), and Dave Barclay (1947).

In the mid-1990s, a multi-million dollar renovation was completed to restore the prestige of the Blue Course to the ranks of Mackenzie's other classics. Arthur Hills was responsible for coordinating the restoration. Hills is a Michigan graduate and a well-recognized golf architect. The renovation included the return of original bunkers, improved tree planting and placement, construction of stately tee areas, and an improved irrigation system. A new practice range was added to assist Michigan's golf squads, as well as a number of practice greens and practice bunkers. The popularity of golf carts necessitated large stretches of cart paths that partition landscaped medians around the course.

GIS Analysis

Introduction

It is important to understand the history of an area in order to better inform decisions regarding the future of that area. Knowing what land cover was once dominant in an area and understanding how the land cover has changed over time can help advise decisions regarding future land changes. Using digitized historical aerial photos allows for comparisons of land cover throughout time. Selecting aerial photos from key points in time, such as before and after a golf course was built, can show impacts of the golf course on the land cover. It is imperative to understand the landscape-scale changes of RFGC, the Blue Course, and the surrounding areas, in order to make better recommendations for sustainable management practices at the courses.

Methodology

For RFGC, four aerial images were selected. The first aerial image, a black and white photo collected from the U.S. Geological Survey, was taken in 1964, before the golf course was constructed. The second aerial image, also a black and white photo collected from the U.S. Geological Survey, was taken in 1966, after the golf course was constructed. The third aerial image, a black and white photo collected from Washtenaw County, was taken in 1990, after the golf course had been established for 25 years. Finally, the fourth aerial image, a color high resolution orthoimage collected from the U.S. Geological Survey, was taken in 2010, showing the present state of the golf course. Other data collected and used include a shapefile of road centerlines from 2010, which was collected from the University of Michigan Clark Library.

The images from 1964, 1966, and 1990 were georeferenced to the 2010 road centerlines shapefile. A boundary was then created by overlaying the four images. The entire area that overlapped in all four images was enclosed in the boundary. For each of the four images, eight land cover types were digitized: coniferous forest/trees, deciduous forest/trees, mixed forest, water feature, impervious surface, open/bare, grass, and turf. The summary statistics of the digitized land cover shapefiles were analyzed, and tables were created highlighting the percentage of each land cover type by year and the percent change in land cover types between years.

For the Blue Course, three aerial images were selected. The first aerial image, a black and white photo collected from the U.S. Geological Survey, was taken in 1963. The second aerial image, a black and white photo collected from Washtenaw County, was taken in 1990. Finally, the third aerial image, a color high resolution orthoimage collected from the U.S. Geological Survey, was taken in 2010, showing the present state of the golf course. Other data collected and used include a shapefile of road centerlines from 2010, which was collected from the University of Michigan Clark Library.

The images from 1963 and 1990 were georeferenced to the 2010 road centerlines shapefile. Then a boundary was created by overlaying the three images together. The entire area that overlapped in all three images was enclosed in the boundary. For each of the three images, eight land cover types were digitized: coniferous forest/trees, deciduous forest/trees, mixed forest, water

feature, impervious surface, open/bare, grass, and turf. The summary statistics of the digitized land cover shapefiles were analyzed, and tables were created highlighting the percentage of each land cover type by year and the percent change in land cover types between years.

Results

*Table 2***.** Land cover types of Radrick Farms Golf Course and the surrounding area by percent area.

	Percent Area			
Land Cover	**1964**	**1966**	**1990**	**2010**
Coniferous Forest/Trees	0.3	0.4	10.0	0.6
Deciduous Forest/Trees	2.4	2.6	1.3	14.0
Grass	**63.8**	**44.0**	36.2	**35.2**
Turf	0	7.5	5.7	4.6
Impervious Surface	3.4	4.0	4.8	8.5
Mixed Forest	28.0	37.5	**38.6**	33.9
Open/Bare	0.1	1.8	0.1	0.2
Water	2.0	2.2	3.3	3.0

*Table 3***.** Percent change in land cover types of Radrick Farms Golf Course and the surrounding area across multiple years.

	Percent Change			
Land Cover	**1964 to 1966**	**1966 to 1990**	**1990 to 2010**	**1964 to 2010**
Coniferous Forest/Trees	+0.1	+9.6	-9.4	**+0.3**
Deciduous Forest/Trees	+0.2	-1.3	+12.7	**+11.6**
Grass	-19.8	-7.8	-1.0	**-28.6**
Turf	+7.5	-1.8	-2.8	**+4.6**
Impervious Surface	+0.6	+0.8	+3.7	**+5.1**
Mixed Forest	+9.5	+1.1	-4.7	**+5.9**
Open/Bare	+1.7	-1.7	+0.1	**+0.1**
Water	+0.2	+1.1	-0.3	**+1.0**

Table 4. Land cover types of the Blue Course and the surrounding area by percent area.

Land Cover	Percent Area		
	1963	**1990**	**2010**
Coniferous Forest/Trees	1.7	5.0	1.1
Deciduous Forest/Trees	1.0	2.9	4.2
Grass	**43.8**	15.7	20.1
Turf	13.7	15.1	17.4
Impervious Surface	30.3	**41.2**	**42.4**
Mixed Forest	5.5	19.5	11.6
Open/Bare	3.7	0.3	2.6
Water	0.3	0.3	0.5

Table 5. Percent change in land cover types of the Blue Course and the surrounding area across multiple years.

Land Cover	Percent Change		
	1963 to 1990	**1990 to 2010**	**1963 to 2010**
Coniferous Forest/Trees	+3.3	-4.0	**-0.6**
Deciduous Forest/Trees	+2.0	+1.3	**+3.3**
Grass	-28.2	+4.5	**-23.7**
Turf	+1.4	+2.3	**+3.7**
Impervious Surface	+11.0	+1.1	**+12.1**
Mixed Forest	+14.0	-7.9	**+6.1**
Open/Bare	-3.4	+2.3	**-1.1**
Water	+0.1	+0.2	**+0.3**

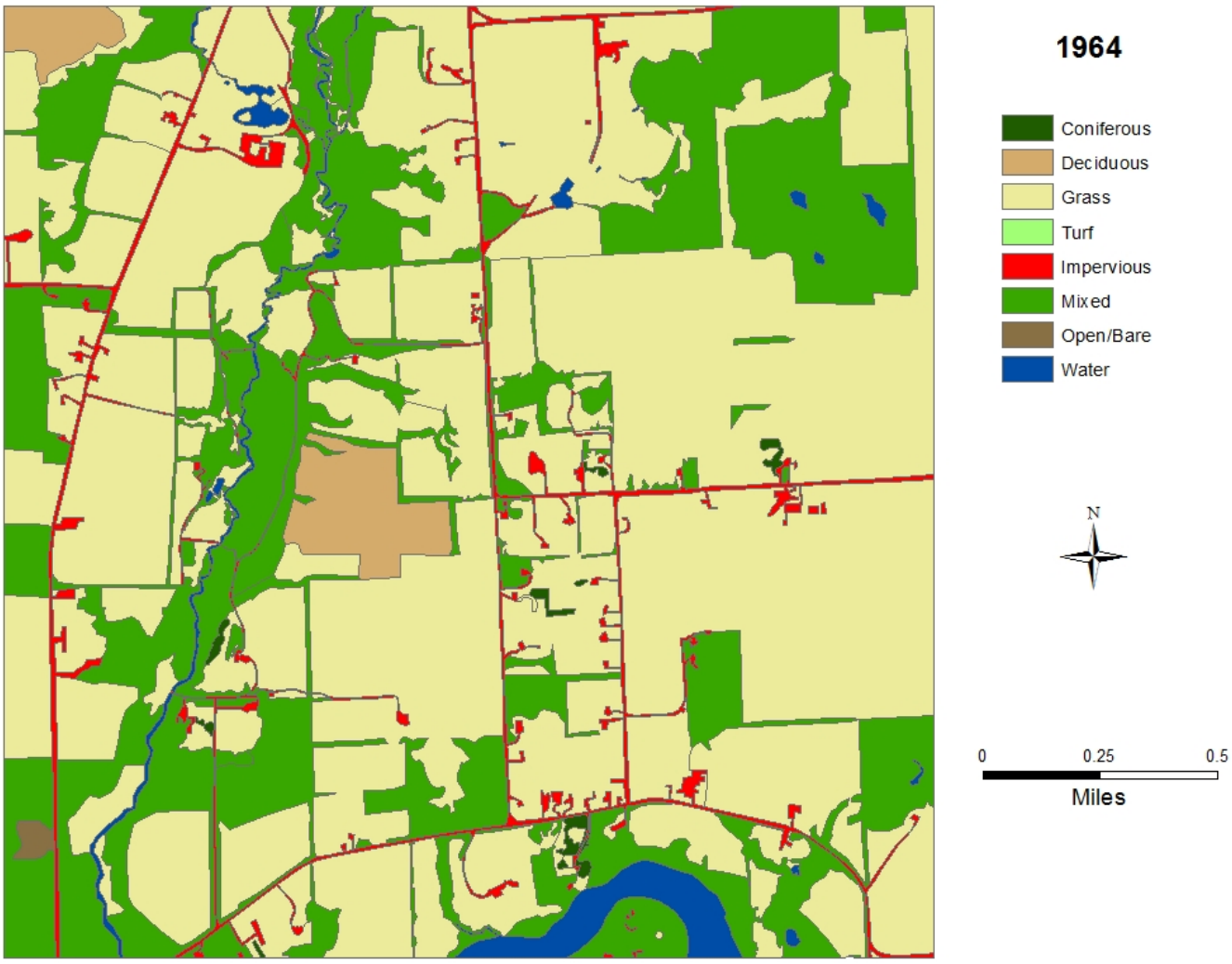


Figure 3. Radrick Farms Golf Course and the surrounding area land cover in 1964.

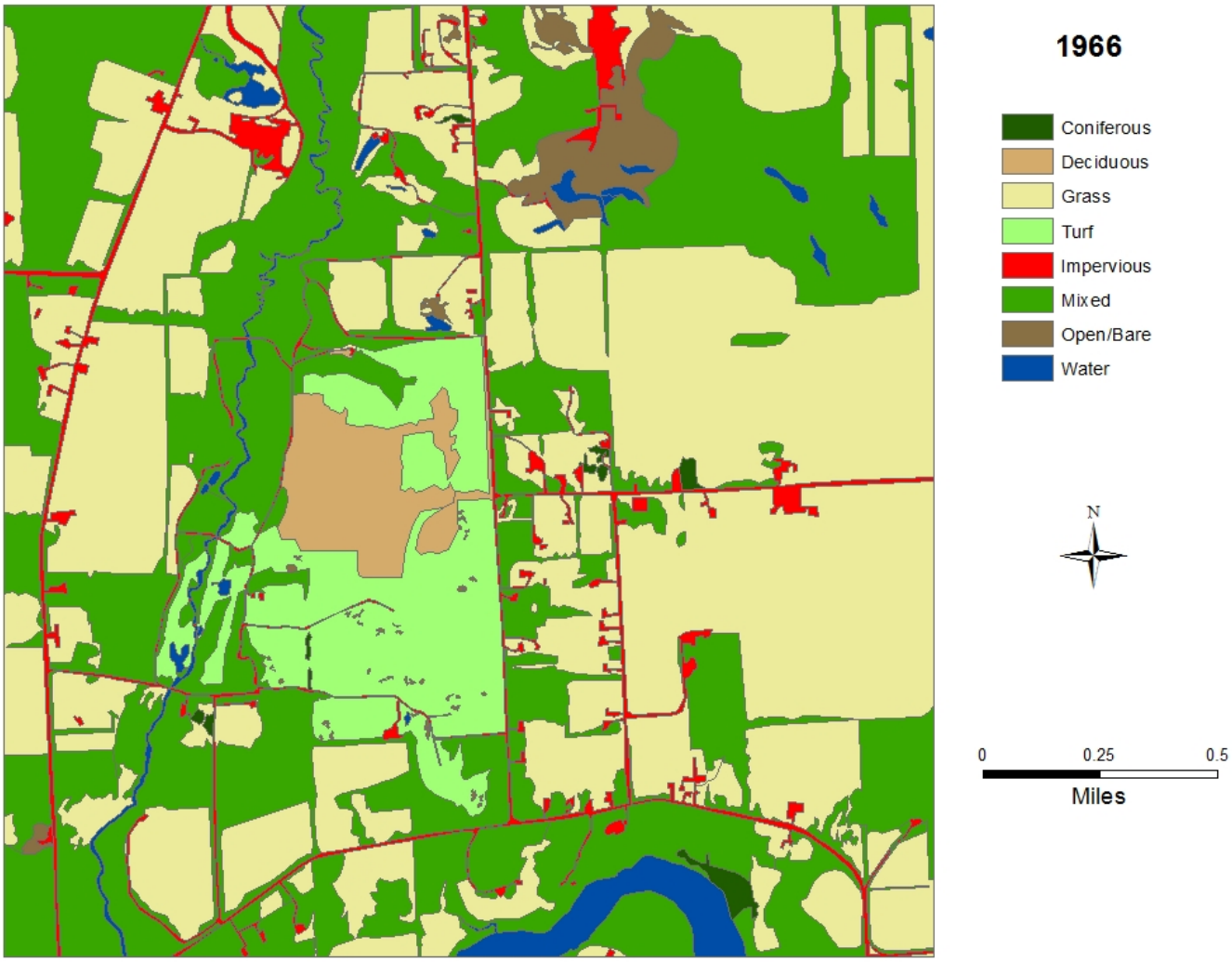


Figure 4. Radrick Farms Golf Course and the surrounding area land cover in 1966.

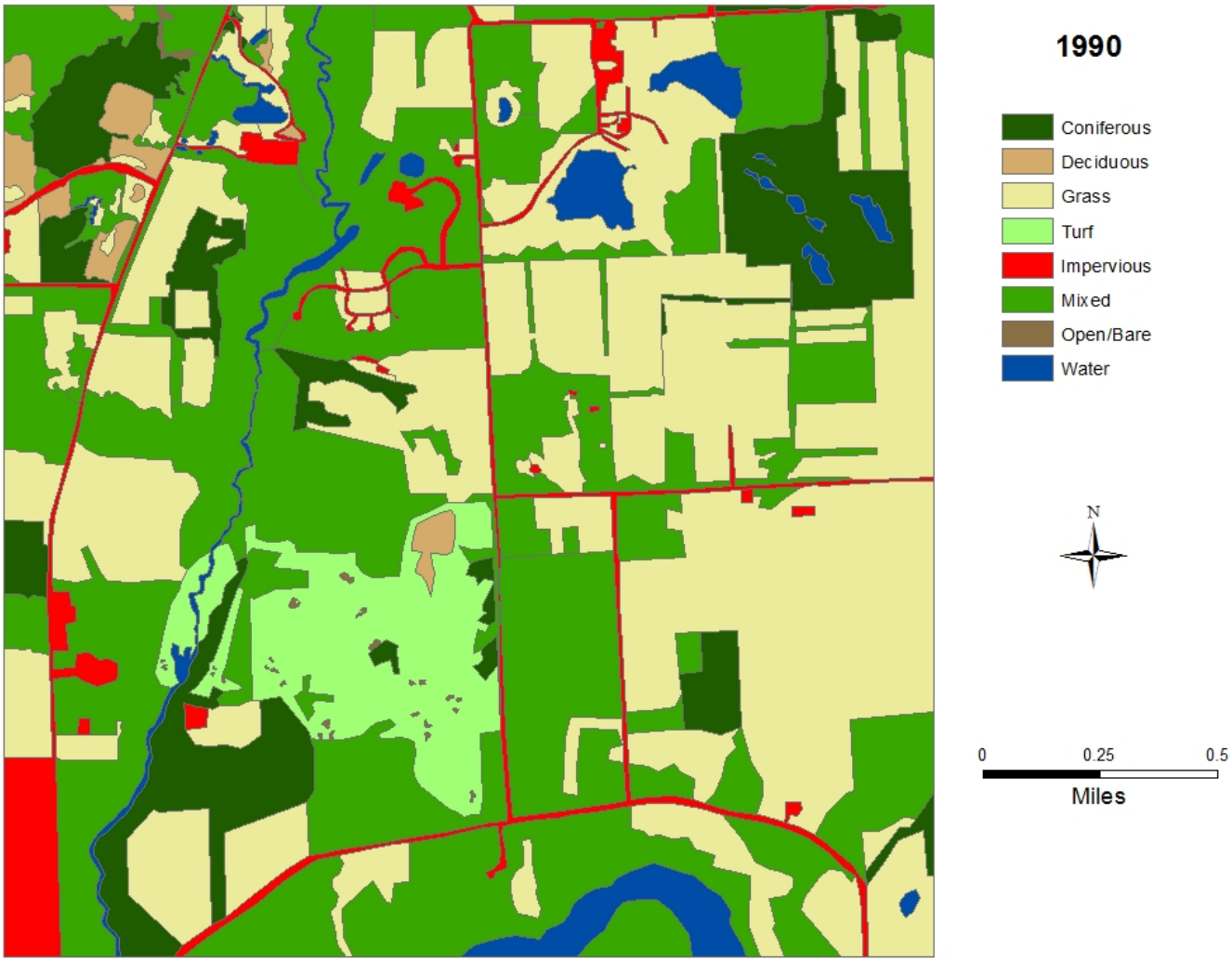


Figure 5. Radrick Farms Golf Course and the surrounding area land cover in 1990.

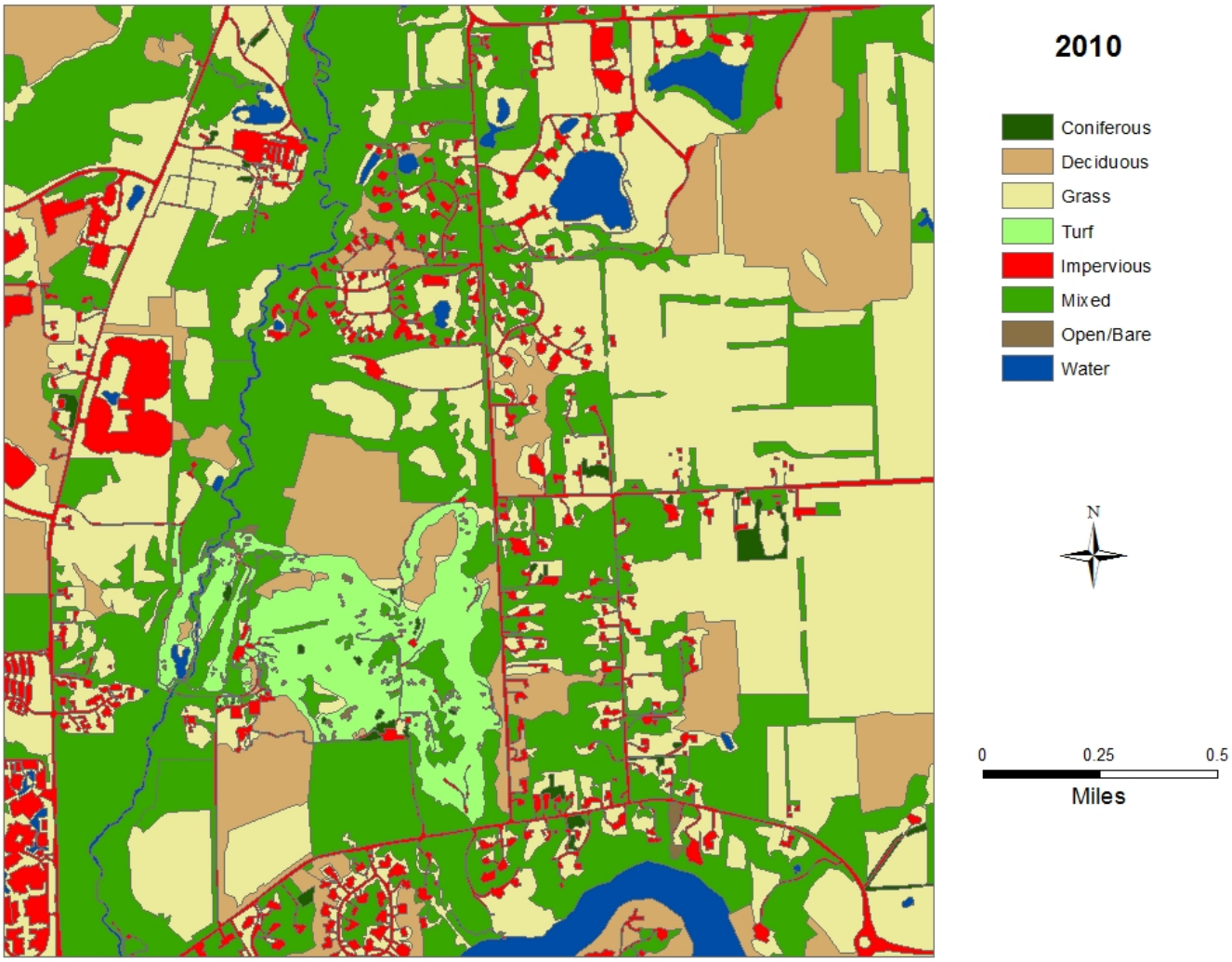


Figure 6. Radrick Farms Golf Course and the surrounding area land cover in 2010.

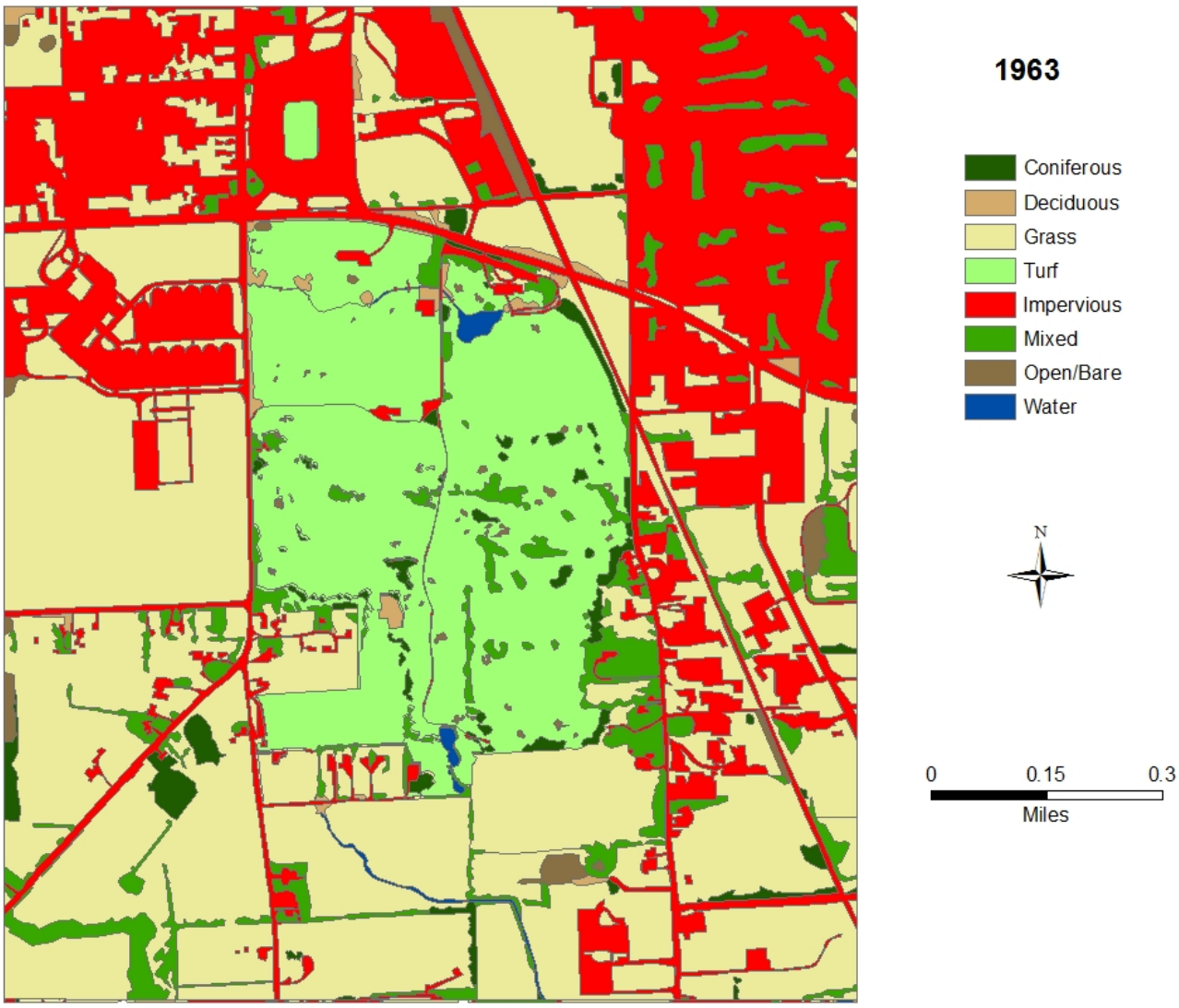


Figure 7. The Blue Course and the surrounding area land cover in 1963.

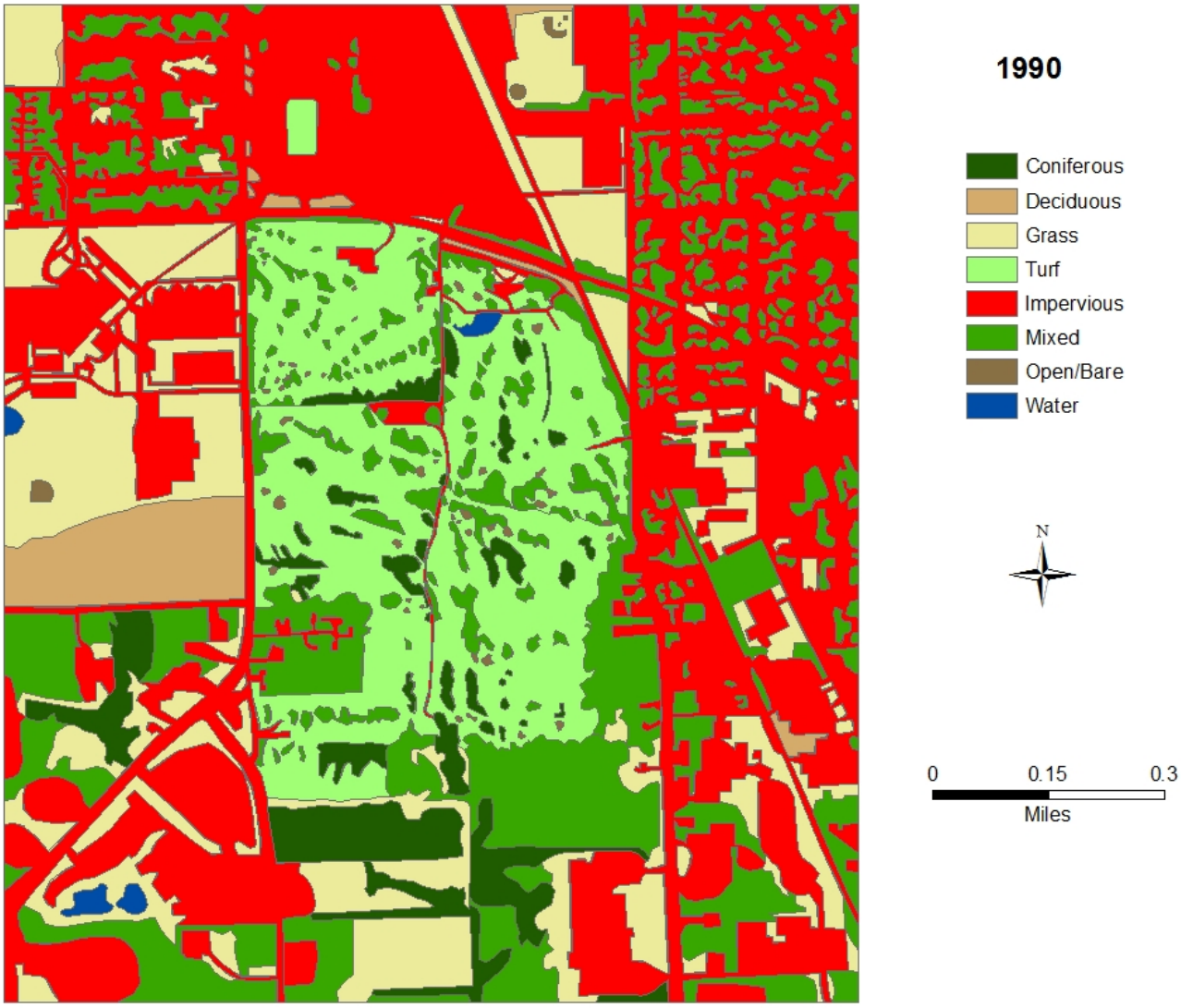


*Figure 8***.** The Blue Course and the surrounding area land cover in 1990.

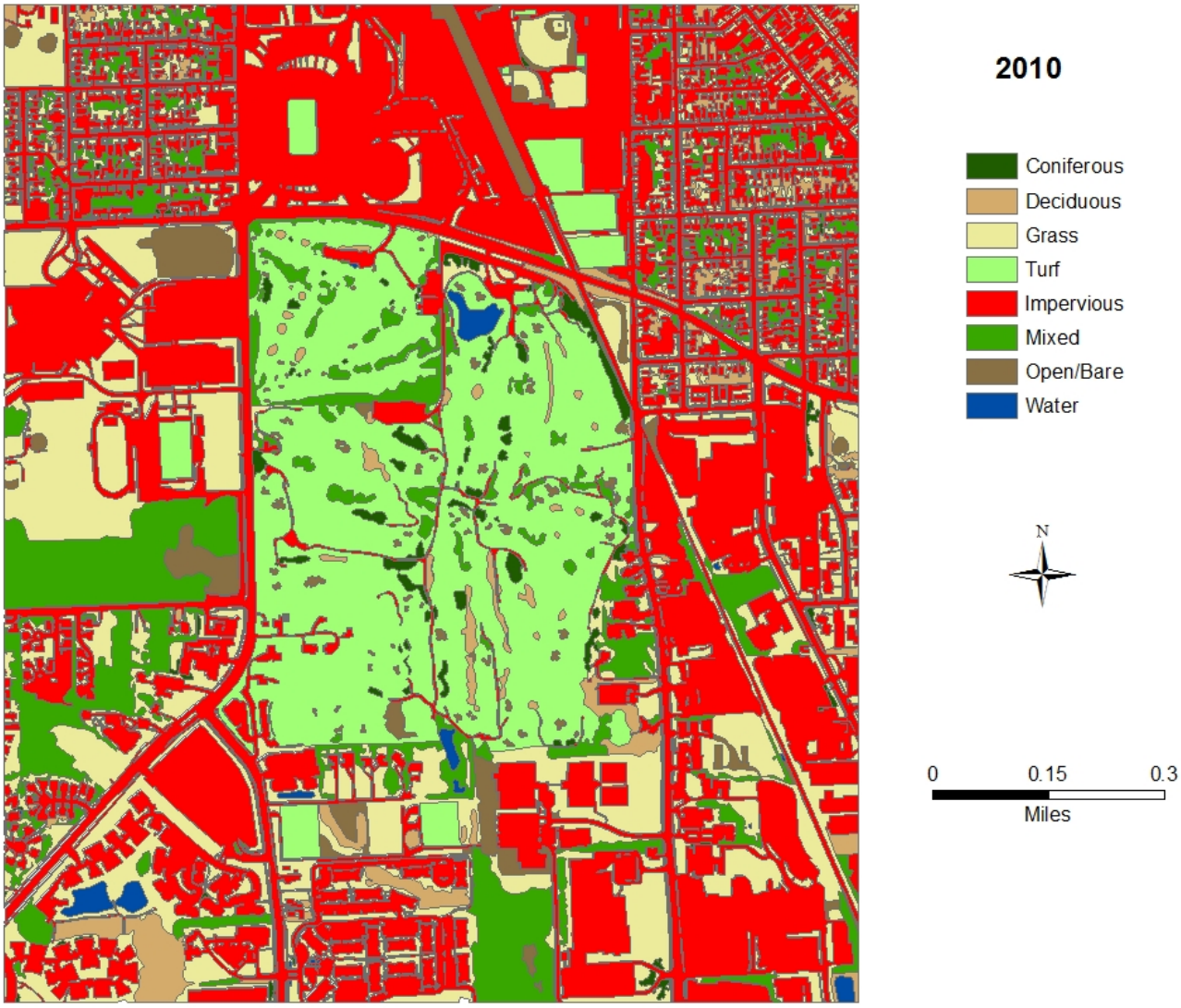


*Figure 9***.** The Blue Course and the surrounding area land cover in 2010.

Discussion

For RFGC and the surrounding area, grass was the dominant land cover type in 1964, 1966, and 2010, and mixed forest was the dominant land cover type in 1990 (*Table 2*). From 1964 to 2010, the largest percent changes in land cover types were grass, with a 28.6% decrease, followed by deciduous forest/trees, with an 11.6% increase (*Table 3*). The percentage of the other land cover types slightly increased between 1964 and 2010. Because the 2010 image was fine resolution and in color, compared to the 1964 black and white coarse resolution image, land cover types could be differentiated easily in the 2010 image, which may explain the decrease in grass and the increase in deciduous forest/trees. There was a 5.1% increase in impervious surfaces from 1964 to 2010 (*Table 3*), which may be explained by increased urbanization. All forest types increased from 1964 to 2010. This phenomenon may be explained by the fruition of Matthaei's replanting efforts after his purchase of the property in the 1930s, but this explanation is not definitive.

For the Blue Course and the surrounding area, grass was the dominant land cover type in 1963, and impervious surface was the dominant land cover type in 1990 and 2010 (*Table 4*). From 1963 to 2010, the largest percent change in land cover types was grass, with a 23.7% decrease, followed by impervious surface, with a 12.1% increase (*Table 5*). The percentage of deciduous forest/trees, turf, mixed forest, and water slightly increased between 1963 and 2010, while the percentage of coniferous forest/trees and open/bare areas slightly decreased. There was a 12.1% increase in impervious surfaces from 1963 to 2010 (*Table 5*), which may be explained by increased occurrence of urbanization. Because of increasing urbanization in this area throughout its history, grass and open/bare areas would decrease as development occurred.

There were several limitations to the project. The first is the inherent subjective nature of digitization. The person doing the digitizing may classify an area differently than another person performing the same digitization process. Georeferencing inaccuracies also occurred, as road centerlines change throughout time, and the road centerlines used for georeferencing were from 2010 and are likely different than the road centerlines in 1963, 1964, 1966, and 1990. Another issue was the lack of available fine resolution and color aerial images for all the years used in the project. The images from 1963, 1964, 1966, and 1990 were coarse resolution and black and white, making it more difficult to distinguish land cover types. The image from 2010 was fine resolution and color, so land cover types were easier to differentiate.

Conclusions

Radrick Farms Golf Course and the surrounding areas have experienced land cover change since 1964 when the golf course was not in existence (*Fig. 3-6*). Although the dominant land cover type remained grass for most years, an overall decrease in grass areas occurred. There may be a correlation between the construction of RFGC and the observed decrease in grass areas. However, it is not conclusive.

The Blue Course and the surrounding area has also experienced land cover change since the early 1960s (*Fig. 7-9*). There was a shift in dominant land cover type from grass to impervious surfaces. This is likely due to urbanization that occurred in this area as the city of Ann Arbor grew. Because aerial photos could not be obtained from dates prior to the construction of the Blue Course, no definitive conclusions can be drawn as to how the construction of the Blue Course affected the landscape.

Ecological Inventory

Introduction

Golf courses have the opportunity to support ecosystems by incorporating natural areas into their designs. Because they provide habitat, naturalistic golf courses are able to support a wider range of wildlife, including threatened and endangered species, than golf courses that do not incorporate natural areas into their designs.[47] Radrick Farms Golf Course currently has some natural areas that are considered suitable habitat for the Eastern Massasauga Rattlesnake (*Sistrurus catenatus*), a rare and threatened species native to Michigan. Increasing the quantity and quality of habitat suitable for these snakes will promote reproduction and population growth. Similarly, increasing the amount and quality of habitat for other rare, threatened, and endangered species will promote reproduction and population growth of those respective species.

Increasing plant species diversity, especially native plant species diversity, at both golf courses will have several positive effects. The number of invasive plant species able to establish will decrease, and the success of current invasive plant species will also decrease.[48] This will allow the native plant species to compete more efficiently with non-native and invasive plants, which will help keep invasive species at a minimum. Areas with minimal invasive species require less maintenance and are thus less costly to maintain, which will save the golf course money in the long run because less chemical and manual control will be needed in those natural areas.[58]

Both RFGC and the Blue Course contain an array of native, non-native, and invasive species. It is important to determine which native, non-native, and invasive species are present on the properties and in what density so that appropriate recommendations for native species plantings can be made and so that an appropriate invasive species control plan can be established. Species diversity and invasive species surveys allow for identification of species in a variety of distinct, classified habitats on both RFGC and the Blue Course.

Methodology

At RFGC, the following four habitat types were chosen for analysis: grassland, wetland, mixed forest, and deciduous forest. Two sites per habitat type were surveyed, for a total of eight sites. At the Blue Course, the following two habitat types were chosen: grassland and deciduous forest. Two sites per habitat type were surveyed, for a total of four sites. At each site, three concentric circles were flagged by measuring the varying diameters with a measuring tape. The smallest circle was four meters in diameter, enclosed by a circle 10 meters in diameter, which was enclosed by a circle 20 meters in diameter. For the species diversity survey, herbs and seedlings were counted in each four meter circle; vines, shrubs, and saplings in the 10 meter circle; and adult trees in the 20 meter circle. Herbs and seedlings were defined as plants having a height of 30 centimeters or less. Vines, shrubs, and saplings were defined as plants having a height greater than 30 centimeters and a diameter at breast height (DBH) of less than 20 centimeters. Adult trees were defined as trees having a height of greater than 30 centimeters and a DBH of more than 20 centimeters. For the invasive species survey, all invasive species within the 20 meter circle were counted. Invasive species in nearby locations were also noted.

The survey areas were also mapped using a GPS device and a GIS (Geographic Information System). GPS coordinates were collected at the center point of each set of concentric circles and

at four points along the circumference of each circle. The polygonal outlines of most of the circles were also recorded with the GPS device. Some circles could not be recorded as they ran through dense patches of poison-ivy (*Toxicodendron radicans*) or were immediately adjacent to Fleming Creek. If a large patch of invasive species was present, GPS data was also collected at that location.

Results

Field observations from both the species diversity and invasive species surveys were collected and compiled into spreadsheets (*Appendix II*).

Figure 10: Ecological survey centers for the eight sites at Radrick Farms Golf Course.

Figure 11: Survey design of a deciduous forest replicate at Radrick Farms Golf Course.

Figure 12: Ecological survey centers for the four sites at the Blue Course.

Discussion

At RFGC, the predominant non-grass species in the grassland habitat are Canada thistle (*Cirsium arvense*) and grass-leaved goldenrod (*Euthamia graminifolia*). Because grass species are difficult to identify, they were not surveyed by species or genera. Approximate number of grass species were noted in the results. Canada thistle is the most commonly recorded invasive species in the grassland habitat. The predominant species in the deciduous forest habitat is Virginia creeper (*Parthenocissus quinquefolia*). Amur honeysuckle (*Lonicera maackii*) is the most commonly recorded invasive species in the deciduous forest habitat. In the mixed forest habitat type, common buckthorn (*Rhamnus cathartica*) and Amur honeysuckle are the dominant species. The most prevalent invasive species in the mixed forest habitat is common buckthorn. Finally, common buckthorn and Joe-Pye weed (*Eupatorium purpureum*) are predominant in the wetland habitat type. Canada thistle was the most commonly recorded invasive species in the wetland habitat. At the second site in the wetland habitat, the largest survey circle of 20 meters in diameter could not be created or surveyed because the site was located immediately adjacent to Fleming Creek, with manicured golf course turf on the opposite side.

Thirteen different invasive species were observed on RFGC. In the grassland habitat, Canada thistle, common mullein (*Verbascum thapsus*), Queen Anne's lace (*Daucus carota*), and common buckthorn were noted. Because Canada thistle was found in dense patches in both grassland replicates, this species would be best controlled through chemical use, which can be combined with mowing.[49] It is best to use chemical (glyphosate) control in two applications per year, one application happening in the spring or early June when the plants are first budding and one application happening in the fall on the new growth of the plants.[49] Common mullein was very sparse, with only two individuals being observed in one of the grassland replicates, so the best way to control this species is through manual methods, such as digging or pulling.[50] The best time for manual control methods are in the spring (May and June).[50] Queen Anne's lace was observed in patches of varying density in one of the grassland replicates. In the patches of higher density, chemical control methods are best, while in patches of lower density, manual control methods, such as digging or pulling while wearing gloves, are best.[51] Both control methods should be done in mid to late summer, before the plant begins seeding.[51] Common buckthorn was somewhat dense in one of the grassland replicates. Methods most effective for controlling common buckthorn are cut-stump treatment on smaller plants, which involves cutting all main stems close to the ground and treating the stumps with a glyphosate herbicide, or girdling on larger plants, which involves slicing a ring around the stem that cuts into the cambium, in combination with chemical control.[52] Both of these methods can be done in the summer, fall, and winter because sap flow is lighter in these seasons.[52]

In the deciduous forest habitat, Amur honeysuckle, autumn-olive (*Elaeagnus umbellata*), Japanese barberry (*Berberis thunbergii*), lily of the valley (*Convallaria majalis*), lesser burdock (*Arctium minus*), and common buckthorn were observed. Amur honeysuckle was found in high density in one of the deciduous forest replicates. The best control method to use for this species is cut-stump treatment, in which the stems are cut and a glyphosate herbicide is applied to the stump, in late summer, fall, and winter.[53] Only two autumn-olives were observed in one of the deciduous forest replicates. Cut-stump treatment, using a glyphosate herbicide, is also the best way to control autumn-olive.[54] The best time to employ control is July through September and during the dormant season.[54]

Only a few Japanese barberry were observed in one of the deciduous forest replicates. Because of the low density, it is best to use cut-stump treatment with a glyphosate herbicide on larger plants in the summer, fall, and winter and manual methods, like pulling, on seedlings when the soil is moist.[55] Burning in the late spring can also be used to kill seedlings, but this method is not currently recommended for Radrick Farms Golf Course because the species is at such low density, and burning would be more effective for higher density patches.[55] Lily of the valley was observed at medium densities throughout one of the deciduous forest replicates. This species should be controlled chemically, specifically by foliar glyphosate application, in the early spring.[56] A single individual of lesser burdock was observed. In this case, due to the low density and small size of the plant, it should be manually controlled through digging or pulling before the plant begins seeding.[57] Common buckthorn was observed at low density and should be treated any time of the year except spring through cut-stump or girdling methods combined with chemical application.[52]

In the wetland habitat, Queen Anne's lace, lesser burdock, white sweet clover (*Melilotus alba*), common buckthorn, autumn-olive, Canada thistle, multiflora rose (*Rosa multiflora*), and purple loosestrife (*Lythrum salicaria*) were the observed invasive species. Due to the high densities at which the Queen Anne's lace was observed, this species is best controlled via wetland-safe chemical treatment in mid to late summer before seeding.[51] Large and small individuals of lesser burdock were observed in one of the wetland replicates, so large plants should be controlled via foliar chemical application during the time between the rosette and bloom stages, and small plants should be controlled by manual methods such as pulling or digging before the plant goes to seed.[57] White sweet clover was sparse. This species should be controlled through manual methods. Digging or pulling of first year plants should be done in the fall, while digging or pulling of older plants should be done in June or July before flowering occurs.[58] Mowing when the plants are in flower can also be employed as a control method.[58]

Common buckthorn, observed in one wetland replicate at high density, and autumn-olive, observed in one wetland replicate at low density, should be controlled in the summer, fall, and winter via cut-stump or girdling methods in combination with glyphosate herbicide application.[52,54] Canada thistle, observed in high density, is best controlled through chemical application twice a year, once in the spring or early June when the plants are first budding and once in the fall on the new growth.[49] Chemical control can be combined with mowing to increase effectiveness.[49] A single multiflora rose was recorded, so it is best controlled via manual methods, specifically digging the plant out, during the growing season (spring or summer).[59] If multiflora rose begins invading at greater densities, the species should be controlled via cut-stump or basal bark glyphosate chemical treatment in July through September and during the dormant season.[59] Purple loosestrife was observed at medium densities throughout one of the wetland replicates. This species is best controlled via manual methods, such as pulling or digging, in June, July, or early August, before going to seed, or chemical methods, such as glyphosate foliar application, in late August.[60] If the plant has already begun seeding, the flower heads should be clipped into plastic bags and put into the trash.[60] Biological methods can also be used to control purple loosestrife. Beetles in the genus *Gallerucella* will cause defoliation of the plant and prevent flowering and seeding, which helps control the population of purple loosestrife.[60]

In the mixed forest habitat, common buckthorn, Amur honeysuckle, and garlic mustard (*Alliaria petiolata*) were the observed invasive species. Common buckthorn and Amur honeysuckle, both found at high densities in both mixed forest replicates, are best controlled through cut-stump or girdling combined with glyphosate treatment of the stumps or girdled

portion.[52,53] Garlic mustard is best controlled via manual methods. The plants should be pulled, put into a bag, and disposed of in a landfill or a compost facility, such as the Ann Arbor Compost Facility.[61]

Following control methods at RFGC, native plant species could be planted in such a way to increase species diversity, which would reduce success and establishment of invasive species and promote habitat suitable for wildlife.[47,48] The following plant species native to Southeast Michigan are recommended for planting in the grassland habitats: big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), black-eyed Susan (*Rudbeckia hirta*), common milkweed (*Asclepias syriaca*), prairie sunflower (*Helianthus petiolaris*), false sunflower (*Heliopsis helianthoides*), grass-leaved goldenrod (*Euthamia graminifolia*), red raspberry (*Rubus strigosus*), river-bank grape (*Vitis riparia*), black walnut (*Juglans nigra*), pignut hickory (*Carya glabra*), and American elm (*Ulmus americana*). The following plant species native to Southeast Michigan are recommended for planting in the deciduous forest habitats: big-leaved aster (*Aster macrophyllus*), black cherry (*Prunus serotina*), bitternut hickory (*Carya cordiformis*), pignut hickory (*Carya glabra*), shagbark hickory (*Carya ovata*), white oak (*Quercus alba*), northern red oak (*Quercus rubra*), hop-hornbeam (*Ostrya virginiana*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), creeping strawberry-bush (*Euonymus obovata*), and common trillium (*Trillium grandiflorum*).

The following plant species native to Southeast Michigan are recommended for planting in the wetland habitats: silky dogwood (*Cornus amomum*), joe-pye weed (*Eupatorium purpureum*), swamp milkweed (*Asclepias incarnata*), river-bank grape (*Vitis riparia*), New England aster (*Aster novae-angliae*), spotted joe-pye weed (*Eupatorium maculatum*), common boneset (*Eupatorium perfoliatum*), dense blazing star (*Liatris spicata*), cutleaf coneflower (*Rudbeckia laciniata*), swamp goldenrod (*Solidago patula*), purple meadow-rue (*Thalictrum dasycarpum*), and golden Alexanders (*Zizea aurea*). The following plant species native to Southeast Michigan are recommended for planting in the mixed forest habitats: red elm (*Ulmus rubra*), Norway spruce (*Picea abies*), prickly gooseberry (*Ribes cynosbati*), black cherry (*Prunus serotina*), red maple (*Acer rubrum*), and eastern white pine (*Pinus strobus*).

At the Blue Course, the predominant non-grass species in the grassland habitat is Canada thistle. Once again, grass species were not identified by species or genera, but rather by approximate number of different species, as noted in the results. The most commonly recorded invasive species in the grassland habitat is Canada thistle. In the deciduous forest habitat, European privet (*Ligustrum vulgare*) and black ash (*Fraxinus nigra*) are the predominant species. Canada thistle and European privet are the most prevalent invasive species in the deciduous forest habitat.

Eight different invasive species were observed on the Blue Course. In the grassland habitat, Queen Anne's lace, Canada thistle, tree-of-heaven (*Ailanthus altissima*), common buckthorn, glossy buckthorn (*Frangula alnus*), and lesser burdock were the observed invasive species. Queen Anne's lace was observed in patches of varying densities. Lower density patches should be controlled via manual methods, such as digging or pulling, in mid to late summer before the plants begin seeding.[51] Higher density patches should be controlled via chemical methods, such as glyphosate foliar application, in the mid to late summer before the plants begin seeding.[51] Canada thistle was observed at high density in both grassland replicates and should be controlled via two chemical (glyphosate) applications per year-one in the spring or early June when the plants are first budding and one in the fall on the new growth of the plant.[49] The chemical control methods can be combined with mowing to increase effectiveness.[49]

Tree-of-heaven, which was observed at medium density, should be controlled via cut-stump or girdling methods in combination with chemical treatment in the summer, fall, or winter.[62] Common buckthorn, observed at high density in one of the grassland replicates, and glossy buckthorn, observed at low density in one of the grassland replicates, should be controlled via cut-stump or girdling methods in combination with glyphosate treatment to the stump or girdled portion.[52,63] The best times to employ control methods for common buckthorn are summer, fall, and winter, while the best times to employ control methods for glossy buckthorn are restricted to fall and winter.[52,63] Lesser burdock, observed at medium density in one of the grassland replicates, should be controlled via manual methods, such as digging or pulling, for smaller individuals before seeding, or chemical methods, such as glyphosate foliar application, for larger individuals between the rosette and bloom stages.[57]

In the deciduous forest habitat, common buckthorn, Canada thistle, European privet, Norway maple (*Acer platanoides*), and lesser burdock were the observed invasive species. Common buckthorn was observed at medium densities in both deciduous forest replicates and is best controlled by cut-stump or girdling methods followed by glyphosate application to the stump or girdled portion.[52] Canada thistle was observed at high density in one of the deciduous forest replicates. This species is best controlled by chemical (glyphosate) foliar application, with one application occurring in the spring or early June when first budding and one application occurring in the fall on new plant growth.[49] European privet, which was observed at high density in one of the deciduous forest replicates, is best controlled via the cut-stump method and chemical (glyphosate) treatment of the stumps in the fall and through the dormant season.[64] Norway maple, observed at low density in both deciduous forest replicates, is best controlled by chemical or manual methods. Chemical methods, such as cut-stump or girdling followed by glyphosate application, should be employed in February to March or June to September on larger individuals.[65] Manual methods, such as pulling, should be used on seedlings when the soil is moist in the spring.[65] Lesser burdock, observed at low density in one of the deciduous forest replicates, should be controlled via manual methods, such as digging or pulling, before seeding.[57] In this case, chemical control is not advised due to the low density at which this species is observed.

Following control methods at the Blue Course, native plant species should be planted to increase defense against invasive species and promote naturalistic areas that are able to support wildlife at the golf courses.[47,48] The following plant species native to Southeast Michigan are recommended for planting in the grassland habitats: big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), black-eyed Susan (*Rudbeckia hirta*), common milkweed (*Asclepias syriaca*), prairie sunflower (*Helianthus petiolaris*), false sunflower (*Heliopsis helianthoides*), river-bank grape (*Vitis riparia*), and choke cherry (*Prunus virginiana*). The following plant species native to Southeast Michigan are recommended for planting in the deciduous forest habitats: bur oak (*Quercus macrocarpa*), common trillium (*Trillium grandiflorum*), and creeping strawberry-bush (*Euonymus obovatus*).

Conclusions

Radrick Farms Golf Course contains a greater number of habitat types than the Blue Course (four habitat types versus two habitat types), as RFGC encompasses a greater amount of land, especially unmaintained natural areas, than the Blue Course. Radrick Farms Golf Course also contains a larger number of species that are considered invasive than the Blue Course. Therefore,

species diversity and the number of different invasive species is greater at RFGC than at the Blue Course.

Site Inventory and Analysis

Introduction

The University of Michigan golf course properties play a crucial role within the surrounding environment. The change in land cover over the past 50 years has shown that Radrick Farms Golf Course and the Blue Course provide a large area of green space in the greater context and are a strong link within the larger network. The green space provided through these courses is beneficial for creating and connecting habitat area, along with fostering mental well-being and motivating ecological behavior of the players and members of the courses' community partnerships. The courses are an oasis for people to connect with nature in a safe environment. With part of Fleming Creek lying within RFGC and the headwaters of Allen Creek lying within the Blue Course, the courses can have a large impact on improving the water quality within the Huron River Watershed. Realizing the importance of the courses and the great impacts they can have on the community and surrounding landscape is essential. An exploration of each of the sites from one end to the other is the next step within our data collection and investigation of how the golf courses can strengthen their sustainability.

Methodology

Radrick Farms Golf Course was toured by golf cart and foot, starting from the first hole through the eighteenth hole. This route was chosen in order to recreate the route and overall experience that a player would have during a full round of golf, 18 holes. The Blue Course was toured in the same manner as RFGC. The features and characteristics collected for the inventory were determined by the Greener Golf Master's Project Team prior to visiting each of the sites. These characteristics all fall under one or multiple ethics of the three Greener Golf ethics: care for the earth-environment, care for the people-community, and fair share-economics. These features include *access points* or connections to the surrounding property (i.e. roads or trails, property boundaries, adjacent land uses, and land cover); *topography* (i.e. views); *hydrology*, including water runoff, points of catchment, and existing creeks or detention ponds; habitat type areas such as *natural areas*; *wooded areas*; *existing habitats*; *built structures*, such as buildings, storm shelters, and bridges; and *sounds*. Included under the earth-environment ethic are the open areas, wooded areas, and existing habitats. Within the people-community ethic are the uses of the built structures and areas that hold events or are used by different university athletic teams. Under the fair share-economics ethic falls highly maintained out of play areas, planted garden areas, and hydrology because it connects to a larger system. Each course is unique with different additional characteristics included into the inventory map. The parameters used in accounting for these features are appropriate to apply to any golf course. The most recent land cover data and points of species collection will be included in the map as well. The characteristics included in the inventory will influence what will also be represented in the individual site analysis of each course.

Results

See *Figure 13* "University of Michigan Radrick Farms Golf Course: Existing Conditions Inventory Map," *Figure 14* "University of Michigan Radrick Farms Golf Course: Future Conditions Analysis Map," *Figure 15* "University of Michigan Blue Course: Existing Conditions Inventory Map," and *Figure 16* "University of Michigan Blue Course: Future Conditions Analysis Map" (following).

Radrick Farms Golf Course

Existing Conditions Inventory Map

Location: 4875 Geddes Road, Ann Arbor, MI 48105

Data Layer Source: 2015 Spatial and Numeric Data Services (SAND) U-M Library

Scale: 1" = 500'

0 500

Note: Specific holes are listed that include inventory on, or related to that hole

Hole 1

1.1 Entrance garden centrally located infront of Clubhouse
1.2 Planting between tees of Hole 1 & 10
1.3 Grassland containing 2 Bluebird, Mixed Forest containing 1 Purple Martin bird house to the East, and planting
1.4 Sod Farm

Hole 2

2.1 Mixed Forest Land Cover with planted area

Hole 3

3.1 View to the North down Hole 3 Fareway and Mixed Forest area

Hole 5

5.1 Grassland containing 4 Bluebird houses, 1 Purple Martin bird house to the South, and planted area to the North
5.2 Small Creek with covered Bridge passageway

Hole 6

6.1 Historic Barn from Radrick Farm by Green

Hole 8

8.1 Grassland containing 4 Bluebird Houses

Hole 9

9.1 View to the North down 9th Fareway and over Grassland

Hole 12

12.1 High Point View to the Southwest
12.2 Mixed Forest and Grassland Land Cover

Hole 13

13.1 View to the Southwest across 13th Hole

Hole 14

14.1 View West across 14th Hole

Hole 15

15.1 View to West towards Fleming Creek
15.2 Pedestrian Access and Connection to Radrick Forest
15.3 Threatened Species: Eastern Massasauga Rattlesnake Habitat in Wetland adjacent to Fleming Creek

Hole 16

16.1 Fry Pond
16.2 View North over Fry Pond

Hole 17

17.1 Fleming Creek runs South through the site

Hole 18

18.1 Three sections of Parking with landscaped area
18.2 Bee Hives in Grassland Field
18.3 Vegetable Garden adjacent to Caretaker Barns
18.4 Automobile Access to Parking for site

Radrick Farms Golf Course

Future Conditions Analysis Map

Location: 4875 Geddes Road, Ann Arbor, MI 48105

Scale: 1" = 500'

0 500

Data Layer Source: 2015 Spatial and Numeric Data Services (SAND) U-M Library

Note: Specific holes are listed that include inventory on, or related to that hole

Hole 1

- 1.1 Entrance garden potential to showcase new combination of native shrubs and perennials including signature species
- 1.2 Potential planting improvement with new native signature species
- 1.3 Potential for invasive removal management plan and habitat fostering plantings for Mixed Forest & Grassland land cover
- 1.4 Educational signage to showcase the different species of sod that are being grown and that space being used as a living lab for turf grass

Hole 2

- 2.1 Potential for invasive removal management plan and habitat fostering plantings for Mixed Forest land cover and potential for updated signature planting

Hole 3

- 3.1 View can showcase Mixed Forest area and updated signature planting

Hole 5

- 5.1 Potential for invasive removal management plan and habitat fostering plantings for Grassland land cover and potential for updated signature planting
- 5.2 Potential area to apply 'Cues to Care' maintenance and more natural plantings

Hole 6

- 6.1 Educational signage for Barn to showcase the history of the course

Hole 8

- 8.1 Potential for invasive removal management plan and habitat fostering plantings for Grassland land cover

Hole 9

- 9.1 View can showcase Sustainable Management Practices of Grassland area

Hole 12

- 12.1 High Point View can showcase new Management of Natural Areas across the course
- 12.2 Potential for invasive removal management plan and habitat fostering plantings for Mixed Forest & Grassland land cover

Hole 13

- 13.1 View to the Southwest across 13th Hole fosters Environmental Stewartship

Hole 14

- 14.1 View West across 14th Hole fosters Environmental Stewartship of Protected Saginaw Forest

Hole 15

- 15.1 View to West towards Fleming Creek fosters Environmental Stewartship of Fleming Creek
- 15.2 Signage to Educate visitors on the Threatened Species: Eastern Massasauga Rattlesnake

Hole 16

- 16.1 Potential area to apply 'Cues to Care' around the retention pond including maintenance and native plantings
- 16.2 View North over Fry Pond can showcase 'Cues to Care'

Hole 17

- 17.1 Potential area to apply 'Cues to Care' maintenance and more natural plantings

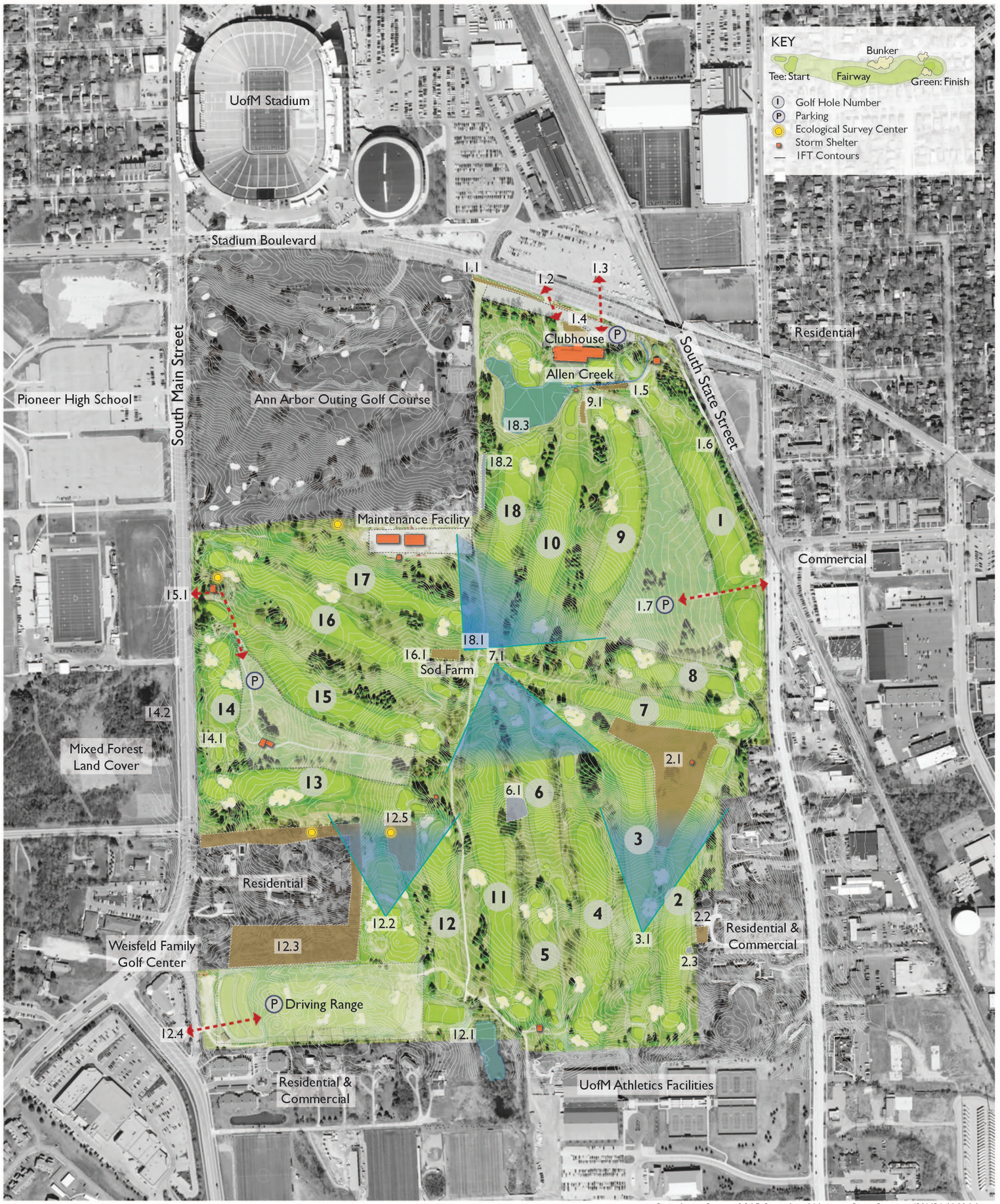
Hole 18

- 18.1 Planting strip adjacent to entrance parking potential for bioswale planting to filter impervious surface runoff

University of Michigan Blue Course

Existing Conditions Inventory Map

Location: 500 East Stadium Boulevard, Ann Arbor, MI 48104



Scale: 1" = 500'

0 500

Data Layer Source: 2015 Spatial and Numeric Data Services (SAND) U-M Library

Note: Specific holes are listed that include inventory on, or related to that hole

Hole 1

- 1.1 Planting strip along wall, seen from parking lot
- 1.2 Entrance from Stadium Boulevard to Clubhouse Parking
- 1.3 Pedestrian Tunnel linking to Stadium Parking lot
- 1.4 Entrance garden in center of drop off area
- 1.5 Planting along Allen Creek head waters
- 1.6 Traffic Noise from South State Street
- 1.7 Parking Access from South State Street for tailgating

Hole 2

- 2.1 Natural Area highly maintained
- 2.2 Vegetable garden on adjacent residential property
- 2.3 Low point containing high moisture tolerant species

Hole 3

- 3.1 View to the North over natural area towards 7th Hole

Hole 6

- 6.1 Low Point between Holes 6 & 11

Hole 7

- 7.1 View down Hole 6 & 11 fareways, to the South

Hole 9

- 9.1 Planting between Holes 9 & 10

Hole 12

- 12.1 Retention Pond with natural buffer
- 12.2 View over 12th green, to the North
- 12.3 Mixed Forest Land Cover
- 12.4 Parking Access from Weisfeld Family Golf Center onto Driving Range
- 12.5 Edible Landscape: Pear Orchard

Hole 14

- 14.1 Traffic Noise from South Main Street
- 14.2 Western adjacency to Mixed Forest Land Cover

Hole 15

- 15.1 Parking Access from South Main Street for tailgating

Hole 16

- 16.1 Sod Farm

Hole 18

- 18.1 View across 18th and 10th hole and the Stadium to the Northeast
- 18.2 Runoff alongside Maintenance Access Road
- 18.3 Detention Pond connected to Allen Creek headwaters

University of Michigan Blue Course

Future Conditions Analysis Map

Location: 500 East Stadium Boulevard, Ann Arbor, MI 48104

Scale: 1" = 500'

0 500

Data Layer Source: 2015 Spatial and Numeric Data Services (SAND) U-M Library

Note: Specific holes are listed that include inventory on, or related to that hole

Hole 1

- 1.1 Planting strip adjacent to entrance parking potential for bioswale planting to filter impervious surface runoff
- 1.2 Entrance garden potential to showcase new combination of native shrubs and perennials including signature species
- 1.3 Potential area to apply 'Cues to Care' maintenance and more natural plantings
- 1.4 To decrease traffic noise, thicken planting buffer and/or add climbing vine to chain link fence
- 1.5 Potential to better program parking to allow for the areas in between to be maintained in a more sustainable manner

Hole 2

- 2.1 Potential to improve the filtraton within the low spot with appropriate wet and dry tolerant native species
- 2.2 Storm Shelter could house bee hives on roof of structure
- 2.3 Educational signage to showcase bees as an important pollinator species
- 2.4 Natural area could be a study on alternative maintenance practices with potential for natural looking native plant installation

Hole 3

- 3.1 View can showcase sustainable maintenance practices of the natural area between Holes 2 & 3

Hole 6

- 6.1 Potential for rain garden in low spot with native wet to dry moisture content species

Hole 7

- 7.1 View can showcase the rain garden between Holes 6 & 11

Hole 9

- 9.1 Potential planting improvement with new native signature species
- 9.2 Educational signage to inform visitors the importance of the headwaters of Allen Creek being located with in the Blue Course

Hole 12

- 12.1 Increase native planting buffer around pond to slow down the water runoff allowing for greater filtration
- 12.2 View overlooks the Pear Orchard
- 12.3 Potential for invasive removal management plan and habitat fostering plantings for mixed forest land cover
- 12.4 Educational signage for orchard planting to foster environmental stewartship among the visitors

Hole 13

- 13.1 Storm Shelter could house bee hives on roof of structure
- 13.2 Educational signage would be to showcase bees as an important pollicator species

Hole 14

- 14.1 To decrease traffic noise from Main Street thickening planting screen and/or add climbing vine to chain link fence, creating a green wall
- 14.2 Potential to connect to adjacent habitat patch of mixed forest

Hole 16

- 16.1 Educational signage to showcase the different species of sod that are being grown and that space being used as a living lab for turf grass

Hole 18

- 18.1 View of over holes 9, 10 & 18 with new potential plantings seen in the distance infront of the Clubhouse and Allen Creek
- 18.2 Potential for swale planting to slow and filter the runoff from the impervious access road for vehicles
- 18.3 Potential area to apply 'Cues to Care' around the retention pond including maintenance and native plantings

Discussion

The Radrick Farms Golf Course inventory results show that the course connects to other University-owned properties that are used for research and education, along with allowing connections to more users. Radrick Farms Golf Course is located within existing mixed forest land cover. The course is located towards the back of the property in relation to the main entrance. The long entrance driveway takes visitors on an exploration of the property before reaching the course itself. The golf course is adjacent to Radrick Forest and has a pedestrian trail connecting the two University of Michigan-owned properties. New residential development is occurring adjacent to the site as well. With the site including a large amount of land surrounding the course, there is opportunity to incorporate many alternative uses within the property boundaries. These alternative uses can offer continuing community connections on site. In regards to the hydrology within the site, RFGC has a fry pond and Fleming Creek running through it. They hold many hydrological functions within them that could have a positive effect on the quality of water that is discharged into Fleming Creek and the groundwater table. Fleming Creek flows along the west side of the property between holes 16 and 17, delivering a unique water feature through the site. There is high potential for habitat connection through the site and restoration of the existing woodland and mixed forest land covers. With a clear sustainable master plan, the course can become a leader in sustainable golf course management and design.

In regards to the Blue Course inventory, the course is constantly holding a range of events that allow connection to different users. The surrounding context of the Blue Course, having both residential and commercial land uses has potential to foster community connections. There are access points that are both visible and also discrete, for programmed use during tailgating and other events. A unique pedestrian tunnel allows pedestrian access to the course. When discussing the fair share-economy ethic, the Blue Course holds many hydrological functions that could have a positive effect on the quality of water that is discharged into Allen Creek and the groundwater table. The headwaters of Allen Creek are located at the beginning of the course; the creek is currently channelized and re-routed underground. Providing ecological interventions for runoff areas could also be a model for sustainability. An orchard planting located near holes 12 and 13 provide an opportunity to educate and showcase the sustainable features within the course. In discussing alterations of more naturalized areas, an alteration in maintenance practices could save the course time and money. With the course's location between two main thoroughfares, Main Street and State Street, holes 1 and 14 that are adjacent to the roads may be subconsciously rushed through during play due to the unsettling noise of traffic. There is a range of habitat types that allow for a diverse ecosystem within the Blue Course. With the course's location between patches of natural areas, the course can provide a connection between areas of habitat refuge. The inventory of the Blue Course has shown that the course is strong example of a sustainable golf course plan.

The main analysis results applicable for both Radrick Farms Golf Course and the Blue Course show potential for using *Cues to Care* maintenance and plantings around the retention pond and Allen Creek. *Cues to Care* means finding a balance between culture and nature to gain people's acceptance of a more natural landscape by showing a presence of human intension.[66] This idea was developed by Joan Iverson Nassauer, a professor of Landscape Architecture at the University of Michigan. Nassauer explains neatness as, "a sign of sociable human intention. Neatness cannot be mistaken for untended nature; it means a person has been in a place and returns frequently. It means a place is under the care of a person."[66] To apply these maintenance principles, the turf would be mowed along the bordering boundary of the water's edge while leaving a strip of

vegetation directly around the water. This allows for the more natural habitat functions to occur along the edge of the water, while showing that the golf course management is still taking care of the pond.

To plan for the potential upgrade of a cohesive planting palette for each course, the use of signature species can be applied. Signature species mean the same plant species or the same mixture of multiple species is used and repeated throughout the course. This concept is one that visitors will instinctively notice while playing or exploring the course. When people understand a pattern within the landscape, they have a better appreciation for it. Using signature species can also be a type of branding tactic and provide a sense of place at each course. It is recommended that the signature species are native pollinator species that can handle a range of environmental conditions such as sun/shade, dry to wet soils, and be deer or salt tolerant. By using native species that are less commonly found in typical suburban environments, this can showcase a unique planting palette. Visitors will be more likely to appreciate the garden areas and want to learn what species were used so they can replicate the inventive garden planting in their own back yard.

The two foot contour data shows on both RFGC and the Blue Course where there are multiple low points within both sites that have the potential to install a rain garden to help mitigate that water collection in those areas. The Huron River Watershed Council advocates for rain garden installation in applicable sites and provides education and training on how to properly prepare and plant a rain garden. The Watershed Council describes rain gardens as "...beautiful landscaping features that capture, hold and soak in runoff from storms. They are specifically designed for areas where rain water habitually pools or to which it is deliberately channeled. Their loose, deep soils and deep-rooted native plants absorb water and filter pollutants."[67] When installing a rain garden, future maintenance needs to be taken into consideration. If a rain garden is properly installed, there can be little maintenance that the golf course employees have to carry out. The Watershed Council lists multiple benefits, including "…drought tolerant and environmentally friendly. They beautify your property and your neighborhood. They can be designed as a manicured formal garden or you can create a more natural look. You can choose plants that purposely attract butterflies and other wildlife."[67]

The land cover data analysis study shows that RFGC and the surrounding area in 2010 was covered with 8.5% of impervious surface, with the Blue Course having 42.4% in 2010. This analysis shows the need for potential bioswales on to be installed on both golf courses. The Natural Resources Conservation Service (NRCS), under the United States Department of Agriculture (USDA), published an educational pamphlet titled, "Helping People Help the Land." Within this pamphlet, it states, "Bioswales are storm water runoff conveyance systems that provide an alternative to storm sewers. They can absorb low flows or carry runoff from heavy rains and snowmelt to storm sewer inlets or directly to surface waters. Bioswales improve water quality by enhancing infiltration of the first flush of storm water runoff and filtering the large storm flows they convey."[68] Bioswales are more intensive than rain gardens when it comes to the design and installation. Research on soils types and soil infiltration rates is important to carry out before deciding if a bioswale is applicable. The NRCS states, "Once established, bioswales require less maintenance than turf grass because they need less water and no fertilizer. Native plants also resist local pests, disease, and weed infestations."[68] Bioswales are a form of green infrastructure that has the potential to improve the water quality of the runoff from impervious land cover within both the RFGC and the Blue Course.

Conclusion

Radrick Farms Golf Course and the Blue Course provide many ecological functions within the greater open space network. These functions include caring for the earth by having the potential to restore habitat and habitat connections and by housing bee pollinator species for the signature plantings found within the aesthetic pollinator gardens, rain gardens, and bioswales. The courses also play a crucial role in caring for people by providing a beautiful open space refuge where visitors can connect back with the natural environment and be motivated to become environmental stewards. Finally, the courses prioritize fair-share and carrying out a beneficial role to the larger watershed and system that is connected with the rest of the community. The data in the inventory and interventions displayed in the analysis of both University of Michigan golf courses have the ability to showcase a higher level of golf course sustainability that can function as a model and living laboratory for other golf courses in the present and future.

Community Survey

Introduction

The first component concerned with the "care for people" tenet of our definition of sustainable golf and the effects golf courses have on the communities that contain them was a survey made available to as wide a population of the Ann Arbor area as possible. The purpose of the survey was to understand the local community's perceptions of the roles of the golf courses with respect to sustainability. In addition to understanding the community's perspective towards golf and sustainability, we aimed to explore whether higher participation at events located at the two University-owned golf courses affected people's opinions about sustainability and stewardship.

Methodology

A survey was written in conjunction with the support and approval of both golf course administrators and project advisors. The survey was distributed online, hosted by the Michigan Qualtrics platform. The survey contained nine questions, ranging from queries to ascertain participants' course usages to those intended to determine participants' perceptions of the University of Michigan's responsibility to institute sustainable practices, and more specifically, the perceived impact that groundskeeping practices and use of the golf courses have on local ecological health.

Apart from course usage, which was a binary yes-no response, questions were written using a rating scale with potential responses ranging from "not at all" to "strongly agree." Question orientation was reversed (i.e., instead of framing using a positive responsibility: "the University should…," a negative framing was used: "local golf courses do not have a responsibility to…") in question 7 to control for lack of participant focus. See attached survey (*Appendix III*).

Website links and a QR code were made available during EarthFest, an activity open to all University students and the general public on the Diag on September 17, 2014. Website links and a QR code were also provided to patrons of both golf courses. Data was collected from September 16, 2014, until October 31, 2014, with the result of 85 completed responses and a 16% drop out rate. Following the closure of the survey, the data was cleaned and re-formatted, and factor analysis was performed through the SPSS statistical analysis package. Factor analysis serves several purposes. It helps condense large data sets, and it reduces the number of variables, collapsing them into underlying, related factors. Finally, factor analysis also allows for a broader sampling of not only people but of their neurons. In short, in reducing variables, this process links similar "bucketed" factors in responses and therefore gains a better understanding of the cognitive linkages between them.

Results

Factor analysis of the community survey data produced two distinct, orthogonal variables, which we have labeled "Community Aware" and "Golf Aware," as seen in *Table 6*. In Table 6, we

include the factor analysis variable and below each the survey questions that correlated with that variable. This type of analysis allows us to find patterns in people responses and bucket these responses into distinct variables for further analysis. For the Community Aware and Golf aware variables, the means are 4.52 and 3.77, and Standard Deviations of .50 and .90, respectively. As seen in these statistics, the Ann Arbor community exhibited a strong response (with a mean of 4.52 out of 5) regarding the importance of a sustainable community and the roles the golf courses must plain that community.

In addition to these variables, a participation variable was created, which aggregated the sum of all events attended by each subject, as seen in *Table 7*. The participation data was calculated as a binary value. If the participant attended the event, the value was one, and if they did not attend, it was zero. Summing all events attended by a participant indicated the variety of events he or she attended, not the frequency. *Table 7* displays the descriptive statistics of these three variables.

Table 6. Community Survey Factor Analysis

Index Name and Items Included	Mean	Standard Deviation
Community Aware *-Grounds-keeping practices at local golf courses affect local environmental health* *-A sustainable community is important to me* *-The University has a responsibility to be a leader in sustainability within the larger Ann Arbor community*	4.52	0.50
Golf Aware *-Local golf courses do not have a responsibility to engage in environmental stewardship* * *-Golf courses should be a multi-use space (e.g., Golf, other recreation, food harvesting)*	3.77	0.90

*CS 12 was multiplied by -1 reverse to match the other responses which were framed as a positive response would lead to higher number selected. Ie. The reverse of this question is "Local golf courses *do have* a responsibility…"

Table 7. Community Survey Descriptive Statistics

	N	Min	Max	Mean	Standard Deviation
Community	69	2.75	5.00	4.52	0.50
Golf	69	1.50	5.00	3.77	0.90
Participation	73	.00	5.00	0.66	1.06

To examine the relationship between participation in golf course events and opinions towards community and golf course sustainability, independent t-tests were applied to the data. The first test examined the relationship between participation and the “Community Aware” variable. This t-test was designed to measure whether there was a significant difference in the “Community Aware” variable between low participation (less than 0.66) and high participation (greater than 0.66). The table below illustrates the results of this test.

Table 8. Community Survey Test of Significance between Community Index and Participation

Descriptive Statistics	**N**	**Mean**	**Std. Dev.**	**Std. Error Mean**
High Participation (>=0.66)	26	4.42	0.60	0.12
Low Participation (<0.66)	43	4.56	0.54	0.08
t-test for Equality of means	**T**	**Df**	**Sig. (2-tailed)**	**Mean Difference**
	-1.09	67	0.28	-0.153

The second test examined the relationship between participation and the “Golf” variable. This t-test was designed to measure whether there was a significant difference in the “Golf” variable between low participation (less than 0.66) and high participation (greater than 0.66). The table below illustrates the results of this test.

Table 9. Community Survey Test of Significance between Golf Index and Participation

Descriptive Statistics	**N**	**Mean**	**Std. Dev.**	**Std. Error Mean**
High Participation (>=0.66)	26	3.50	0.95	0.19
Low Participation (<0.66)	43	3.90	0.81	0.12
t-test for Equality of means	**T**	**Df**	**Sig. (2-tailed)**	**Mean Difference**
	-1.99	67	0.05*	0.21523

Discussion

To begin, we note that following initial factor analysis of this data, a change was necessitated to adjust the "Principal Component" option due to our comparatively low number of returned surveys. This is a limitation of the survey analysis, as it assumes we understand what the components are from the start.

With this said, we believe that our analysis has yielded encouraging results. The lack of a statistically significant link between increased participation and increased feeling of importance of sustainable practices indicates that community members across Ann Arbor recognize the importance of sustainability practices in the community at large. An interesting result of the survey was the significant difference in means with respect to golf course stewardship and participation levels. The t-test for the "Golf" variable had significantly different means between high and low participation. However, it was unexpected that the low participation group had a higher mean with respect to valuing golf course stewardship. This suggests that spending time on the golf courses does not lead to a subject's belief that golf course stewardship is important. This result could be due to the fact that people who have been on the courses have done so for activities such as golfing or clubhouse events. Since these activities have a set purpose unrelated to sustainability, individuals may not correlate the relationship between golf courses and stewardship.

Although the t-test suggested there is a difference in opinion between the "Community Aware" and "Golf Aware" questions, the overall means of responses were high. The means for all the questions were greater than three. This suggests that people responded neutral to positive to all the questions related to sustainability and golf.

Conclusions

We feel that the community support of sustainable practices at the golf courses indicates the potential opportunity for further educational activities hosted at the golf courses. Further, it is evident that there is an opportunity to engage current patrons of the courses regarding sustainability. We believe that through events such as a "Greener Golf Clinic" or the School of Natural Resources and Environment Open, as well as updated and expanded Stewardship and Sustainability educational pamphlets (*Appendix VI)* available at both courses as well as online, the University of Michigan Athletic Department can continue its Sustainability Initiatives and deepen its relationship with the Ann Arbor community. More specifically to the sport of golf itself, it is encouraging that golfers are aware of not only the state of the courses they play, but the methods used to maintain this state.

Golf Course Pre- and Post- Test: Cognitive Function Survey

Introduction

The second component of the care for the people tenet was a survey made available to patrons of both the Blue Course and the Radrick Farms Golf Course to ascertain golf's ability to encourage mental restoration by measuring change in self-reported cognitive function before and after completion of a round of golf.

Methodology

A survey was written in conjunction with the support and approval of both golf course administrators and project advisors. The survey was distributed in the golf shop at both courses as a printed version that patrons took with their scorecard.

The survey consisted of two sets of five identical questions written using a rating scale with potential responses ranging from "not at all" to "strongly agree." See attached survey (*Appendix IV*). The first set of five questions was to be answered prior to the start of the patron's round of golf as a baseline measure of self-reported cognitive function and state of mind. The second set of questions was to be answered following the completion of the round to ascertain change in self-reported cognitive function and state of mind. A follow-up group of four questions inquires as to the patron's potential attribution of any change in cognitive function to activity in an outdoor setting. A total of 72 surveys were returned**.**

Following the closure of the survey, the data was cleaned and re-formatted, and factor analysis was performed through the SPSS statistical analysis package. Factor analysis serves several purposes. It helps condense large data sets, and it reduces the numbers of variables, collapsing them into underlying, related factors. Finally, factor analysis also allows for a broader sampling of not only people but of their neurons. In short, by reducing variables, this process links similar "bucketed" factors in responses and therefore gains a better understanding of the cognitive linkages between them. *Table 10* demonstrates the results of the factor analysis.

Results

Factor analysis produced two distinct, orthogonal variables, which we have labeled "Happy and Content ($Happy_0$)" and "Mentally Tired and/or Distracted ($Tired_0$)," as seen in *Table 10*. In Table 6, we include the factor analysis variable and below each the survey questions that correlated with that variable. This type of analysis allows us to find patterns in people responses and bucket these responses into distinct variables for further analysis. The Means for the Happy and Tired variable are 3.77 and 2.17, and the Standard Deviations are .93 and .86, respectively. These variables were created using the pre-golf questions; we then created mirror variables for the post-golf data, called "$Happy_1$" and "$Tired_1$". This creation of mirror variables was to enable the examination of significant change in the participants' happiness and tiredness level before and after playing a round of golf. The table below (*Table 11)* demonstrates the descriptive statistics of these four variables.

Table 10. Golf Survey Factor Analysis Results

Index Name and Items Included	Mean	Standard Deviation
Happy and Content *-I am energized* *-I feel a sense of calm*	3.77	0.93
Mentally Tired and/or Distracted *-I am easily distracted* *-I feel mentally drained*	2.17	0.86

Table 11. Golf Survey Descriptive Statistics #1

	N	Min	Max	Mean	Standard Deviation
$Happy_0$	72	1.00	5.00	3.77	0.93
$Happy_1$	72	1.00	5.00	3.46	0.97
$Tired_0$	72	1.00	4.50	2.17	0.86
$Tired_1$	72	1.00	5.00	2.30	1.00

To examine the effect playing a round of golf had on the participants, independent t-tests were applied comparing the before and after means. The first t-test was designed to measure if there was a significant difference in the mean of "$Happy_0$" and "$Happy_1$." To perform this test, we split $Happy_0$ into two categories, $Happy_0$ High and $Happy_0$ Low, as defined by the mean of $Happy_0$. As seen in Table 12, there were 37 respondents in the $Happy_0$ High group, and 35 $Happy_0$ Low. In the test of significance we are looking to see if there is a significant difference in the golfer's

response to the $Happy_1$ given if they are in the $Happy_0$ High and $Happy_0$ Low categories. For example, is the mean of $Happy_1$ significantly higher than $Happy_0$ Low, suggesting that after a round of golf the participant was happier. The significance for this test is .10, suggesting that there is no difference in $Happy_1$ means for the $Happy_0$ High and $Happy_0$ Low categories at the 95% confidence level (Table 12).

Table 12. Golf Course Survey Test of Significance between before and after Happy Index

Descriptive Statistics	**N**	**Mean**	**Std. Dev.**	**Std. Error Mean**
$Happy_0$ High (>=3.77)	37	3.65	0.90	0.15
$Happy_0$ High (<3.77)	35	3.27	1.02	0.17
t-test for Equality of means	**T**	**Df**	**Sig. (2-tailed)**	**Mean Difference**
	1.67	70	0.10	0.38

The second t-test was designed to measure if there was a significant difference in the mean of "$Tired_0$" and "$Tired_1$." The same methodology as the happy variables was used by dividing $Tierd_0$ into high-low categories. The table below (*Table 13)* illustrates the results of this test. The significance for this test is .26, suggesting that there is no difference in $Tierd_1$ means between the $Tierd_0$ High and $Tierd_0$ Low categories at the 95% confidence level (Table 13).

Table 13. Golf Course Survey Test of Significance between before and after Tired Index

Descriptive Statistics	**N**	**Mean**	**Std. Dev.**	**Std. Error Mean**
$Tired_0$ High (>=3.47)	33	2.44	0.77	0.13
$Tired_0$ Low (<3.47)	39	2.18	1.17	0.19
t-test for Equality of means	**T**	**Df**	**Sig. (2-tailed)**	**Mean Difference**
	1.15	64.52	0.26	0.26

In addition to answering questions about his or her state of mind before and after a round of golf, each golfer answered questions about the effect being outdoors and playing golf has on his or her mental state. Below (*Table 14)* are the descriptive results for these questions.

Table 14. Golf Survey Descriptive Statistics #2

	N	Min	Max	Mean	Standard Deviation
I was able to block out distractions	72	1.00	5.00	3.60	0.974
I feel mentally rejuvenated	72	1.00	5.00	3.32	1.07
I believe that being outside contributed to any changes in my previous mental state	71	1.00	5.00	3.73	1.22
I believe that being active contributed to any changes in my previous mental state	71	1.00	5.00	3.99	1.13
I believe that being active outside contributed to any changes in my previous mental state.	70	1.00	5.00	3.94	1.17
I golf because it improves my mental state.	71	1	5	3.27	1.33

Discussion

Having completed our analysis, we found that there was no statistically significant change in cognitive function and mental state that occurred during the course of the subjects' rounds of

golf. This could be due to several factors. First, there is a possibility that subjects have equated cognitive function with affective feeling, perhaps interpreting feelings of frustration following a disappointing round of golf as indicative of decreased cognitive ability. Questions were written with the intent of avoiding this conflation. However, the ease with which factors were discovered and labeled as "Happy" and "Tired," and the very semantics of this language in and of itself, indicate that perhaps the framing of the questions was not sufficient to separate cognitive function from emotional feeling, or even physical state, as is indicated by "Tired."

There is also the possibility that the mentally-demanding nature of a round of golf does in fact require significant amounts of directed attention and therefore does not allow for the directed attention restoration that a walk in nature would. This survey was designed to study whether or not golf would afford the same mental restoration as other green exercise that has been studied, such as walking in a natural setting, by allowing the mind to focus on naturally fascinating subjects, such as trees, wildlife, water, etc. These features have elements that are fascinating—they attract people's attention without overwhelming it, meaning that people do not have to work to stay focused on these subjects, and directed attention, the type of attention that is required to focus the mind on everything from work in an office to mentally demanding yet enjoyable projects, is able to rest and concurrently be restored. It is possible that golf, whether played in a social or competitive environment, might contain elements that are both enjoyable and inherently fascinating—everything from tracking progress against a personal best score or a competitor to mentally calculating the distance to the next hole or gauging wind to maintaining social interaction with a golfing partner—that do not allow these elements of the natural environment that are fascinating to fully restore directed attention. Please see a full discussion of directed attention, its restoration in nature, and a review of relevant literature in *Appendix V: Directed Attention Literature Review.*

Finally, there is a possibility that the elapsed time between the completion of a round of golf and the subjects' survey response was insufficient to allow for subjects to become cognizant of potential benefits or detriments to cognitive functioning. Any of these explanations, or a combination of them, seem plausible.

With this said, subjects did report a statistically significant link between the environment and any change in cognitive function. Even if on an aggregate level there was no change in cognitive function, subjects did feel, on average that any change in their own mental state was in fact a result of being in nature. This seems to indicate that whether or not their cognitive abilities, or even their emotional state, do change during the course of their round of golf, subjects attribute any change to being in nature.

Conclusion

While there is no statistically significant evidence that a round of golf positively impacts cognitive function and is therefore as mentally restorative as other forms of "green exercise," such as walking in nature, this could relate to conflation subjects' affective states with their cognitive ability, or might also reflect the mentally-demanding nature of golf and the resultant decreased opportunity for directed attention restoration, or it could be that the post-golf test measured self-reported cognitive function prior to the realization of potential benefits. We recommend further research relying upon pre-and post-tests of cognitive function measured by performance on activities relying on directed attention rather than self-reported metrics as a way to better

characterize golf's effect on cognitive function. We also recommend the addition of a longitudinal component allowing for slower manifestations of resultant cognitive function effects.

Even without this additional research however, we find it encouraging that subjects did attribute any change in cognitive function or emotional state to their time in nature. We feel that efforts to draw golfers' attention to some of the fascinating aspects on the golf course, from the vistas at several different tees to the wildlife or water features, could in fact enhance the restorative ability of the course and generate increased perceptions of nature's importance in a golfer's own cognitive and emotional health, all while ultimately improving customer satisfaction. We have produced additional content for the Radrick Farms' Stewardship Guide reflecting our findings in the "Care for People" studies and suggest that this pamphlet be made available with golfers' score cards, and further, that a QR code and/or link be made available on commonly accessible literature at golf courses to allow access during and after rounds of golf.

Economic Overview

Introduction

While a full cost-benefit analysis regarding specific investments at either of the University of Michigan Golf Courses was beyond the scope of this project, we completed a high-level overview of financial opportunities from sustainable activities on the golf course. This overview stems from the overarching hypothesis that financial profitability and environmental and social sustainability are not mutually exclusive.

As the courses consider implementing further sustainability practices, it is important to consider the economic implications. Although in some cases the upfront cost of our recommendations is higher than business as usual, long term economic benefit is possible and will lead to a more secure future, necessitating the need for adoption of extended time horizons. In considering the operating expenses of the courses, there are two categories: non-capital and capital. Our recommendations focus on the non-capital side of the courses' budgets. Although the comparison of "business as usual" practices and sustainable alternatives was also outside of this project's scope, we would like to highlight several opportunities for cost-saving and sustainable progress.

Fuel

A recent study focused on the economic challenges golf courses currently face in light of the economic recession and decline in the sport. Within this study, courses were asked, "What was your greatest budget challenge?" Over one quarter of both private and public courses responded with rising fuel costs. Although fuel expenses are not a large budget item for most, the impact of volatility in prices poses a serious problem in properly budgeting and forecasting revenue. It is difficult to manage fuel costs because there are many factors that are outside of the superintendent's control. However, many new options exist for electric-powered equipment and alternative fuel sources. For these courses, it may be cost-effective to pay for a higher-priced piece of equipment that has greater energy savings in the long term.[69]

Another consideration regarding fuel is the emissions associated with the burning of these resources. Air pollution and climate change are becoming pivotal issues in the world. To move towards a more sustainable golf course, emissions associated with maintenance equipment, golf carts, and transportation vehicles should be considered.

The courses have the potential to both minimize the effect of volatile fuel prices and mitigate emissions by considering new technology that is more fuel efficient or uses an alternative fuel. One example is a solar golf cart which has a small solar panel on its roof that generates power for the cart. This technology has high upfront costs but provides a fuel-less alternative to the current golf cart fleet. Also, the solar power generating potential for the roofs of the facility buildings is an additional issue to weigh when considering future equipment purchases. Electric equipment could replace gas powered equipment and when powered with energy generated from rooftop photovoltaics, there is significant environmental and economic savings.

Another fuel-free recommendation that is both more unorthodox but more traditional to golf's heritage in Scotland is the use of grazing animals for the removal of invasive species. Golf courses have already begun to employ goats as a tool for clearing large spaces of land. In Santa Cruz, California, the Pasatiempo Golf Course used goats to help clear non-native plant growth from 12 acres of land. The choice to use goats was made in part due to the challenging terrain of the area. In addition, the cost of this method was about one-tenth that of requisite manpower and machinery.[40] We recognize that employing goats on the courses poses logistical challenges and that there are alternative maintenance options that could still improve sustainability.

Electricity

Within the same study noting economic challenges for golf courses, electricity costs were cited by one-third of the courses as a budgeting challenge. Related to the volatility of fuel, electricity costs can vary, and often a course exercises little control over these variations. More efficient products, such as energy efficient lighting fixtures and bulbs lead to long term savings in energy and cost-savings. In addition, energy efficiency is a growing area of research and technological innovations are quickly helping these products become more cost-competitive. In addition to considering more efficient products within buildings, there is the opportunity to generate energy on site. The golf courses can consider solar panels on the roofs of suitable buildings. Solar panels provide emission-free electricity and provide an affordable alternative to purchasing electricity from the grid. In addition, there are financing options in which the courses could receive subsidies for the installation of solar panels and sell excess electricity to the energy grid.

Water

Another resource that is a large cost item for golf courses is water. Technology and research now exist to help courses use less water more effectively. "Sustainable irrigation can reap huge financial rewards—saving tens or hundreds of thousands of dollars a year."[38] For example, a course installed a water treatment plant in which 60% of its irrigation water comes from recycled domestic and industrial waste water. This system allows the courses to save up to $70,000 each year.[38] One of the common mistakes of irrigation is irrigating more than necessary; therefore, thoughtful planning should take place when considering sustainable irrigation options.

Fertilizers and Chemicals

Fertilizers and chemicals used to maintain the grounds of a golf course can also account for a large portion of the budget. For the University-owned courses, fertilizers and chemicals account for almost 40% of the budget. In consideration of a more sustainable future, we recommend reducing the application of some fertilizers and chemicals. Planning and scheduling fertilizing for critical times will help improve the efficiency of the material and minimize the need for excess. Further, planting more native species and reducing managed areas on the golf courses will require less chemical and manpowered intervention. The move to naturalization will help minimize the fertilizer and chemical expense in the long run. We recommend further studies to produce exact timelines for maximized efficiency in fertilizer and chemical management.

Labor

As part of the university institution, the courses should consider opportunities to work with professors and students. These resources are available for little to no cost to the courses and can provide insightful research and other labor options. Not only will partnerships with the University minimize the cost to the courses, but the courses will provide a living laboratory for students to learn.

Conclusion

The University of Michigan has been an institution at the forefront of many innovations in technology, social movements, and progressive advancements, bolstering its identity as being the "leaders and best." "Golf can be a catalyst for sustainable living. As large natural and semi-natural spaces, golf courses bring people into direct contact with the natural world. They can provide the link between business, community and environment."[70] The University has the opportunity to be progressive in its sustainable practices and set a trend, especially for other university-owned courses. Further, as University-owned courses, there is a unique opportunity from a business perspective. The University of Michigan is a nonprofit, academic institution. As such, it does not have stakeholders and shareholders to whom it must provide quarterly financial reports. This status provides the University the opportunity to invest in more progressive projects with longer time-horizons that may be challenging for traditional golf courses to justify.

5) Synergistic Recommendations for the University of Michigan Golf Courses

Introduction

Having conducted extensive studies into the three separate tenets of sustainability as applied to golf, and more explicitly applied to the University of Michigan Golf Courses, we were pleased to find many areas of potential overlap and synergy. As discussed in our application of the permaculture ethics, sustainable golf is characterized by these innovative intersections of care for the earth, care for the people, and fair share. We therefore propose below three recommendations that have emerged from our research. We are aware that they are potentially revolutionary and even unorthodox. However, the University of Michigan has long been a hotbed of unprecedented, pioneering ideas; these are merely our suggestions in continuing to push the boundaries of what it truly means to support sustainable golf.

Recommendation #1: Engagement

A primary and overarching finding born of the Greener Golf Master's Project Team's work on this project is the immensely valuable yet often underutilized resources available through the University. Maintenance of the both the Blue Course and Radrick Farms Golf Course can potentially be informed by longitudinal, multi-disciplinary research conducted at one of the top research universities in the world. These various research opportunities have the potential to provide deepened understanding of the multitude of systems, ranging from ecological to economical, hydrological to intrapersonal, and so many more, that comprise both sites. The Resident Caretaker Program at RFGC is only the beginning of the benefits to be realized from the augmented partnership with the University.

We therefore suggest that the Blue Course and RFGC engage more consistently and more deeply with the University to host a variety of field research opportunities that cut across schools and disciplines. We understand that this will require up-front investment of time and resources in order to initiate these studies and continued, smaller investments to maintain and update them. However, benefits to the courses, the University as a whole and its students, the local ecology, and the local community not only far outweigh these investments but get to the heart of truly sustainable golf. (Photo source: top[71], bottom[72])

Recommendation #2: Accessibility

One of the most pervasive findings from the literature review conducted regarding the benefits golf courses can offer to their host communities is their preservation of green space in developed, urban areas. This green space allows for individual cognitive health, which is important in maintaining individual mental health and community connectedness, complimenting medical treatment to improve physical health and decrease healthcare expenditure, and ultimately in promoting local pro-environmental action. However, the provision of these benefits is contingent upon community access to this green space; restoration is only provided by time spent looking at or walking in nature.

We therefore suggest that in order to become more truly sustainable, both the Blue Course and RFGC must allow for multi-use scenarios-from walking paths in the summer to cross-country skiing paths in the winter, from disc and soccer golf courses to plots for community gardens, from contemplative meditation sites to hosting community events. We understand that these multi-use scenarios will require operations expertise in both scheduling and groundskeeping to maintain the high level of maintenance and playability that patrons expect from both courses, but we ask the University to understand that our master's project team believes strongly that Ann Arbor is a vibrant community engaged in a sort of symbiotic relationship with the University of Michigan and that only by sharing these nearly four hundred acres of green space can this largely untapped shared value be fully realized. By our definition, sustainable golf cannot be partitioned off and isolated. Golf as a sport has shrunk, not grown from this approach. Sustainable golf—truly sustainable for the environment, for the community, and for the sport—must allow access. The Blue Course was born from Yost's vision of "Athletics For All," and we believe it is time for the University to allow "Nature for All." (Photo source: top[73], bottom[74])

Recommendation #3: Innovation

Through our research into the many aspects of golf, it is evident that sustainable practices and planning are already underway. Therefore, our final recommendation is to consider the innovative technology for future projects. Changes in practices and equipment have allowed courses to improve efficiency and minimize resources used, therefore leading to cost-savings. It is easy to fall into a more conventional way of proceeding, but we urge the golf courses to consider what is cutting-edge in the industry. As observed in the Fair Share portion of Section 4, as part of the University, these courses have the opportunity to plan more long-term return on investments and challenge existing practices.

Several ideas that demonstrate the opportunity for innovative technology are the use of goats as a maintenance tool, solar panels on roofs, and recycling water systems. Goats may not seem like a natural fit for the golf courses, but they provide a low impact method for invasive species removal, which is critical in some areas of the courses. The use of goats avoids emissions associated with motor-mowers, and goats minimize the cost of labor. Reducing dependency on resources is important for both the courses' bottom lines and their sustainability, for ultimately these issues are tied. Consideration of resource use should include new water technology that promotes recycling. Recycling water significantly decreases the courses' impacts on the surrounding environment and will help save costs in other areas. The purpose of these ideas are to demonstrate the possibility of innovation. We recognize that they may not be appropriate for both courses. However, we are confident that there are innovative options that will fit the needs of the courses and further their sustainability. (Photo source: top[75], bottom[76])

Recommendations in Practice

The University of Michigan's Gateway Course: A Living, Learning Laboratory for Sustainable Golf

As a physical manifestation of these three final recommendations for the University of Michigan's two golf courses, the Greener Golf Master's Project Team prepared a master plan on a 19-acre site on the Radrick Farms property called "The Gateway Course". This master plan is a practice course design located at the entrance of the Radrick Farms property, separate from the main 18-hole course. The course consists of three green complexes and is designed to optimize the space on site with eight unique ways to play to the three greens. This design includes all of the characteristics that can transform a golf course into what the Greener Golf Master's Project Team has defined as sustainable golf.

The site has been named the Gateway Course because of its proximity to the entrance to Radrick Farms, its role as a gateway for potential new golfers to take up the game, as well as its mission to open a new door to how golf courses can play a role in society in the future. The Gateway Course introduces users to another competitive sport, disc golfing, and holds a pavilion with restrooms and services for holding events. The Gateway Course site is able to be used throughout the year, adding onto the existing trail system of the property, providing a designated trail for cross country skiers during the winter season. New educational signage is also included that promotes environmental stewardship through the understanding of how the site is constructed, maintained, and used. The multi-functionality of the site promotes accessibility for users to benefit from the open space that the Radrick Farms property provides.

The Gateway Course has the potential to serve as a living, learning laboratory on which to continue ecological research, experiment with innovative maintenance techniques, and integrate many of our team's recommendations, promoting multi-use, environmental stewardship, habitat creation, efficiency of operations, community engagement, and creative use of resources. The Gateway Course design continues the creation of bird houses across the Radrick Farms property that was established in the out of play areas on the 18-hole course. Honeybee colonies are also a feature included to increase the pollination of the native species on site and in the surrounding areas. There are numerous ecological features included such as orchard trees, native habitat, and pollinator species plantings. Rain gardens and bioswales are found across the site, along with a signature planting pallet to emphasize an aesthetic sense of place as soon as you step into the Gateway. In addition, features such as native grass bunkers are designed within the course to cut down on maintenance resources and showcase sustainable practices.

We feel that the Gateway Course is a culmination of the Greener Golf Master's Project Team's findings and would greatly enhance the University of Michigan golf courses' ability to continue to innovatively redefine sustainable golf by experimenting with sustainable golf course management prior to implementation on the 18-hole golf courses.

The Gateway Course Design Guide

Please see supplemental documentation in the design packet for further details of the Gateway Course Design Guide. This guide takes you through the step by step process to analyze, design, and integrate sustainable golf practices into a site.

6) Conclusion

Historically the golf industry has fought against the incorporation of sustainability goals into their management strategies for fear of short-term costs and risks to quality of play. The multiple examples of golf courses' efforts to reduce their impacts on the environment, combined with the holistic investigation by the Greener Golf Master's Project Team, serve to exhibit that environmental sustainability and economic profitability in the golf industry are not mutually exclusive. Using the Greener Golf Master's Project Team's definition of sustainable golf that is built around care for the earth, care for the people, and fair share, there appears to be significant opportunity for the creation of shared value.

The golf industry stands at a critical juncture; incorporation, exploration, and development of these opportunities for shared value appear as a strong chance for fostering the next generation of committed, responsible golfers and mitigating the effects of climate change on the game. We hope that this report will serve as not only the foundation of a strategic roadmap for the University of Michigan Golf Courses but also as an inspiration for many other courses throughout the industry. We strongly urge the use of holistic and long-term considerations in golf course management decisions, as we feel that the adoption of these concerns offers an exciting, fruitful future for the sport of golf.

7) Appendix I: Project Summary, *For Distribution*

Introduction

The multi-disciplinary group of graduate students from the University of Michigan School of Natural Resources and Environment, known as the Greener Golf Master's Project Team, initiated an investigation into the challenges and opportunities golf courses face with regard to environmental, economic, and social sustainability. Given these diverse backgrounds of academic study, the Greener Golf Master's Project Team has approached the investigation into sustainable golf from a deliberately holistic perspective, adopting and adapting the three ethics of permaculture: care for the earth, care for the people, and fair share.

The term permaculture is a combination of the words "permanent" and "culture," and thus refers to the design, development, and promotion of a systems thinking approach to problem solving and understanding of the natural mechanisms and relationships of a system in order to enable a manager to intervene at strategic points in the system to make the most effective and efficient positive changes. This holistic approach to addressing the research, combined with the diverse expertise of the Greener Golf Master's Project Team, provided the framework for the development of several synergistic recommendations for the golf courses that will enhance the environment (both on site and at the scale of the surrounding area and region), the community (of both golfers and non-golfers alike), and the economics (of the golf facilities financial statements as well as from the perspective of the University and the community). Ultimately, the Greener Golf Master's Project Team hopes that given appropriate adaptation to various geographic, climatic, financial, and institutional contexts, these recommendations can be useful across the golf industry.

Path to Sustainability: University of Michigan Golf Courses

The University of Michigan golf facilities comprise the University of Michigan Golf Course (Blue Course), a Dr. Alister Mackenzie design constructed in 1929, and Radrick Farms Golf Course (RFGC), a Pete Dye design constructed in 1965. Both golf courses have had great success developing and implementing strategies for the sustainable management of their facilities. Especially over the past decade, RFGC has implemented a number of strategies to improve their environmental impact while maintaining their bottom line and keeping their customers pleased with the overall experience of the course.

Radrick Farms Golf Course's path to sustainability began even before its founding. In 1957, Frederick Matthaei, Sr., donated the land that now is home to RFGC and the University of Michigan's Botanical Gardens. The previous use of the site was a gravel mine. Matthaei, whom golf course designer Pete Dye referred to as "ahead of his time" regarding ecology, planted a variety of native trees on the site, which now provide a significant amount of ecological and aesthetic benefits to the golf course. Because the roots of RFGC are deep with regard to sustainability, the management of the facility strives to continually become better stewards of the environment.

Recommendations: University of Michigan Golf Courses

The recommendations presented by the Greener Golf Master's Project Team highlighted three approaches to pushing the boundaries of what it means to be a sustainable golf course. These three approaches are Engagement, Accessibility, and Innovation.

Engagement refers to the importance of developing the partnership with the University of Michigan and utilizing the university's position and resources as a leading research institution as a partner for the golf facilities. Some initial investment of time and resources to develop relationships with the variety of programs on campus will lead to educational opportunities for the students and faculty as well as enrich the understanding and data bank of the golf courses, thus providing a better knowledge base from which to make informed decisions for the future of the golf courses. Programs like the Radrick Farms Caretaker Program have begun to develop this partnership, creating opportunities for graduate students to conduct research on site that benefits both their educational experience and the golf course as well. Augmentation of these research opportunities will enhance the understanding of the sites, which, in turn, will supplement the understanding of the systems in place at the course, and therefore give managers and decision-makers a vast data set from which to intervene and create the greatest potential benefits.

Accessibility refers to the expansion of the opportunities for community members to participate in the sites. An extensive literature review and an analysis of the community survey results demonstrate the benefits of green space, especially access to green space, with regard to community health, individual mental health, and promotion of environmental stewardship, and further, the golf courses' ability to provide this green space. Full realization of these benefits is of course contingent upon community access to this green space. We therefore recommend the adjustment of management strategies of the golf courses to accommodate more uses and engage more people. While this will not be a simple, or even unanimously accepted decision, the long-term benefits of developing such programs that encourage golfers and non-golfers alike to enjoy and benefit from these spaces will warrant these adjustments.

Innovation refers not only to willingness to adopt technological advancements but also willingness to think in unorthodox ways in order to address the complex issues surrounding sustainable management strategies. Partnering with natural systems and mechanisms is a key component of this recommendation. Harnessing the power of the sun, though initially a costly investment, will provide significant return on investment when considered from a long-term investment perspective. Additional examples of potential partnerships with nature includes using goats as invasive species managers and raising honeybees on-site to promote pollinator heath. While it may be difficult for golf courses to realize the immediate benefit of adopting these innovative strategies, the long-term benefits are substantial. Goats on the golf course may seem like a superintendent's nightmare, but these creatures are extremely efficient and organic turf managers. Goats prefer broadleaf plants over grasses and therefore can manage the encroachment of invasive plants into turf areas. Raising honeybees also benefits the ecosystem as a whole by providing pollination services to the surrounding area, benefiting local gardens and farms, and further serving as an indicator species of ecosystem health. In addition to these benefits, honeybees are a species of great interest (and importance) to the public; simply having honeybees on site will peak people's curiosity regarding environmental issues.

Recommendations: Industry-Wide Adaptation

It was the hope of The Greener Golf Master's Project Team to not only assess and provide recommendations for the expansion of the University of Michigan Golf Courses' sustainability but to also provide first steps and recommendations for several strategies for management of other golf courses throughout the industry to begin or continue to build momentum for sustainable golf. As a golf course superintendent, general manager, owner, or decision-maker at a golf facility, it may be a daunting task to think about incorporating sustainable practices into the mission and management plan of a golf operation; most superintendents are very familiar with practices on their golf courses but may not be as familiar with the complexity of ecological processes present on site. Additionally, cultivating partnerships with local institutions may seem like a challenge, but the benefits of these relationships will deepen understanding of the golf course and benefit the golf facility in the long-term.

1. Creating a Living Learning Laboratory

The key to making informed decisions is simply to be informed, but given the time constraints of demanding responsibilities, how can a manager invest in the resources needed to get a better understanding of the golf course ecosystems? If golf course managers can more holistically integrate the golf course into a symbiotic relationship with the surrounding community, they can ensure a great first leap forward sustainability. Knowing what institutions surround the golf facility and where mutually beneficial partnerships can be forged holds positive implications for the future management of the golf course. Initiating partnerships with local research institutions and nearby schools will connect the learning objectives of those entities, while providing the golf course with valuable data collection regarding a number of beneficial criteria for the golf course by providing more background for management decision-making in the future.

These programs should be created with a long-term approach, so as to build the setting for ideal longitudinal research conditions. Research programs could easily be adapted to younger students, college students, or doctoral students and faculty. Because of the complexities of golf courses and their relationships to the ecology, economy, and community, the opportunities are endless.

Additionally, by opening the golf facility to research opportunities, the golf course managers are exposing a range of new demographics to the golf facility, thereby potentially simultaneously growing their customer base and promoting environmental stewardship.

2. **Taking Inventory**

Building off of the previous suggestion, knowledge of the site, knowledge of the local resources, and knowledge of the systems in play on the site is of the utmost importance. When there is observation and data collection regarding the hydrology, ecology, biology, anthropology, and economy of the golf course, better-informed decisions can be made regarding the long-term health and sustainability of all aspects of the golf operation in mind.

Partnerships with local research institutions will provide the golf facility with a greater understanding of what is happening on the golf course. Knowing the site allows for

the golf course manager to be better aware of critical areas, underutilized resources, how people interact with the site, and opportunities to promote positive change.

Golf courses require the use of significant amounts of resources. Often, these resources originate from great distances away from the golf facility. This is not a sustainable activity. By first knowing the site, managers can assess alternatives to importing these resources by creatively looking at what is present on site. Are there local pockets of sand or gravel that can be used? Are there local sources of organic materials that can be turned into compost that will replace needs for fertilizers? Are there goats nearby that could be employed to manage the encroachment of invasive species and reduce the need for potentially harmful chemical herbicides? These are just a few potential questions to ask, but it is important for the golf course superintendents of the future to think outside of the box when it comes to the sustainable management of their courses.

Lastly, it is critical to know the systems in place on the site. Golf courses have complex ties to the local ecosystems and often have significant impacts on those systems. Again, once data is collected and analyzed, systems diagrams can be created to map the complex systems in place on site. Once these systems are laid out, the manager can choose strategically at which point to intervene in these systems in order to best promote and attain the goals of the management program in parallel with the health of his or her course.

Conclusion

Historically the golf industry has fought against the incorporation of sustainability goals into their management strategies for fear of short-term costs and risks to quality of play. The multiple examples of golf courses' efforts to reduce their impacts on the environment, combined with the holistic investigation by the Greener Golf Master's Project Team, serve to exhibit that environmental sustainability and economic profitability in the golf industry are not mutually exclusive. Using the Greener Golf Master's Project Team's definition of sustainable golf that is built around care for the earth, care for the people, and fair share, there appears to be significant opportunity for the creation of shared value.

The golf industry stands at a critical juncture; incorporation, exploration, and development of these opportunities for shared value appear as a strong chance for fostering the next generation of committed, responsible golfers and mitigating the effects of climate change on the game. We hope that this report will serve as not only the foundation of a strategic roadmap for the University of Michigan Golf Courses but also as an inspiration for many other courses throughout the industry. We strongly urge the use of holistic and long-term considerations in golf course management decisions, as we feel that the adoption of these concerns offers an exciting, fruitful future for the sport of golf.

8) Appendix II. Field Observations from Ecological Surveys

Radrick Farms Golf Course Species Diversity Field Observations					
Habitat	**Replicate**	**Circle**	**Species**	**# Individuals**	**Size Class**
Grassland	1	1	3 species of grasses	Dense	Herb
Grassland	1	1	Grass-leaved goldenrod (*Euthamia graminifolia*)	55	Herb
Grassland	1	1	Canada thistle (*Cirsium arvense*)	10	Herb
Grassland	1	2	Common milkweed (*Asclepias syriaca*)	1	Herb
Grassland	1	2	Common mullein (*Verbascum thapsus*)	2	Herb
Grassland	1	2	Canada thistle (*Cirsium arvense*)	40	Herb
Grassland	1	2	Red raspberry (*Rubus strigosus*)	1	Herb
Grassland	1	2	River-bank grape (*Vitis riparia*)	1	Herb
Grassland	1	3	Boxelder (*Acer negundo*)	2	Adult
Grassland	2	1	Various species of grasses	Dense	Herb
Grassland	2	1	Canada thistle (*Cirsium arvense*)	55	Herb
Grassland	2	2	Black walnut (*Juglans nigra*)	2	Sapling
Grassland	2	2	Pignut hickory (*Carya glabra*)	2	Sapling
Grassland	2	2	American elm (*Ulmus americana*)	1	Sapling
Grassland	2	2	River-bank grape (*Vitis riparia*)	1	Shrub
Deciduous Forest	1	1	Virginia creeper (*Parthenocissus quinquefolia*)	172	Herb
Deciduous Forest	1	1	Big-leaved aster (*Aster macrophyllus*)	72	Herb
Deciduous Forest	1	1	Black cherry (*Prunus serotina*)	3	Seedling
Deciduous Forest	1	1	Bitternut hickory (*Carya cordiformis*)	4	Seedling
Deciduous Forest	1	1	Japanese barberry (*Berberis thunbergii*)	3	Herb
Deciduous Forest	1	2	Black cherry (*Prunus serotina*)	1	Sapling
Deciduous Forest	1	2	Musclewood (*Carpinus caroliniana*)	1	Sapling
Deciduous Forest	1	3	White oak (*Quercus alba*)	3	Adult
Deciduous Forest	1	3	Pignut hickory (*Carya glabra*)	2	Adult
Deciduous Forest	1	3	Red maple (*Acer rubrum*)	3	Adult
Deciduous Forest	1	3	Northern red oak (*Quercus rubra*)	1	Adult
Deciduous Forest	2	1	Virginia creeper (*Parthenocissus quinquefolia*)	43	Herb
Deciduous Forest	2	1	Lily of the valley (*Convallaria majalis*)	2	Herb
Deciduous Forest	2	1	Bitternut hickory (*Carya cordiformis*)	1	Seedling
Deciduous Forest	2	1	Pignut hickory (*Carya glabra*)	1	Seedling
Deciduous Forest	2	2	Black cherry (*Prunus serotina*)	1	Sapling
Deciduous Forest	2	2	Sweet cherry (*Prunus avium*)	2	Sapling
Deciduous Forest	2	2	Common buckthorn (*Rhamnus cathartica*)	1	Sapling
Deciduous Forest	2	2	Hop-hornbeam (*Ostrya virginiana*)	1	Sapling
Deciduous Forest	2	3	Shagbark hickory (*Carya ovata*)	1	Adult
Deciduous Forest	2	3	Northern red oak (*Quercus rubra*)	1	Adult
Deciduous Forest	2	3	Bitternut hickory (*Carya cordiformis*)	1	Adult
Deciduous Forest	2	3	Red maple (*Acer rubrum*)	1	Adult
Wetland	1	1	Queen Anne's lace (*Daucus carota*)	11	Herb
Wetland	1	1	Poison-ivy (*Toxicodendron radicans*)	12	Herb
Wetland	1	1	Common milkweed (*Asclepias syriaca*)	1	Herb
Wetland	1	1	Common buckthorn (*Rhamnus cathartica*)	28	Herb
Wetland	1	1	River-bank grape (*Vitis riparia*)	3	Herb
Wetland	1	1	Multiflora rose (*Rosa multiflora*)	1	Herb
Wetland	1	1	2 species of grasses	Dense	Herb
Wetland	1	1	Late goldenrod (*Solidago gigantea*)	2	Herb
Wetland	1	1	Boxelder (*Acer negundo*)	3	Seedling
Wetland	1	1	Amur honeysuckle (*Lonicera maackii*)	1	Seedling
Wetland	1	3	River birch (*Betula nigra*)	2	Adult
Wetland	1	3	Black cherry (*Prunus serotina*)	1	Adult

Habitat	Replicate	Circle	Species	# Individuals	Size Class
Wetland	2	1	Purple loosestrife (*Lythrum salicaria*)	2	Herb
Wetland	2	1	Joe-pye weed (*Eupatorium purpureum*)	5	Herb
Wetland	2	1	Orange jewelweed (*Impatiens capensis*)	3	Herb
Wetland	2	2	Silky dogwood (*Cornus amomum*)	6	Shrub
Wetland	2	2	Joe-pye weed (*Eupatorium purpureum*)	35	Shrub
Wetland	2	2	Cutleaf coneflower (*Rudbeckia laciniata*)	22	Shrub
Wetland	2	2	Orange jewelweed (*Impatiens capensis*)	13	Shrub
Mixed Forest	1	1	Virginia creeper (*Parthenocissus quinquefolia*)	2	Herb
Mixed Forest	1	1	Black ash (*Fraxinus nigra*)	6	Seedling
Mixed Forest	1	1	Common buckthorn (*Rhamnus cathartica*)	12	Seedling
Mixed Forest	1	1	Amur honeysuckle (*Lonicera maackii*)	9	Seedling
Mixed Forest	1	1	Poison-ivy (*Toxicodendron radicans*)	5	Herb
Mixed Forest	1	2	Common buckthorn (*Rhamnus cathartica*)	2	Sapling
Mixed Forest	1	2	Red elm (*Ulmus rubra*)	1	Sapling
Mixed Forest	1	3	Norway spruce (*Picea abies*)	8	Adult
Mixed Forest	2	1	Fescue grass (*Festuca spp.*)	5 ft^2	Herb
Mixed Forest	2	1	Virginia creeper (*Parthenocissus quinquefolia*)	11	Herb
Mixed Forest	2	1	Amur honeysuckle (*Lonicera maackii*)	7	Seedling
Mixed Forest	2	1	Common buckthorn (*Rhamnus cathartica*)	7	Seedling
Mixed Forest	2	1	Garlic mustard (*Alliaria petiolata*)	1	Herb
Mixed Forest	2	1	Prickly gooseberry (*Ribes cynosbati*)	2	Herb
Mixed Forest	2	2	Common buckthorn (*Rhamnus cathartica*)	6	Sapling
Mixed Forest	2	2	Black cherry (*Prunus serotina*)	1	Sapling
Mixed Forest	2	2	Red maple (*Acer rubrum*)	1	Sapling
Mixed Forest	2	3	Red maple (*Acer rubrum*)	7	Adult
Mixed Forest	2	3	Eastern white pine (*Pinus strobus*)	2	Adult
Mixed Forest	2	3	Black cherry (*Prunus serotina*)	2	Adult

Radrick Farms Golf Course Invasive Species Field Observations				
Habitat	**Replicate**	**Circle**	**Species**	**# Individuals**
Grassland	1	3	Canada thistle (*Cirsium arvense*)	50
Grassland	1	3	Common mullein (*Verbascum thapsus*)	2
Grassland	2	3	Queen Anne's lace (*Daucus carota*)	89
Grassland	2	3	Canada thistle (*Cirsium arvense*)	564
Grassland	2	3	Common buckthorn (*Rhamnus cathartica*)	47
Deciduous Forest	1	3	Amur honeysuckle (*Lonicera maackii*)	132
Deciduous Forest	1	3	Autumn-olive (*Elaeagnus umbellata*)	2
Deciduous Forest	1	3	Japanese barberry (*Berberis thunbergii*)	3
Deciduous Forest	2	3	Lily of the valley (*Convallaria majalis*)	39
Deciduous Forest	2	3	Lesser burdock (*Arctium minus*)	1
Deciduous Forest	2	3	Common buckthorn (*Rhamnus cathartica*)	12
Wetland	1	3	Queen Anne's lace (*Daucus carota*)	192
Wetland	1	3	Lesser burdock (*Arctium minus*)	10
Wetland	1	3	White sweet clover (*Melilotus alba*)	7
Wetland	1	3	Common buckthorn (*Rhamnus cathartica*)	180
Wetland	1	3	Autumn-olive (*Elaeagnus umbellata*)	7
Wetland	1	3	Canada thistle (*Cirsium arvense*)	750
Wetland	1	3	Multiflora rose (*Rosa multiflora*)	1
Wetland	2	3	Purple loosestrife (*Lythrum salicaria*)	32
Mixed Forest	1	3	Common buckthorn (*Rhamnus cathartica*)	18
Mixed Forest	1	3	Amur honeysuckle (*Lonicera maackii*)	12
Mixed Forest	2	3	Common buckthorn (*Rhamnus cathartica*)	504
Mixed Forest	2	3	Amur honeysuckle (*Lonicera maackii*)	224
Mixed Forest	2	3	Garlic mustard (*Alliaria petiolata*)	1

Blue Course Species Diversity Field Observations					
Habitat	**Replicate**	**Circle**	**Species**	**# Individuals**	**Size Class**
Grassland	1	1	3 species of grasses	Dense	Herb
Grassland	1	1	River-bank grape (*Vitis riparia*)	3	Herb
Grassland	1	1	Boxelder (*Acer negundo*)	1	Seedling
Grassland	1	1	Choke cherry (*Prunus virginiana*)	1	Seedling
Grassland	1	3	Pear (*Pyrus spp.*)	3	Adult
Grassland	2	1	4 Species of Grasses	Dense	Herb
Grassland	2	1	Canada thistle (*Cirsium arvense*)	130	Herb
Grassland	2	1	White clover (*Trifolium repens*)	Spotty Dense, 15% Coverage	Herb
Grassland	2	1	Eastern cottonwood (*Populus deltoides*)	1	Seedling
Grassland	2	2	Glossy buckthorn (*Frangula alnus*)	3	Shrub
Deciduous Forest	1	1	1 species of grass	56	Herb
Deciduous Forest	1	1	White avens (*Geum canadense*)	5	Herb
Deciduous Forest	1	1	Poison-ivy (*Toxicodendron radicans*)	2	Herb
Deciduous Forest	1	1	European privet (*Ligustrum vulgare*)	31	Seedling
Deciduous Forest	1	1	Common buckthorn (*Rhamnus cathartica*)	14	Seedling
Deciduous Forest	1	2	Boxelder (*Acer negundo*)	2	Sapling
Deciduous Forest	1	2	Common buckthorn (*Rhamnus cathartica*)	3	Sapling
Deciduous Forest	1	2	Black ash (*Fraxinus nigra*)	21	Sapling
Deciduous Forest	1	2	European privet (*Ligustrum vulgare*)	37	Shrub
Deciduous Forest	1	3	Norway maple (*Acer platanoides*)	1	Adult
Deciduous Forest	2	1	White avens (*Geum canadense*)	4	Herb
Deciduous Forest	2	1	Poison-ivy (*Toxicodendron radicans*)	1 per 6 in², 70% Coverage	Herb
Deciduous Forest	2	1	Virginia creeper (*Parthenocissus quinquefolia*)	9	Herb
Deciduous Forest	2	1	American pokeweed (*Phytolacca americana*)	13	Herb
Deciduous Forest	2	1	Lesser burdock (*Arctium minus*)	7	Herb
Deciduous Forest	2	2	Bur oak (*Quercus macrocarpa*)	1	Sapling
Deciduous Forest	2	2	Common buckthorn (*Rhamnus cathartica*)	20	Sapling
Deciduous Forest	2	3	Norway maple (*Acer platanoides*)	4	Adult
Deciduous Forest	2	3	White mulberry (*Morus alba*)	1	Adult
Deciduous Forest	2	3	Bur oak (*Quercus macrocarpa*)	1	Adult

Blue Course Invasive Species Field Observations				
Habitat	**Replicate**	**Circle**	**Species**	**# Individuals**
Grassland	1	3	Queen Anne's lace (*Daucus carota*)	60
Grassland	1	3	Canada thistle (*Cirsium arvense*)	45
Grassland	2	3	Tree-of-heaven (*Ailanthus altissima*)	27
Grassland	2	3	Canada thistle (*Cirsium arvense*)	490
Grassland	2	3	Common buckthorn (*Rhamnus cathartica*)	42
Grassland	2	3	Glossy buckthorn (*Frangula alnus*)	3
Grassland	2	3	Lesser burdock (*Arctium minus*)	26
Deciduous Forest	1	3	Common buckthorn (*Rhamnus cathartica*)	26
Deciduous Forest	1	3	Canada thistle (*Cirsium arvense*)	166
Deciduous Forest	1	3	European privet (*Ligustrum vulgare*)	68
Deciduous Forest	1	3	Norway maple (*Acer platanoides*)	1
Deciduous Forest	2	3	Lesser burdock (*Arctium minus*)	7
Deciduous Forest	2	3	Common buckthorn (*Rhamnus cathartica*)	20
Deciduous Forest	2	3	Norway maple (*Acer platanoides*)	4

9) Appendix III. Community Survey

The following is a survey regarding adoption of further sustainable practices and environmental stewardship initiatives by the University of Michigan and the U of M Athletic Department at its two golf courses - Radrick Farms on Geddes Avenue and the Blue Course on Stadium Boulevard.

Please indicate all events you have attended.

Blue Course		**Radrick Farms**	
• **Golf**	☐	• **Golf**	☐
• **Tailgate**	☐	• **Event In Club House**	☐
• **Event in Clubhouse**	☐	• **Other: _____**	☐
• **Other: _____**	☐		

Please complete the following survey by indicating the degree to which you agree with the following statements:

1: Not at All **2**: Slightly **3**: Somewhat **4**: Agree **5**: Strongly Agree

The University has a responsibility to be a leader in sustainability within the larger Ann Arbor community	1	2	3	4	5
A sustainable community is important to me	1	2	3	4	5
Grounds-keeping practices at local golf courses affect the health of the surrounding community and environment	1	2	3	4	5
Grounds-keeping practices at local golf courses affect local environmental health	1	2	3	4	5
Local golf courses do not have a responsibility to engage in environmental stewardship	1	2	3	4	5
Golf courses should be a multi-use space (e.g., Golf, other recreation, food harvesting)	1	2	3	4	5

If you are interested in receiving more information on this study and the sustainable golf practices, please write your email address here:

_____.

Thank you.

10) Appendix IV. Pre- and Post-Golf Cognitive Function Survey

Pre- and Post-Golf Round Mental Clarity Survey

Please indicate the course on which you are playing: Radrick ☐ Blue ☐

Please complete the following survey immediately before your round of golf.

Please indicate how much you agree with the following:

1: Not at All **2**: Slightly **3**: Somewhat **4**: Agree **5**: Strongly Agree

I am energized	1	2	3	4	5
I feel a sense of calm	1	2	3	4	5
I am easily distracted	1	2	3	4	5
I feel mentally drained	1	2	3	4	5
My mind is alert and awake	1	2	3	4	5

Please complete the following immediately after completing your round of golf.

Please indicate how much you agree with the following:

I am energized	1	2	3	4	5
I feel a sense of calm	1	2	3	4	5
I am easily distracted	1	2	3	4	5
I feel mentally drained	1	2	3	4	5
My mind is alert and awake	1	2	3	4	5
I was able to block out distractions	1	2	3	4	5
I feel mentally rejuvenated	1	2	3	4	5
I believe being outside contributed to any changes from my previous mental state	1	2	3	4	5
I believe that being active contributed to any changes in my previous mental state	1	2	3	4	5
I believe that being active outside contributed to any changes in my previous mental state	1	2	3	4	5
I golf because it improves my mental state	1	2	3	4	5

----------cut here----------

If you are interested in receiving more information on this study and the effects of green exercise, please provide your email address:_____

11) Appendix V. Attention Restoration Abilities and Limitations of Golf Courses and Golf: Preferred Environments and Directed Attention Literature Review

Numerous studies have been conducted regarding the ability of time spent in nature to restore an individual's Directed Attention capacity. More recently, De Young has focused on the positive impacts of walking in nature, and Pretty has studied the synergistic effects of physical activity performed in an outdoor setting, finding that exercise in both "rural pleasant and urban pleasant" settings resulted in a significantly larger improvement in self-reported self-esteem as well as blood pressure.[77] Coon found that exercising in natural environments was associated with greater self-reported "feelings of revitalization and positive engagement, decreases in tension, confusion, anger, and depression, and increased energy."[78] This study builds on these by hypothetically applying findings to a new, and to the author's knowledge previously unstudied, form of green exercise: golf. Through this literature review and application, we hoped to understand the potential cognitive and psychological benefits of playing golf at the University of Michigan's two golf courses and in doing so gain better appreciation of the courses' value to the health of their surrounding community.

From James' early explorations of human attention, it has become relatively well-accepted that attention exists in two forms: involuntary attention, now known as fascination, and voluntary attention, now known as directed attention.[79] Directed Attention allows the human mind to inhibit more interesting stimuli in order to focus on what is important in the moment; this inhibition requires effort. Over the latter half of the century following James' discoveries regarding these two types of attention, the Kaplans' work at the University of Michigan School of Natural Resources and the Environment has shown Directed Attention to be a finite resource—one that fatigues due to the effort involved in inhibiting other stimuli.[80] The Kaplans have further shown that in order to restore the Directed Attention mechanism, it must be rested, which can best be achieved in preferred environments that are rich in fascination. By allowing the mind to be drawn to inherently fascinating subjects and processes, the directing of attention is not necessary, therefore allowing directed attention to restore. Below, we explore the theoretical elements of golf which seem either suitable or unsuitable for the restoration of Directed Attention and then use these to complement the discussion of our own results and to inform recommendations.

<u>Characteristics of Golf/Golf Courses Suitable for Directed Attention Restoration</u>:

A round of golf contains many fascinating elements that engage fascination, therefore allowing Directed Attention to rest and concurrently restore. The Kaplans have developed a framework to better understand preferred environments most conducive to Directed Attention restoration and found four common requirements to be a sense of "being away," a combined

connectedness and scope which together comprise “extent,” “compatibility,” and of course “fascination.”[81]

Golf courses, particularly in a relatively urban setting such as Ann Arbor, seem a logical fit for the “being away” aspect, in both a physical way by escaping the confines of an office as well as a more mental way by putting aside a golfer’s usual work.[81] Further, assuming sufficient quality in the design of the golf course, and it seems likely that renowned designers MacKenzie and Dye have achieved this quality in the Blue Course and Radrick Farms course, respectively, then the courses most likely appear to the golfer as a “whole” and other world.[81] The holes and terrain have interrelated geographical and conceptual characteristics that allow for connectedness that is the first part of “extent.” The second piece of “extent” is scope, meaning that it must provide “enough to see, experience and think about” to merit the construction of mental models.[80] Given the 146 acres and rolling hills of the UM Blue Course, and the 275 acres and extensive patches of forest and open meadows at Radrick Farms, most likely either course would provide sufficient scope to fulfill the “extent” requirement.

“Compatibility” is primarily concerned with the alignment of the environment with an individual’s purposes and intents.[v] While the relative support for restoration provided by a golf course’s “compatibility” therefore depends somewhat on both the environmental (i.e. weather, the proper maintenance of the playing surfaces) and individual context (i.e. relative physical health and golf ability), most courses do contain helpful elements that provide measures of compatibility. Extensive grounds-keeping work is intended to maintain highly-functional playing surfaces, and signage is often provided support easy navigation through the course.

Finally, golf courses potentially contain many elements that easily elicit “fascination,” or stimuli that involuntarily draw attention and that therefore enable function with minimal use of directed attention.[81] To James’ early list of fascinating content, the Kaplans have added “many objects found in nature” including specifically sources of soft fascination such as “clouds, sunsets…the motion of leaves in the breeze.”[80, 81] These sources of “soft” fascination have been found to have the additional benefit of allowing for deeper restoration. Fascination can also be provided by process. On a golf course, the opportunity to watch and learn from the swing of an expert golfer could provide process fascination. Similarly, the process of reading the undulations of a putting green to solve a difficult but not impossible problem (i.e. which direction and with what amount of force to putt the ball) could also provide process fascination.[80]

Although both Radrick Farms and the UM Blue Course do offer golf carts, many golfers choose to during walk their round of golf, and in doing so they perhaps unwittingly improve the opportunity for directed attention restoration. De Young has built on Pretty’s work on “green exercise” to develop conditions under which walking in nature most effectively restores directed attention, and many can be realized at golf courses.[82] De Young sites additional research by Berman, Jonides and Kaplan which found that more rural walking routes better improved post-walk cognitive function (a result of restored directed attention); this seems to indicate that more secluded courses further from roadways, such as Radrick Farms, could offer improved restoration opportunities.

Characteristics of Golf/Golf Courses Ill-Suit for Directed Attention Restoration:

Despite these characteristics that are potentially conducive to directed attention restoration, there are also some characteristics of golf courses, and time spent golfing on them, that could be poorly suited for restoration. Although the actual process of playing a round of golf, including but not limited to the focus on one's swing, attention to wind direction and speed of a green, could be more pleasant and more fascinating than office work, Kaplan notes that "even a thoroughly enjoyable project, and sufficiently intense and sufficiently prolonged, is likely to lead to" directed attention fatigue.[80] A round of golf can last anywhere from two to four hours, and the attentional resources required to adequately focus and judge ever-changing conditions and make constant adjustments to swing, club choice, strategy, etc., far from allowing directed attention to rest and restore, could in fact further deplete the mechanism.

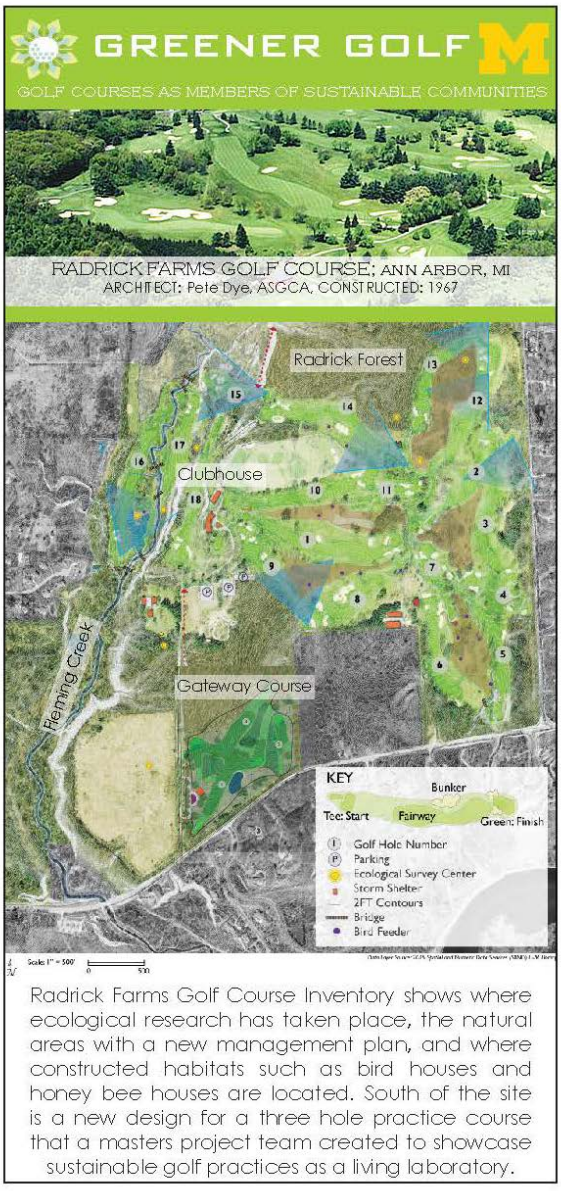
As mentioned above, one other preferred environment characteristic in question is the "compatibility," and this characteristic is largely dependent upon individual context. Kaplan explains this characteristic further by explaining the alignment of the environment with the individuals purpose such that "one carries out one's activities smoothly and without struggle."[80] This of course underlines the inherent importance of context, for indeed a "preferred environment" is not a universal classification, and in this case could depend greatly upon a golfer's skill-level relative to the difficulty of the course, as well as his or her intentions or purposes while golfing. A golfer whose skill might not be adequate to handle the challenging designs of MacKenzie and Dye's courses but who intended his or her round as nothing more than an excuse to be outside and socialize could in fact still find their round of golf restorative. In contrast, a golfer with the same skill level but with an intention to focus entirely on the competitive implications of their performance during their round could have a completely different experience, and far from completing the eighteenth hole restored, could depart the course more cognitively fatigued than they arrived.

Building on the notion of the importance of context in restorative capabilities of golf courses is the further implications of social interactions during a round of golf. De Young notes that "social interaction can be intense or gentle… if a social interaction is riveting with lively back-and-forth conversation, than it is likely that additional directed attention will be consumed through the process of ensuring civil discourse."[82] This seems particularly pertinent given golf courses' perhaps stereotypical yet often accurate informal designation as an external setting for business. Rounds of golf which host discussions of client relations and contract negotiations are likely to entail high levels of "lively, back-and-forth conversation" and potentially intense competitive environments punctuated with banter, potentially demanding high levels of directed attention and therefore minimizing, if not eliminating entirely, potential for restoration. Further, transplanting business conversations onto the golf course could also negate the sense of "being away" previously provided by the courses; Kaplan notes that "continuing to struggle with old thoughts in a new setting is unlikely to be restorative."[82, 83]

Conclusion:

Given this review of relevant literature relating to directed attention and its restoration in natural settings and the balance of characteristics conducive or ill-suited to directed attention restoration in golf and on golf courses, it is not surprising that the Greener Golf Pre- and Post-Cognitive Function Survey yielded results of no statistically significant change in subjects' self-reported cognitive function. This review of relevant literature has however served to direct recommendations for further study, as well as informed updated content for the Radrick Farms Stewardship Guide aimed at enhancing cognitively restorative opportunities on the course (*See Appendix VI*).

12) Appendix VI. Stewardship in Sustainability Educational Pamphlet



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