BIODIVERSITY ON GOLF COURSES: THE ROLE OF SUSTAINABILITY CERTIFICATIONS

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In this paper we examine relationships between golf courses and biodiversity. We review existing research linking biodiversity and golf. Next, we identify key ecological principles shaping a golf course's ability to impact biodiversity. Then, we evaluate the biodiversity dimensions of two prominent golf course sustainability certification frameworks (GEO Foundation and Audubon International). We make a qualitative assessment of how well the certification programs incorporate ecological concepts into their rating systems. Given the inherent connections between the sport of golf and the natural landscape, there are many opportunities for course owners and operators to take biodiversity factors into consideration when designing, renovating, and managing their facilities. However, positive outcomes in this area will only be achieved through careful planning and sustained commitment on the part of course managers as well as education and outreach to the golfing public.

Keywords: golf, biodiversity, sustainability certification, sport management, sport ecology

INTRODUCTION

Sport has not escaped scrutiny regarding sustainability impacts in recent years (Orr, Pippard, et al., 2022). All sports make some type of environmental impact. While that particular impact will vary based on the nature of the activity, few sports have as intimate a relationship with the physical landscape itself as golf. In golf, the physical territory is a vital component of the game and courses are shaped to create unique, challenging, and aesthetically pleasing playing experiences. As such, golf courses are intensively designed, engineered, and managed, which can in turn result in a range of negative environmental impacts. Yet, given golf's close relationship to the land itself, with careful thought and planning the sport has just as many opportunities to be a positive environmental force with regard to water use and stormwater management, air pollution mitigation, agrichemical use, and even mitigating the urban heat island effect (Merrick, 2024).

In this paper we narrow the focus to the relationships between golf courses and biodiversity. According to the World

Wildlife Fund, "biodiversity" is understood as "all the different kinds of life… in one area—the variety of animals, plants, fungi, and even microorganisms like bacteria that make up our natural world." (World Wildlife Fund, n.d.) Biodiversity also extends to the genetic diversity *within* species, scales up to the diversity *between ecosystems*, and encompasses the *interactions between organisms*. Biodiversity is critical to the overall functioning of any ecosystem, and tremendous international attention is being paid to preserving biodiversity in light of global climate change, habitat destruction, and land use change (United Nations Environmental Programme, 2012). Golf must surely play a role in biodiversity: on one hand, golf courses, oriented as they are towards uniform playing conditions and the cultivation of large areas of monoculture grasses, directly oppose the principle of biodiversity. Conversely, all golf courses feature less-managed areas (e.g., "rough," waste areas, out-of-bounds areas, water hazards, and penalty areas) that not only serve as obstacles for players but also play aesthetic, landscaping, and drainage roles. These areas could logically serve to benefit biodiversity. And depending on its spatial context, a golf course may represent a green oasis in an urban or suburban area, providing habitat to species otherwise displaced by human settlement or infrastructure development.

The purposes of this paper are: first, to systematically review the literature linking biodiversity and golf; second, to identify key ecological concepts at play on golf courses; and third, examine how those concepts are articulated in two prominent sustainability certification programs for golf facilities. All of this is undertaken with an eye towards supporting golf course owners' and operators' efforts to improve biodiversity performance. Our paper begins by situating our study in the Sport Ecology scholarly literature as well as the literature on sustainability certifications before presenting background on the global golf industry and existing sustainability certification programs available to golf courses. Next we present our research methods and findings, beginning with our systematic review of scholarship on biodiversity and golf, then moving to identify and articulate the ecological concepts "at play" in assessing the biodiversity performance of a golf course, and finally evaluating the biodiversity dimensions of two prominent golf course sustainability assessment frameworks. Our goal is to make a qualitative assessment of how well the certification programs incorporate ecological concepts into their rating systems. We then discuss the implications of our findings for the golf industry before presenting some avenues for future research.

Background, Part 1: The Sport Ecology Scholarly Literature

While the sport management literature has considered environmental issues on an ad hoc basis for many years, the relatively recent emergence of "Sport Ecology" as a subdiscipline within sport management has led to more profound and consistent engagement (McCullough et al., 2020). Sport Ecology emphasizes the significance of the natural environment and the need for a dedicated focus on sustainability within the field of sport management, a conceptualization which aligns with the growing recognition of the environmental impacts of sports and the necessity for managing these impacts effectively (McCullough et al., 2020). It is thus within the Sport Ecology literature that we position our study on golf and biodiversity. However, while a range of environmental topics fit within the Sport Ecology conceptual area, in practice Sport Ecology research has focused especially on the relationship between sport and climate change, sport and environmental justice, and sports and pollution.

The Sport Ecology concept has been utilized to elucidate the climate vulnerabilities faced by sport organizations; in other words, the impacts of climate change on sport. For instance, Orr & Inoue (2019) highlight the importance of understanding and managing climate vulnerability in sport organizations (Orr & Inoue, 2019). Other studies have investigated the effects of climate change on organized sport, emphasizing the need for climate change mitigation efforts within the sports sector (Orr, Inoue, et al., 2022). Sports clubs and organizations have been highlighted for their responsibility in climate change mitigation efforts (Schneider & Mücke, 2024). Research has also examined the impact of climate change on specific sports activities. For instance, winter sport activities are at considerable risk due to global warming affecting snow duration and amount (Frühauf et al., 2020), and some adaptation efforts may potentially worsen sustainability performance (Steiger et al., 2019). Conversely, the impact of sport emissions on climate change has also been a focus, emphasizing the significant contributions of the global sports industry to carbon emissions and sustainability practices (Wilby et al., 2023).

The Sport Ecology literature also includes a focus on environmental justice. Scholars have highlighted the need for sport management professionals to address environmental and ecological issues through the lens of environmental justice (see Chen & Kellison, 2023 for a review of this area). This emphasis is crucial as athletes engaging in outdoor sports are directly impacted by adverse environmental conditions (McCullough et al., 2020). A related strand of research has examined how athletes have come to play a prominent role in climate activism within particular sectors, for instance winter sports (Knowles et al., 2024). The integration of environmental justice into sport ecology involves understanding how ecological, socio-political, and economic forces interact.

Lastly, the Sport Ecology literature has actively engaged with the topic of pollution, providing insights into the complex relationship between pollution levels and sports participation. For instance, researchers have explored the effects of air pollution on professional soccer players' productivity, utilizing data on air pollution levels near stadiums to understand players' exposure and its effects on performance (Lichter et al., 2017). Similarly, studies have examined how the deterioration of the environment, leading to increased air pollution and noise pollution, might hinder outdoor sports participation (Guo et al., 2022). Other studies have investigated the impact of air pollution on sport attendance (Locke, 2019). Researchers have explored the influence of local air pollution on game attendance and vice versa, emphasizing the interconnectedness between environmental factors like air pollution and sports activities (McCullough et al., 2020).

While the Sport Ecology and broader sport management literatures have not engaged as extensively with biodiversity, the issue is undoubtedly connected to research on climate change, environmental justice, and pollution. Nevertheless, studies have specifically highlighted the importance of understanding the effects of sports-oriented land uses on biodiversity, and how considering biodiversity conservation in land-use planning for sports activities can mitigate negative impacts (e.g., Laiolo & Rolando, 2005). Research has also engaged with the notion that coordinated management and cooperation between sport, land management, and biodiversity stakeholders is vital to preserve native biodiversity while managing land for sport activities (e.g., Boiral & Heras-Saizarbitoria, 2017b). Additionally, research has explored the potential impacts of sports on biodiversity conservation efforts, emphasizing the need for specific approaches and practices to address biodiversity issues (e.g., Boiral & Heras-Saizarbitoria, 2017a). This recognition suggests that biodiversity conservation requires tailored management systems distinct from general environmental management systems. It is this segment of the Sport Ecology literature that motivates and contextualizes our study of golf.

Background, Part 2: Scholarly Literature on Sustainability Certifications

For this study we also consider scholarly literature on sustainability certifications. Sustainability certifications exist to ensure customers that performance criteria are being met by a product or organization. With a certificate, logo, or official statement, they are understood to be a third-party quality assurance. On the "producer" side of the market equation, a number of studies have demonstrated that participation in a sustainability certification, such as Fairtrade, can notably improve household living standards and amplify the implementation of sustainable practices for farmers and food processors (Chiputwa et al., 2015; Raynolds et al., 2007). Specifically for agricultural products, sustainability certifications have been shown to distinguish goods produced in line with positive social and environmental practices, thereby signaling to consumers that their purchase can aid in the preservation of biodiversity and sustainable agricultural methods (Milder et al., 2015).

On the "consumer" side of the market equation, various studies have explored consumer behavior, preferences, and attitudes towards sustainability certifications. A study of the wine sector (Sogari et al., 2016) has shown that sustainability certifications play a crucial role in helping consumers identify sustainable products, increasing perceptions of producer trustworthiness, and educating consumers about sustainability, which suggests that consumers value sustainability certifications as a means to make more-informed choices. A second study of the wine sector corroborated these findings (Stanco & Lerro, 2020), showing that consumers prioritize CSR initiatives such as sustainable agricultural practices, health and food safety, and air pollution in the wine sector, and suggesting that consumers are attentive to sustainability certifications that align with their values and concerns regarding environmental and social issues. In the consumer electronics sector, research highlighted that consumers are motivated to buy green products and engage in ethical consumption due to concerns about the health and safety of natural ecosystems (Mansoor et al., 2022) and indicated a consumer inclination towards sustainable products and services that are certified to be environmentally friendly.

Consumer responses to sustainability certifications are not entirely uniform, however. For instance, research has shown that consumer preferences and willingness to pay for sustainable certifications in the wine sector differ across countries (Menozzi et al., 2020). Other studies have shown that consumers' attitudes towards sustainability-certified products are influenced by their underlying environmental values and beliefs, highlighting the impact of individual perceptions on the benefits of sustainability certifications (Sogari et al., 2015).

Within the sports, tourism, and leisure industries, the implementation of environmental management practices and certification initiatives has become attractive for organizations looking to mitigate their actual negative impacts on the environment while also communicating to consumers and regulators that the organization is committed to sustainability (Babiak & Trendafilova, 2011). In addition, the potential economic benefits of certification programs are supported by the research identifying linkages between financial and social performance in professional sports, highlighting the economic significance of corporate social responsibility initiatives, including certification programs (Babiak & Wolfe, 2009). Other studies have examined the impacts of sustainability certifications on various aspects of sports and tourism enterprises, including financial performance, customer satisfaction, and employee satisfaction. For instance, one study examined sustainability-certified tourism enterprises to understand the perceived impact of sustainable practices on financial issues like revenue and operational costs, as well as intangible benefits such as customer and employee satisfaction (Hellmeister & Richins, 2019). In this paper, we aim to connect the literature on sustainability certifications to the golf industry with the goal of understanding the value of these tools in helping the sport achieve more positive environmental outcomes.

Background, Part 3: The World of Golf and Golf's Sustainability Certifications

Worldwide, more than 66 million people reported playing golf in 2020, with the majority of golfers located in North America, the British Isles, western Europe, Japan, South Korea, and Australia (Golf Course Industry Staff, 2021). The Royal & Ancient ("R&A"), one of the major global organizations overseeing the game, reported more than 38,000 golf courses around the world that same year. However, the distribution of courses is highly concentrated: about 80% of the world's courses were located in those top golfing countries and regions, with 42% of the world's golf courses found in the United States alone (The R&A, 2021, p. 4). The footprint of golf courses varies across countries as well. Globally, golf courses occupy nearly 57 thousand square miles (nearly 148 million square kilometers); average densities range from one golf course every 22.8 square miles in England to one course every 235 square miles in the United States, though density is not uniform across any given national territory and differs based on local population and demand characteristics (The R&A, 2021).

While golf originated in the cool, damp, sandy-soil coastal climes of Scotland, golf courses can today be found in more than 200 countries (The R&A, 2021), meaning that courses are being established, maintained, and renovated in every climate and biome imaginable. Until 2021, there was even a golf course on Antarctica; and who could forget US astronaut Alan Shepard famously hitting golf balls on the surface of the moon? As the R&A observed,

> Golf has its origins in the sandy ground along the British coastline. The naturally draining soils and moderate climate were ideal for the sport to develop along what was called "linksland". As golf increased in popularity and a growing middle class could afford to participate, courses sprang up on less than ideal sites that had to be especially prepared for golf, including open meadow, farmland and tree-lined parkland. Thus was born the craft of golf architecture and with it, a whole industry of golf course development and management. In the process, even more diverse lands became cultivated for golf, including deserts, mountains, landfills and purpose-built residential suburbs (The R&A, 2021, p.6).

There is nothing inherent to golf that would preclude the growth of the sport in new locations—the game itself can be played with nothing more than makeshift "holes" and a great imagination. But many new courses in emerging golf markets are aiming to replicate the landscape formations, lush grasses, water features, and firm, sandy playing conditions of coastal Scotland, in geographies that may not necessarily accommodate such a style. For instance, a course recently opened on the outskirts of Bangkok, Thailand ("Ballyshear Golf Links") was constructed to near-identically replicate an historic, coastal North Atlantic, links-style American course known as Lido (Cyrgalis, 2021). Governments and entrepreneurs in both Saudi Arabia and the United Arab Emirates have invested heavily in creation of new golf resorts modeled on European and North American clubs, intensively modifying the desert environment to achieve similar aesthetic and playing condition experiences as courses in the British Isles (Croley, 2022). The same phenomenon can be observed across the United States' "sunbelt" region, and the states of Arizona, Florida, and Texas in particular.

Recent studies note that the major golfing countries and regions represent mature markets for the sport, meaning that growth is occurring at a much more rapid pace in Asia, Africa, and the Middle East than it is in the core historical markets for golf (Matuszewski, 2019; The R&A, 2021; B. Thomas, 2021). And rather than being standalone sports facilities, in many instances new golf courses are associated with the development of resorts and other tourism infrastructure. In fact, the R&A found that nearly two-thirds of all new courses established or under development as of 2021 were associated with destination resorts, where customer expectations for the golfing experience might be especially high (López-Bonilla et al., 2020; The R&A, 2021). We can infer from these trends that the sport is growing and in new locations, but also perhaps placing heavier demands on local environments in those locations than courses built in golf's "native" habitat.

Research examining the environmental impacts of golf has been published by scholars and industry groups alike, such as the United States Golf Association (USGA), The R&A, the Golf Course Superintendents Association of America (GSCAA), and the American Society of Golf Course Architects (ASGCA) among other organizations mainly outside the US. One organization, the GEO Foundation, has even emerged with a specific focus on sustainability and commitment to "inspire, support, and reward credible sustainability action and to strengthen and promote golf's social and environmental value."(*About | GEO Foundation for Sustainable Golf*, n.d.) A considerable literature has developed around the topics of turfgrass management (e.g. Fitzpatrick et al., 2020; Strandberg et al., 2012; Tidåker et al., 2017), agri-chemical use (fertilizers, pesticides, etc.; e.g. Bekken et al., 2021; Millington & Wilson, 2016), and water issues (conservation, pollution, erosion and stormwater management, etc; e.g. Mackey et al., 2014; Mankin, 2000; Scott et al., 2018), as well as studies examining attitudes towards sustainability among golf "producers" (e.g., course managers) and "consumers" (e.g., players and spectators; e.g. Millington & Wilson, 2013; Minoli et al., 2018; Minoli & Smith, 2011). Economics and finance scholars have also contributed to the body of golf studies literature, and in particular around the issue of golf course and adjacent property valuation (e.g., Crompton, 2000; Crompton & Nicholls, 2020; Yates & Cowart, 2019). Though this final topic may initially appear unrelated to sustainability concerns, financial decisions are—unsurprisingly—a major factor in the overall sustainability narrative for golf. In particular, recent surges in land and housing prices in the USA, for example, have motivated some groups of activists and policymakers alike to question the benefits of golf courses occupying land that could instead be used for housing or meeting other public needs (e.g., Bivins, 2020; Hall, 2022). These entities have advocated for the closure and demolition of golf courses, a step which would preclude the course's ability to make any sort of positive environmental impact.

At the time of writing there are two major sustainability assessment and certification frameworks for the game of golf. One is the Audubon Cooperative Sanctuary Program for Golf ("ACSP"), which according to Audubon International is "an award-winning education and certification program that helps golf courses protect our environment and preserve the natural heritage of the game of golf." ("ACSP for Golf," n.d.) The other is the GEO Foundation's GEO Certified program, which according to the GEO Foundation is intended to "Celebrate your environmental stewardship, climate action and community value" through a "comprehensive modern certification, developed to the highest credibility standard, to help golf facilities, developments and tournaments demonstrate and be recognized for their environmental and social responsibility." (*GEO Certified | GEO Foundation for Sustainable Golf*, n.d.) Both programs have certification options for existing courses as well as new golf facility developments, and GEO Foundation also offers certifications for specific golf tournaments and events. Both programs are available to golf courses worldwide, though it happens that the ACSP program is more prominent in the United States while the GEO Foundation programs are more commonly utilized in Europe.

We offer below an overview of each program, before examining the biodiversity-focused aspects of each program in closer detail later in this paper.

Audubon Cooperative Sanctuary Program for Golf Courses: Established 100 years ago, the Audubon Society of New York was renamed in 1996 to Audubon International ("AI"), and AI has no formal affiliation with the National Audubon Society(Audubon International, n.d.-a). AI focuses specifically on different types of sustainability certifications, while the National Audubon Society is focused on broader conservation and wildlife issues.

AI is guided by the core belief that healthy functioning of the ecosystem is worth preserving, and that the process of maintaining healthy and functioning ecosystems begins at a local level (Audubon International, n.d.-a). To that end, AI has enrolled over 4,000 properties within the golf, recreation, and hospitality industries (Audubon International, n.d.-a). The USGA has supported the organization's sustainability efforts within the golf industry, providing more than $2 million over a twenty-year period to offset the costs of AI's programs for golf courses (Audubon International, n.d.-a).

The largest of these programs is the Audubon Cooperative Sanctuary Program for Golf Courses ("ACSP"), which was first offered in 1991 (Audubon International, n.d.-b). According to AI, ACSP "[membership] is open to golf courses in the United States and internationally, including private clubs, public and municipal courses, PGA sites, 9-hole facilities, resort courses, and golf residential communities." ("ACSP for Golf," n.d.) At the time of writing, there are 712 certified ACSP Golf members including public, private, and military golf courses across the United States and internationally (Audubon International, n.d.-c). ACSP certification is available only to existing courses. Courses in the planning and development stage are ineligible for ACSP certification though there are other AI certifications which they can apply for. We do not evaluate these other programs in this study, focusing instead only on the ACSP.

ACSP certification involves a site assessment, development of an environmental plan, and documentation that the plan has been implemented. The certification process can take up to three years to complete, and requires that applicants address six environmental categories: Environmental Planning, Wildlife and Habitat Management, Water Conservation, Chemical Use Reduction and Safety, Water Quality Management, and Outreach and Education. The application process also requires courses to provide documentation of their efforts, including photographs, labeled maps, integrated pest management records, water quality test results, samples of education materials, and a wildlife inventory. A site visit is required to verify the details offered by the course in their application.

GEO Foundation "GEO Certified" Programs for Golf Courses: The GEO Foundation for Sustainable Golf is a not-for-profit founded in North Berwick, Scotland in 2007, and is the only organization focused specifically on sustainability in the golf sector. GEO Foundation works with a range of entities ranging from individual courses to professional tours to provide sustainability strategies and solutions (*About | GEO Foundation for Sustainable Golf*, n.d.).

GEO Foundation has a three-part mission: first, improving the social, environmental, and climate contributions of the golf industry; second, enhancing the image, reputation, and resilience of golf; and third, helping the golf industry inspire players globally (*Purpose | GEO Foundation for Sustainable Golf*, n.d.). The "GEO Certified" program is a comprehensive certification to help existing facilities, new developments and golf tournaments demonstrate their commitments to environmental and social responsibility. The certification is ISEAL Code Compliant and has been developed over several years with broad stakeholder involvement (*Credibility | Assurance | Voluntary Standards*, n.d.). The certification can be achieved through successful completion of the OnCourse data collection survey, which addresses a broad spectrum of environmental and social issues. A site visit is also encouraged for applicants. Any golf entity, from small 9-hole courses to international resort courses, professional tournaments, and elite amateur golf events can engage with the certification process. Approximately 60 tournaments and more than 1200 golf courses are GEO Certified, at the time of writing. Courses and tournaments with the certification are found in nearly 80 countries (*Sustainable Golf Course Directory | Tournaments*, n.d.). The analysis in this study focuses on the GEO

Certified programs for existing golf courses, in order to make a direct comparison with ACSP. We do not evaluate the GEO Certified programs for tournaments in this study.

RESEARCH METHODS

The purposes of this paper are: first, to systematically review the literature linking biodiversity and golf; second, to identify key ecological concepts at play on golf courses; and third, examine how those concepts are articulated in two prominent sustainability certification programs for golf facilities. We explain below how we have approached each of these areas of empirical work.

Systematic Review of Scholarly Literature on Biodiversity and Golf: We conducted a systematic search of English-language, peer-reviewed journals in the fields of sports management, landscape architecture, urban and environmental planning, ecology, and environmental science. We searched both Google Scholar and Scite during the summer of 2022, with no restrictions on publication date. We utilized various search phrasings including the keywords "golf" and "biodiversity." We also employed a snowball sampling method to identify relevant studies: once we identified a study focused on the relationship between biodiversity and golf, we examined the bibliography of that article to find additional studies on the topic.

Ecology Concepts: Each of the papers we discovered in our systematic search of scholarly literature was qualitatively evaluated by our ecologist team member to identify the ecology and scientific concepts playing the most important roles in the study.

Qualitative Assessment of Existing Sustainability Certifications for Golf: We reviewed the certification criteria for both the ACSP and GEO Foundation programs, focusing in particular on the aspects of the certifications that most directly relate (even if not explicitly) to wildlife, habitat, and biodiversity management. We then aimed to assess how well the criteria aligned with the ecology concepts identified earlier, and made note of where each certification implemented (or did not implement) the ecology concept.

We describe our approach to these empirical tasks as "thematic analysis research." This method entails recognizing, analyzing, and presenting patterns or themes within qualitative data. Thematic analysis enables researchers to explore underlying meanings and concepts within something broad like a sustainability framework. Thomas & Harden introduced methods for the thematic synthesis of qualitative research in systematic reviews, refining these methods over time to apply thematic analysis more explicitly (J. Thomas & Harden, 2008). Braun & Clarke discussed the widespread adoption of thematic analysis in the social and health sciences, highlighting the approach's popularity and utility in research (Braun & Clarke, 2014).

FINDINGS, PART 1: SCHOLARLY LITERATURE ON BIODIVERSITY AND GOLF

We conducted our systematic literature review according to the procedure outlined above. Ultimately, our search produced 23 peer-reviewed studies published between 1987 and 2020. Summary attributes of the papers appear in Table 1 and Table 2 (see appendix).

The literature on golf and biodiversity is largely positive about the potential for golf courses to play a significant role in protecting wildlife and landscape. Research showed, in several instances, courses acting as refugia for otherwise rare or declining species. For instance in Kent, England, a study found that rare species and relic landscapes were found almost exclusively on golf courses (Green & Marshall, 1987). Studies in Japan, Australia, and the United States reached similar conclusions (Hodgkison et al., 2007; Winchell & Gibbs, 2016; Yasuda & Koike, 2006).

In virtually all instances, research demonstrates that the surrounding landscapes of the golf course is vitally important with regard to biodiversity (Petrosillo et al., 2019). Courses embedded within an urban, suburban, or agricultural landscape context had greater biodiversity than courses surrounded by wilderness or nature preserves. For instance, the biodiversity of golf courses in Surrey, UK, was found to be higher than adjacent farmland, with birds, ground beetles, and bumblebees showing greater species richness and abundance on golf courses (Tanner & Gange, 2005). In fact, one meta-analysis found that golf courses had higher ecological value than immediate surroundings in 64% of comparative cases, particularly in studies of species richness focused on birds and insects (Colding & Folke, 2009). Other studies showed a similar effect for plant species (Nguyen et al., 2020).

The design and management practices of golf courses are also a vital consideration for enhancing biodiversity. One study argued that so-called "naturalistic" golf courses, which are designed to incorporate substantial native wildlife habitat, have greater potential to benefit biodiversity while also reducing water runoff and more effectively engaging people in wildlife preservation than golf courses which aim to tackle biodiversity issues in a more haphazard fashion (Terman, 1997). In fact, seven of the studies we identified describe the importance of golf course design decisions in shaping biodiversity outcomes and articulate the need for ecological concepts to be more intentionally incorporated into new and renovated courses (Colding et al., 2009; Colding & Folke, 2009; Dobbs & Potter, 2016; S.-J. C. Fox & Hockey, 2007; Green & Marshall, 1987; Hodgkison et al., 2007; Terman, 1997). Another important dimension of management and design in this regard is the human element. One study, focused on golf course managers, found that although formal management planning for biodiversity was generally limited, course managers expressed a positive attitude towards promoting biodiversity (Hammond & Hudson, 2007). This is in line with historical research examining evolving attitudes towards sustainability more generally among golf course managers and staff (Millington & Wilson, 2013). However, conflicts between biodiversity management and golfing surely could emerge, highlighting the importance of education and engagement with club members/golfers to enhance conservation efforts. We return to this point towards the end of our paper.

Findings, Part 2: Key Ecological Concepts for Understanding the Biodiversity Impacts of Golf Courses

In reviewing the existing literature on golf courses and biodiversity, we were able to identify six recurring ecological phenomena. While it is not necessarily the case that each paper explicitly addressed each of the concepts below, taken as a whole, the following ecological concepts appear to be most salient with regard to biodiversity and golf courses. We offer below a brief explanation of each concept including citations for foundational papers from the ecology literature for each topic. The ecological concepts are presented in alphabetical order.

Abundance, Richness, and Evenness (e.g,. Kempton, 1979; Potts & Elith, 2006; Tokeshi, 1993): Most species in a community tend to be moderately abundant, while a few tend to be highly abundant or extremely rare. Diverse communities include both the common species and those that are more rare. The species diversity of an individual ecological community depends on both the number of species that are present (species richness) and the relative abundance of individuals among species (species evenness). Communities with high species diversity generally have both high species richness and evenness. Two commonly used metrics to quantify species diversity include the Shannon-Weiner Index and the Simpson's Index (McDonald et al., 2010).

Alpha-Beta-Gamma diversity (e.g., Magurran, 2021): Species diversity within a landscape can also be described at different scales: alpha, beta, and gamma. Alpha diversity describes the species diversity in a single community and is the scale of species diversity most commonly referred to. Beta diversity is used to describe the species diversity of two or more communities and whether they are similar or dissimilar. Gamma diversity describes species diversity at the largest spatial scale and encompasses entire ecoregions.

Disturbance and Equilibrium (e.g., Morin, 2011; Roughgarden, 1983): Stable ecosystems that do not experience much environmental change are said to be in a state of equilibrium. Under these conditions, competition theory suggests that only the most effective competitors will be able to persist over time. This would act to lower species richness since those species that are not as effective in competition will become locally or globally extinct. However, most ecosystems are subject to disturbance albeit at differing frequency and intensity. Disturbance may alter patterns of species abundance, and/or change the environmental conditions present in an ecosystem making it more favorable to other species that may be less competitively dominant. The intermediate disturbance hypothesis suggests that diversity will be highest when disturbances are not so frequent and intense that only effective colonizers can persist and not too infrequent and minimal so that only effective competitors can persist (J. F. Fox, 1979; Roxburgh et al., 2004).

Environmental Complexity (e.g., Connell & Orias, 1964; Kovalenko et al., 2012): One potential explanation for the species-area relationship and why large islands should have more species richness is that they contain more unique habitat types. These habitat types could include wetlands, meadows, shrublands, forests, and lakes to name a few. Vertical complexity in forests has been shown to have particularly significant impacts on bird species richness. In essence habitat complexity creates more potential niche space for a wider variety of species to occupy.

Regional Species Pool and Community Assembly (e.g., HilleRisLambers et al., 2012; Kraft et al., 2015; Weiher et al., 2011): Within a given geographic region there exists a pool of species native to that particular region that may potentially occupy habitat patches. Whether a particular species occupies a habitat patch depends on the physical suitability of that habitat and this is often described as the abiotic filter. These factors may be related to things such as climate, substrate, or nutrient availability among others. Assuming species make it through the abiotic filter, their persistence depends on the outcome of ecological interactions such as competition, predation, and mutualism and this is termed the biotic filter.

Species-Area Relationship and Island Biogeography (e.g., Connor & McCoy, 1979; Drakare et al., 2006; Lomolino, 2000; MacArthur & Wilson, 2001): A well supported biodiversity pattern is the species-area relationship which posits that larger habitats support more species. The species-area relationship is closely associated with the theory of island biogeography which generates predictions about patterns of biodiversity on islands. It predicts that large islands support more species than small ones and islands that are closer to sources of immigrants support more species than those far away. Although this theory was initially developed to explain biodiversity patterns on literal islands, it can be more broadly applied to any favorable habitat patches in fragmented or disturbed landscapes.

Findings, Part 3: Examining the Biodiversity Aspects of Existing Golf Sustainability Frameworks

We qualitatively evaluated the incorporation of the ecology concepts we outlined earlier; summary findings appear in Table 3 (see appendix).

Overall, both the ACSP and the GEO Certified program emphasize a comprehensive environmental management approach. The programs encourage golf courses to assess their unique settings, develop environmental plans, and implement sustainable practices tailored to their specific conditions, all of which, at a high level, work to encourage and support biodiversity. Next we will examine how the ecological concepts outlined above are observed in the ACSP and GEO Certified frameworks.

Abundance, Richness, and Evenness. The ACSP framework generally encourages golf courses to foster an environment where common and rare species alike can thrive. The framework investigates and encourages practices that support a variety of habitats within golf courses. These actions include maintaining natural (or naturalized) areas that can host diverse plant and animal species via preserving or restoring woodland, wetland, and grassland habitats. These types of actions would mean that the golf course is at least creating the habitat conditions to support a range of species (the "richness" part of the concept). Monitoring and documenting species through inventories helps raise awareness about species abundance and provides the raw data to understand the balance between common and rare species.

Likewise, GEO Certified criteria also encourage diverse ecosystems, supporting various species and promoting ecological stability. The criteria for habitat and biodiversity advocate for the protection and enhancement of native species, which supports the presence of both abundant and rare species. Encouraging facilities to implement bird boxes, bee homes, and "bug hotels" are specific examples that contribute to species richness and evenness by providing habitats for various species.

Alpha-Beta-Gamma Diversity. The ACSP framework unsurprisingly – given the nature of a sustainability certification program focused on individual golf courses – focuses on Alpha diversity, or diversity within a single location (e.g. the golf course pursuing ACSP certification). Alpha diversity is addressed by ACSP's focus on investigating and enhancing individual habitat and species types within a golf course. Beta and Gamma diversity are less directly addressed in the ACSP framework, being the species diversity of two or more communities and the species diversity at the ecoregion scale, respectively. Nevertheless, the framework does investigate and encourage the creation of wildlife and aquatic corridors, which would be the types of connections that would potentially encourage biodiversity on adjacent properties and the broader regional scale.

In the same fashion, GEO Certified criteria are focused more on Alpha diversity. The habitat management practices suggested in the framework mostly foster local diversity (alpha). Beta and Gamma diversity are addressed indirectly, and like ACSP incorporated through enhancements to natural corridors and habitat connectivity.

It is worth noting that managing for Beta and Gamma diversity would require coordination between courses across larger spatial scales, and there is not necessarily a strong incentive other than altruism for courses to engage in this coordination. A parallel can be drawn from conservation research in agricultural contexts: farmers who employ various strategies to promote biodiversity on their own farms often do not coordinate with other farmers within the regional landscape, ultimately limiting the potential for biodiversity conservation at the ecosystem level.

Disturbance and Equilibrium. Readers will recall from our earlier explanation of ecological concepts that biodiversity will likely be highest (ceteris paribus) when disturbances are not so frequent and intense that only effective colonizers can persist, and not too infrequent and minimal so that only effective competitors can persist.

The ACSP framework promotes practices that can mitigate disturbance. For example, the section on Wildlife and Habitat Management identifies a number of practices focused explicitly on minimizing disturbance, such as leaving dead trees standing (when safe to do so), cordoning off especially sensitive areas (such as nesting sites or areas containing threatened and/or endangered species), and routing service and cart paths to the edges of habitat areas. The concept of equilibrium is not directly addressed, but it can be reasonably inferred from the ACSP framework that the normal activities of a golf course are adequate to ensure some level of regular, low-level disturbance that healthy ecosystems do in fact have. Nevertheless, practices promoting habitat stability and health indirectly support equilibrium.

In the GEO Certified criteria, similar to ACSP, practices focusing on minimizing pollution, establishing buffer zones, and careful resource management are offered to help in maintaining stable ecosystems. For instance, the GEO Certified framework suggests guidelines for emergency spill responses and also establishing and maintaining buffer zones around water bodies and sensitive habitat areas in order to minimize ecological disturbances. The framework also suggests creation of transition zones between different habitat types, promoting equilibrium by protecting these habitats from potential pollution and physical disruption.

Environmental Complexity. The framework encourages the maintenance of various habitat types (e.g., woodlands, wetlands) and promotes vertical complexity, especially in forested areas, supporting environmental complexity and niche diversity. For example, ACSP encourages the maintenance and enhancement of structural diversity in vegetation (e.g., varying heights and types of plants), which creates a more complex environment and thus more niches to support various birds, insects, and other wildlife.

In the GEO Certified framework, as with ACSP, the emphasis on native species and diverse habitats supports environmental complexity, offering multiple niches for species. The emphasis on diverse habitats, such as grasslands, woodlands, and wetlands, along with the encouragement of vertical complexity in vegetation, enhances environmental complexity. For instance the framework encourages establishment and growth of understory vegetation as well as the establishment and growth of indigenous aquatic and shoreline plant species of varying size and structure. These practices create varied niches, promoting a broader range of species.

Regional Species Pool and Community Assembly. The ACSP framework encourages understanding the local ecosystem and selecting native plants, supporting the regional species pool concept. This approach ensures that the species with the potential to thrive in a given area are considered, facilitating community assembly that reflects the natural ecological processes. In fact, the ACSP framework sets as a target having 80% of landscaped trees, shrubs, flowers, and other plants – except the playing surface turfgrass itself – be comprised of plants indigenous to the local ecosystem, and further encourages landscaped plants to be purchased within the local ecosystem in the interest of supporting genetic integrity of local plant communities. Community assembly through biotic and abiotic filters is not explicitly detailed but is supported by the overall focus on habitat suitability.

In the GEO Certified criteria, the overall emphasis on native vegetation and ecological understanding aids in aligning golf course management with regional ecological dynamics, as it does within the ACSP framework. However, the suggestions and directives in this area are much less specific than in ACSP, with the framework simply encouraging prioritization of native trees and shrubs.

Species-Area Relationship and Island Biogeography. Maybe unsurprisingly, the ACSP framework does not explicitly address the species-area relationship or the concept of island biogeography, likely for the same reasons that the framework does not address the concept of Gamma diversity. However, there is some attention to this concept that can be inferred from the overall focus on supporting habitat. By increasing habitat size through conservation areas or connecting fragmented habitats, golf courses can support more species, aligning with the species-area relationship. Additionally, promoting corridors and connectivity between habitats can mitigate the effects of isolation, a concept derived from island biogeography.

In just the same way as ACSP, the GEO Certified criteria do not directly address the concepts of species-area relationships and island biogeography even while the overarching principles of habitat conservation and connectivity implied in the criteria do clearly support these ecological concepts. However, GEO Certified criteria do ask golf course applicants to examine whether their property is within a broader protected area or ecological management zone (such as a UNESCO World Heritage site or RAMSAR treaty area). Furthermore, the GEO Certified framework includes an item on "ecological and cultural consultation" where applicants are asked to indicate whether they have met with any of cultural and natural heritage interest groups active in their geographic area, which can be inferred as encouragement to think of the golf course property as a part of a wider ecological and cultural region.

Discussion

Our research findings clearly connect with the literature on sports and biodiversity that was outlined earlier. As discussed earlier, studies highlighting the importance of understanding the effects of sports-oriented land uses on biodiversity agree that considering biodiversity conservation in land-use planning for sports activities can mitigate negative impacts (e.g., Laiolo & Rolando, 2005). Both the GEO Certified program and ACSP provide a comprehensive framework for sustainability in golf course management. Both frameworks generally align with the key ecological concepts that we outlined earlier in this paper, though there is some variation in areas of emphasis as well as the specificity of the criteria or the guidance that is offered to applicants aiming to complete the certification process. We will examine first the areas in which one or both certifications fall short as far as the ecological criteria we outlined earlier, before offering some general observations and critiques of the frameworks, some of which underscore ongoing scholarly and practitioner discussions about the value of voluntary certification programs in general.

We find that both frameworks perform well in terms of directly addressing the concepts of abundance, richness, and evenness; alpha and beta diversity; disturbance and equilibrium, and environmental complexity. Within the frameworks there is clear attention to these concepts (even if not articulated as such) and suggestions are made as to how biodiversity is enhanced through actions and projects that the course can take. This outcome is perhaps not surprising given the nature of the certification programs, and the fact that they are focused on improving sustainability performance for a single golf course at a time. The ecological principles that are "done well" in the frameworks also focus on small-scale and local ecological concepts. To that end, we conclude that both frameworks are helpful in guiding course owners and operators towards specific biodiversity improvements. In that regard, the certifications do function well as a third-party assurance that sustainability criteria are being met. This is a key attribute of any sustainability certification, as we discussed in the literature review section above.

Sport and biodiversity research encourages coordinated management and cooperation between sport, land management, and biodiversity stakeholders as a means to preserve biodiversity while managing land for sport activities (e.g., Boiral & Heras-Saizarbitoria, 2017b). Both ACSP and GEO Foundation frameworks allude to or imply the role of golf courses in broader spatial contexts, through suggestions and inventories of connectivity and corridors, but both could be more direct and specific about the role of courses vis-a-vis Gamma diversity, species-area relationships, and concepts from island biogeography. Each of these concepts relates to an aspect of the role that golf courses can play for regional biodiversity. As we described above, the GEO Certified criteria do ask applicants to indicate the spatial context of their course within broader ecological and cultural settings, and both frameworks ask applicants if they are currently managing their facilities in line with applicable legal requirements which we presume to be environmental regulations intended to address issues at a broader scale than just a single golf property. However, we would suggest that both frameworks could more directly include criteria encouraging connections and collaborative projects among golf courses and other properties in the same geographic area and also between golf courses and other regional conservation projects as a means to leverage the benefits courses can provide with regard to Gamma diversity, species-area relationships, and island biogeography. For instance, neither framework presently accounts for the fact that proximity to existing favorable habitat patches (sources of "colonists" to the courses) can positively influence biodiversity. That is to say, neither framework would reward courses for simply supporting species and habitats immediately adjacent to their properties. This would be analogous to the ecology concept that islands close to the mainland are more easily colonized than islands far away. We suggest that an additional provision be added to both frameworks that would ask certification applicants about their engagement with regional land use planning and conservation efforts; foregrounding the species-area and island biogeography concepts might be useful justification in this regard.

We also find that both frameworks could be more specific and perhaps stringent with regard to the concepts of regional species pool and community assembly. Both ACSP and GEO Certified make frequent reference to the idea of native species and that courses should be prioritizing these into their managed areas and especially their landscaped areas. ACSP suggests a target of having 80% of landscaped plants be indigenous to the region; GEO Certified does not set a target at all but simply suggests that native plantings be prioritized. While this is certainly valuable, it is not clear as to why a more ambitious target could not be set in both frameworks, alongside a requirement for all plants to be procured from the local region. We note further that both frameworks somewhat minimally address removal of exotic and invasive species, and that these suggestions are focused on mitigating problematic species only in areas of the property that are actively managed. It is not clear why facilities should not also survey "out of play" areas of the course for invasive species and aim to remove them from these locations if possible. This would have biodiversity benefits both locally and in the immediate vicinity of the course. On a related note, neither framework addresses the very real issue of native, but "nuisance" species (e.g., beavers or coyotes). While species like these can be native, and even critical, parts of a local ecosystem, they may also represent a source of negative biotic filter-type interactions that occur after species make it through an abiotic filter and successfully colonize and establish a population; in other words, they are native species which can effectively eradicate other species from an ecosystem like a golf course. While it may be something of a philosophical leap to encourage golf course owners and operators to view non-human species as equal stakeholders in biodiversity issues, balancing the needs and habits of various species might be usefully considered part of the coordinated management and cooperation necessary for improving biodiversity outcomes. The certification frameworks could be useful in guiding that type of coordination and planning.

The research outlined earlier explained that sustainability certifications typically do lead to benefits on the "producer" side (e.g., implementing sustainability practices leads to better financial and social outcomes), but that the calculus on the "consumer" side is less clear and dependent on many factors including individual values and perceptions of the product or activity in question. In the specific case of golf courses, consumer demand for environmental quality has been assessed through hedonic pricing studies, indicating that the increase in marginal benefits of certification is approximately equal to the increase in marginal costs (Limehouse et al., 2010). This is in large part due to the fact that sustainability improvements for golf courses often result in economic savings in terms of chemical inputs, labor, and equipment necessary to meticulously manage all areas of a course. That is to say, there is considerable economic value available to golf courses for implementing sustainability initiatives. However, a separate question is whether or not there is value in pursuing a particular sustainability credential like ACSP or GEO Certified, or in some hypothetical biodiversity-focused credential. Insofar as pursuing certification drives implementation of other costs savings, then certifications are surely worth the costs.

However, whether certifications are a source of additional revenue and profit is a slightly different question – in other words, can courses collect a price premium by virtue of their certification? Research discussed earlier (Boiral & Heras-Saizarbitoria, 2017a) emphasized the idea that biodiversity conservation requires tailored management systems distinct from general approaches to sustainability. Are golfers willing to pay more specifically because a course has earned (and maintains) a sustainability certification? What about a specific biodiversity certification? The scholarly evidence is mixed. Certifications offered through an alternative AI program focused on golf resorts (Audubon Certified Golf Resorts, "ACGR") were shown to influence customers' decisions on which golf resort to choose in some instances but not others (Minoli et al., 2015). Managers of German golf courses holding the "Golf&Natur" certification felt that the focus on sustainability issues led to improvements in course quality and member satisfaction, in turn generating economic benefits through higher member and greens fees (Huth, 2017). Furthermore, research in the European market has demonstrated that amidst a constellation of other factors related to perceived course quality and prestige, a sustainability certification can lead to players' willingness to pay higher greens fees; however, it is less clear that holding a certification alone, ceteris paribus, will support players paying higher greens fees (Huth, 2019).

It is clear from this study and the related scholarly literature that additional research is necessary to better understand the function and value of sustainability credentials in the golf industry. We point to several avenues for future research. First, credentials like ACSP and GEO Certified are a binary proposition – courses either earn or do not earn the credential. Within that there is potentially variation in sustainability performance. For instance, a course could earn the overall sustainability credential due to strong performance in certain areas but actually perform minimally with regard to biodiversity. We raise this not as a criticism of either framework, but rather as a call to refine or better articulate the credentials to reflect exceptionally strong performance in certain areas like biodiversity and habitat management. To that end, additional metrics for strong biodiversity and habitat management performance must be devised for golf courses, and perhaps could also be devised for other critical environmental areas like climate change resilience and water management, so that commitments and success in these areas can be quickly and easily communicated to consumers and other stakeholders.

Second, the economic impacts of sustainability credentials for golf need to be further articulated and refined. The question of determining the economic value of a sustainability credential can be more directly examined through willingness-to-pay studies and other research approaches. This additional knowledge will support efforts, like those led by GEO Foundation and other golf industry stakeholders, to "sell" sustainability and inspire golfers, course managers, and golf property owners to more fully engage with improving the sustainability performance of the golf industry. Some of this work must focus on quantifying the enhanced sustainability outcomes of golf courses pursuing or earning credentials not only in terms of cost savings associated with eco-efficiency (e.g., using fewer inputs, labor, or water) but also in the language of ecosystem services: what is the value of a course that installs pollinator gardens, reconstructs wetland habitat, or builds wildlife corridors and how does the course (and the golf industry as a whole) capture that value? Clearer links to various emerging markets and credit programs can also be forged, as some studies have attempted previously (Burgin & Wotherspoon, 2009).

Summary and Conclusions

This paper explored the relationship between golf courses and biodiversity, emphasizing how golf's extensive land area offers unique opportunities and challenges for performance in this area. We reviewed existing research focusing on connections between golf and biodiversity, and we observed that there is considerable diversity in what constitutes research on this topic. Despite this diversity, there is clear consensus in the scholarly literature that golf courses are potential biodiversity havens when managed properly, despite many courses' historical trajectory in opposition to many biodiversity principles. We synthesized the scholarly literature on golf and biodiversity in light of ecological theories in order to identify key ecological concepts that are at play with regard to golf facilities, and these are abundance, richness, and evenness; Alpha-Beta-Gamma diversity; disturbance and equilibrium; environmental complexity; regional species pool and community assembly; and species-area relationship and island biogeography concepts. We then critically examined two major golf sustainability certification programs, the Audubon Cooperative Sanctuary Program (ACSP) and GEO Certified, assessing their alignment with these key biodiversity concepts. While we found that both programs generally support biodiversity through various practices, we also suggested improvements to the frameworks and in particular a greater focus on leveraging individual courses' contributions to make wider, regional biodiversity impacts.

It is hopefully clear from this study that education and engagement with club members and golfers is crucial for enhancing any type of conservation efforts on golf courses, because it is ultimately the users of a course who directly influence the acceptance and support of sustainable practices. By educating golfers about the environmental impact of their activities and the benefits of conservation measures, golf courses can foster a culture of sustainability and commitment to supporting biodiversity. Engaged and informed members are more likely to support initiatives that protect wildlife, conserve water, and maintain natural habitats. This collective awareness and participation can lead to more effective and widespread conservation efforts, ultimately benefiting both the golfing experience and the surrounding ecosystem.

Ultimately, we conclude that while golf courses certainly *can* be a positive force for biodiversity, for the vast majority of modern golf courses this has rarely been an *intentional* outcome. Yet, golf courses inherently present a set of spatial and resource conditions that might enhance the sustainability credentials of the sport overall. Thus, the best biodiversity outcomes linked to golf courses will only be achieved through careful planning and sustained commitment on the part of course managers, supported by education and outreach to the golfing public. If all of the stakeholders in a given golf course can work together with biodiversity in mind, then golf as a sport may be able to move away from the more negative aspects of its environmental reputation.

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APPENDIX

Table 1
Paper titles, first authors, journal titles, and years of publication

Paper Title	First Author	Journal Title	Year
An Assessment of the Role of Golf Courses in Kent, England, in Protecting Wildlife and Landscapes	Green	*Landscape and Urban Planning*	1987
Natural Links: Naturalistic Golf Courses as Wildlife Habitat	Terman	*Landscape and Urban Planning*	1997
Are Golf Courses Providing Habitat for Birds of Conservation Concern in Virginia?	LeClerc	*Wildlife Society Bulletin*	2005
Effects of Golf Courses on Local Biodiversity	Tanner	*Landscape and Urban Planning*	2005
Do Golf Courses Provide a Refuge for Flora and Fauna in Japanese Urban Landscapes?	Yasuda	*Landscape and Urban Planning*	2006
Impacts of a South African Coastal Golf Estate on Shrubland Bird Communities	Fox	*South African Journal of Science*	2007
Environmental Management of UK Golf Courses for Biodiversity—Attitudes and Actions	Hammond	*Landscape and Urban Planning*	2007
The Conservation Value of Suburban Golf Courses in a Rapidly Urbanising Region of Australia	Hodgkison	*Landscape and Urban Planning*	2007
The Potential for Golf Courses to Support Restoration of Biodiversity for BioBanking Offsets	Burgin	*Urban Ecosystems*	2009
The Role of Golf Courses in Biodiversity Conservation and Ecosystem Management	Colding	*Ecosystems*	2009
Golf Courses and Wetland Fauna	Colding	*Ecological Applications*	2009
Recommendations for Design and Management of Golf Courses and Green Spaces Based on Surveys of Breeding Bird Communities in Montreal	Hudson	*Landscape and Urban Planning*	2009
Use of Habitats by Resident and Migrant Birds in and around a Golf Course on the Atlantic Coast of Morocco	Greig-Smith	*Bird Study*	2014
Forging Natural Links with Golf Courses for Pollinator-Related Conservation, Outreach, Teaching, and Research.	Dobbs	*American Entomologist*	2015
Are Eco Labels Profitably Employed in Sustainable Tourism? A Case Study on Audubon Certified Golf Resorts	Minoli	*Tourism Management Perspectives*	2015

Naturalized Habitat on Golf Courses: Source or Sink for Natural Enemies and Conservation Biological Control?	Dobbs	*Urban Ecosystems*	2016
Legacy Effect of Trees in the Heritage Landscape of a Peri-Urban Golf Course	Jim	*Urban Ecosystems*	2016
Golf Courses as Habitat for Aquatic Turtles in Urbanized Landscapes	Winchell	*Landscape and Urban Planning*	2016
Integrating Biodiversity Considerations into Urban Golf Courses: Managers' Perceptions and Woody Plant Diversity in the Eastern Cape, South Africa	Jarrett	*Journal of Land Use Science*	2017
What Shapes Plant and Animal Diversity on Urban Golf Courses?	Nooten	*Urban Ecosystems*	2018
Can a Golf Course Support Biodiversity and Ecosystem Services? The Landscape Context Matter.	Petrosillo	*Landscape Ecology*	2019
Vegetation Trends Associated with Urban Development: The Role of Golf Courses	Nguyen	*PLoS one*	2020
Golf Courses as Potential Habitat for Urban Coyotes	Wurth	*Wildlife Society Bulletin*	2020

Table 2

Summary data for papers included in this study, identifying geographic species, habitat and study design attributes

Region	***# of studies***	**Species**	***# of studies***	**Habitat**	***# of studies***	**Study Design**	***# of studies***
Global / None Specified	*5*	Fauna (non-avian)	*8*	General / Comparative	*9*	Experimental / Ecology Field Work	*18*
USA	*4*	Birds	*6*	"Periurban" (suburban and exurban areas)	*10*	Literature Review	*3*
Australia	*4*	All	*4*	Urban	*4*	Social Science methods	*3*
UK - England	*3*	Insects	*4*	Wetlands-focus	*2*		
South Africa	*2*	Flora	*4*	Coastal-focus	*2*		
Sweden	*1*						
Morocco	*1*						
Canada	*1*						
Hong Kong	*1*						
Japan	*1*						
Total	**23**		***26*[1]**		**27[2-]**		***24*[3]**

[1]One study examined two major species types; one examined plant, bird, and ant species.
[2]Several studies combined characteristics (e.g., peri-urban and coastal).
[3]One study employed a mixed-methods approach.

Table 3

Qualitative evaluation matrix for assessing incorporation of ecology concepts in ACSP and GEO Foundation sustainability frameworks

Concept	**Description**
Abundance, Richness, and Evenness	Checking for guidelines or measures in the framework that encourage a balance between common and rare species, and strategies to enhance species diversity on the golf course.
Alpha-Beta-Gamma Diversity	Identifying whether there are practices or policies that focus on biodiversity within a single golf course, compare biodiversity between different courses, and consider the broader regional biodiversity.
Disturbance and Equilibrium	Evaluating the framework's handling of ecological disturbances and its approach to maintaining or restoring equilibrium, ensuring that the golf course supports a variety of species at different successional stages.
Environmental Complexity	Analyzing how the framework promotes habitat diversity and vertical structure in vegetation, creating niches for a wide variety of species.
Regional Species Pool and Community Assembly	Assessing whether the framework considers local species pools and how the golf course supports or restricts species colonization based on physical (abiotic) and biological (biotic) conditions.
Species-Area Relationship and Island Biogeography	Reviewing how the framework addresses habitat size and isolation, and strategies for managing biodiversity in fragmented landscapes or habitat patches.