Community sports fields and atmospheric climate impacts: Australian and Canadian perspectives

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ABSTRACT

Background: This paper presents a study aimed at developing insights into community-level sports clubs' (CLSC) vulnerability and/or resilience to atmospheric climate impacts in regions of Australia and Canada, and organizational responses. CLSCs offering outdoor sport on playing fields with grass turf surfaces may be exposed to extremes of atmospheric climate which is potentially problematic for CLSC facilities and participants. A qualitative methodology was thus used with a research design using multiple cases selected via purposeful sampling. Data (interviews, documents) was collected from 23 CLSC organizations responsible for managing grass turf sport fields.

Results: The results demonstrate that CLSCs in temperate climate zones of both nations are vulnerable to climate impacts. Significant direct damage resulted from extreme climate events to playing fields, and indirect impacts such as higher injury risks, insurance risks, interrupted and/or cancelled competitions, and higher operating and capital costs. Three forms of organizational adaptation were evident: modified water management, replacement of grass turf with drought-tolerant or synthetic grasses, and revised operational policies.

Conclusions: The results challenge understandings of the sport-climate relationship by scholars and industry, yet suggest considerable scope exists in both the northern and southern hemispheres to adapt sport management practices to generate resilience for climate-exposed sport.

Keywords:
Adaptation, climate, impacts, sport, vulnerability

1. Introduction

This paper presents an empirical study on the impacts of atmospheric climate on community-level sports fields with turf (natural grass) playing surfaces in regions of Australia and Canada. Community-level sports clubs (CLSCs) are a core element of sport systems in a range of countries such as Australia (Cuskelly, 2004), Canada (Misener & Doherty, 2009), Germany (Breuer & Wicker, 2011), and the United Kingdom (Allen, Gill, Zeila, Pryszlak, & Postlethwaite, 2018). These clubs are important for the opportunities they offer for participation, social inclusion, social capital creation, and for pathways of elite athlete development (Doherty & Misener, 2008; Houlihan & Green, 2008; Hoye, Nicholson, & Houlihan, 2010). Many CLSCs offer outdoor sport on playing fields with grass turf surfaces that are exposed to atmospheric climate extremes (i.e. high/low temperatures, low/high rainfall) with potentially disruptive impacts. Examples of climate impacts include those *experienced* from hurricanes/cyclones (Filo, Cuskelly, & Wicker, 2015) and *projected* impacts from drought or higher temperatures (Dawson & Scott, 2013; Forster & Sambrook, 2018). However, extant research into the sport-climate relationship is very limited in terms of foci, sports, geography and levels of analysis.

The scarcity of sport-climate research is surprising for two reasons. First, in an era of long-term global climate change (Intergovernmental Panel on Climate Change, 2014a, 2014c), most disciplines are now contemplating the actual and potential implications of climate (Grieneisen & Zhang, 2011; Haigh & Griffiths, 2009). From economics to engineering to medicine and psychology, climate impacts are now a topic of discussion within and across discipline areas. Second, outdoor sport that relies upon a natural resource (e.g. grass turf or snow) as the competition surface, is also fundamentally dependent on a stable climate to provide and/or maintain that surface in good condition.

Examples of such “climate-dependent assets” (Packard & Reinhardt, 2000, p. 130) in sport include snow fields for skiing, snowboarding and biathlon, and grass turf fields for football codes, golf, baseball, tennis, cricket and horse racing.

Climate-dependent assets have been defined as those relying on particular temperatures and seasonal conditions (Pinkse & Gasbarro, 2016), or natural resources provided by the climate system (e.g. rainwater, snow). Studies of climate impacts on climate-dependent assets have proliferated in recent years for industrial sectors such as agriculture, forestry and tourism, (e.g. Allen et al., 2010; Amelung & Moreno, 2009, 2012; Anwar, Li Liu, Macadam, & Kelly, 2013; Hamilton, Maddison, & Tol, 2005). Yet research on climate-dependent assets in sport is limited.

Key limitations of existing research focused on climate-dependent sport assets are that they are concentrated on likely *future* impacts, and are largely confined to the northern hemisphere (e.g. Moen & Fredman, 2007; Rutty et al., 2015; Scott & Jones, 2007; Scott, Steiger, Rutty, & Johnson, 2015). Of these studies, the sports considered are limited to snow or ice-based sports, the Winter Olympics, and golf (Hewer & Gough, 2017). Studies of past or current impacts on climate-dependent sports are focused on the ski industry, and again, largely the northern hemisphere (e.g. Rutty, Scott, Steiger, & Johnson, 2014). As a consequence, little guidance is available to managers of CLSCs as to how best to anticipate and manage any climate impacts.

No studies could be found on grass turf-based community sport and climate that considered both extremes of temperature and rainfall, and which offered comparisons of the situation at northern hemisphere sites with those in the southern hemisphere. Accordingly, three research questions (RQ) guided our inquiry. (RQ-1): what, if any, climate *impacts* are there on community-level sport fields in regions of Australia and Canada? (RQ-2): How do any climate impacts, vulnerability or resilience of community sports fields in the Australian state of Victoria *compare* with those in the Canadian "Golden Horseshoe" region? (RQ-3): if there are any organisational responses to such impacts, *why* are they occurring, and *how* do they *compare* between Australia and Canada?

We begin by outlining key concepts from climate science that underpin our study, and follow this with links to literature around climate impacts, vulnerability and/or resilience to such impacts, and potential adaptation responses. We then integrate this literature with research on sport and climate. An overview of the research design and methods is then provided, followed by the results and discussion. We end by presenting our conclusions, and suggestions for future research.

2. Literature review

2.1 ***Atmospheric climate: a conceptual overview***

Underpinning our study was the application of four fundamental meteorological concepts: (1) *weather,* (2) *climate,* (3) *natural climate variability, and* (4) *climate change.* Distinguishing between these concepts is important for the task of accurate interpretation of any climate impacts on sport. *Weather* has been described as the location-specific atmospheric variations that exist on a daily, and sub-daily, timescale (American Meteorological Society, 2017; Bureau of Meteorology, 2017b; World Meteorological Organization, 2017b). It is distinguished by tangible yet varied elements including temperature, precipitation, and humidity. In contrast, *climate* is a statistical description (average) of long-term weather patterns for a geographic location, and so is a more abstract concept than weather (Bureau of Meteorology, 2017b; Intergovernmental Panel on Climate Change, 2007b; Met Office, 2018; NASA, 2016; World Meteorological Organization, 2017b). Using the Köppen system, climate is typically classified into climate zones that are variously tropical, temperate, arid, equatorial, snow and polar (Rubel & Kottek, 2010). *Natural climate variability* is the range of natural variations for a climate over year-to-year and longer timescales (Bureau of Meteorology, 2017b; Bureau of Meteorology & Commonwealth Scientific and Industrial Research Organisation, 2016; World Meteorological Organization, 2017a).

In contrast, *climate change* has been defined as "variability" in "average weather" caused by "natural" and "anthropogenic (human-induced) factors" (World Meteorological Organization, 2017a, 2017b). A multitude of impacts from climate change are noted, ranging from minor to severe, and which are potentially "irreversible" (Intergovernmental Panel on Climate Change, 2014a; 2014b, p. 41; 2014c). Such impacts include: sea-level rise, coastal flooding, and an increased frequency of extreme weather events (e.g. droughts, hurricanes/cyclones, and floods) (Bureau of Meteorology, 2017b; Cai et al., 2015; Intergovernmental Panel on Climate Change, 2014a, 2014c). Such impacts, are expected to be, "observed across all continents and oceans" (Intergovernmental Panel on Climate Change, 2014c, p. v), but to be "unevenly distributed" (Intergovernmental Panel on Climate Change, 2014c, p. 13). Consequently, the increased frequency of extreme weather events is likely to make resultant impacts challenging for climate-dependent industries, including potentially in sport. The four meteorological concepts are summarised in Table 1 below.

INSERT TABLE 1 HERE

*2.2 **Impacts, vulnerability, resilience, adaptation and climate-dependence***

Extending the conceptual basis to our study were four climate-specific concepts: (1) *impacts,* (2) *vulnerability*, (3) *resilience*, and (4) *adaptation.* Within the scientific literature there is agreement that these concepts are essential to understand the implications of climate, and climate change (Janssen & Ostrom, 2006). We argue that a further concept, (5) *climate-dependence* (Packard & Reinhardt, 2000; Pinkse & Gasbarro, 2016), is also central to any sport-climate research. Climate-dependence has been defined as a situation where there are assets that rely on particular temperatures and seasonal conditions (Pinkse & Gasbarro, 2016), or natural resources provided by the climate system (e.g. rainwater, snow). Finally, whilst the literature pertaining to vulnerability, resilience, and adaptation is mostly specific to climate change, we argue that they apply equally to climate, and natural climate vulnerability. These five concepts are summarised in Table 2 below.

INSERT TABLE 2 HERE

Climate impacts are defined by the Intergovernmental Panel on Climate Change (IPCC) as the effects on "natural and human systems" of "physical events, of disasters, and of climate change" (IPCC, 2012, p. 561). Business and management literature (e.g. Haigh & Griffiths, 2012; Linnenluecke, Griffiths, & Winn, 2013) has increasingly noted that climate impacts are one of a range of strategic challenges for organisations. Organisational disruption through climate impacts include damage to business infrastructure from "extreme weather events" (e.g. cyclones, droughts and bushfires);

“gradual impacts” (e.g. sea-level rise, higher ocean acidity); and “large-system changes” where gradual impacts exceed “critical thresholds” (Pinkse & Gasbarro, 2016; Winn, Kirchgeorg, Griffiths, Linnenluecke, & Gunther, 2011, p. 158). Climate impacts have also been identified as posing risks to organisational assets including “asset integrity” (e.g. decreased functionality or efficiency, decreased levels of safety and reliability), and “staff health and safety” (e.g. worsened working conditions, increased accidents and/or injuries, increased resource use to comply with legal standards) (Aguinaldo, Daddi, Hamza, & Gasbarro, 2018, p. 6).

As a consequence, organisations with climate-exposed assets may experience a degree of *vulnerability*—a susceptibility to harms (Adger, 2006; Winn et al., 2011)—to climate impacts. Vulnerability is distinguished by vulnerable “situation(s)”: environmental, economic or social “systems”; “hazards” (risks) to those systems; and a temporality (time) horizon (Füssel, 2007b, p. 165). Notably, the concept of climate vulnerability has received increased attention in recent sport management literature (e.g. Fairley, Ruhanen, & Lovegrove, 2015; Orr & Inoue, 2018).

In contrast, *resilience* (Füssel, 2007a; Gallopín, 2006) has been defined as the ability to, “absorb shocks and still maintain function” (Folke, 2006). At the organisational-level, resilience means an ability to cope with external harm, but also to recover from negative external impacts (Linnenluecke, 2017; Winn et al., 2011).

Adaptation, in contrast, is a process involving adjustments or actions by systems (e.g. a household, group, organization or nation) that enable better coping and recovery from “unusual or extreme climate events”, hazards or risks (Biagini, Bierbaum, Stults, Dobardzic, & McNeeley, 2014; Intergovernmental Panel on Climate Change, 2007a, p.

879; Smit & Wandel, 2006, p. 98). Adaptation is also a strategy for “reducing and managing the risks of climate change” (Intergovernmental Panel on Climate Change, 2014c, p. 17). Like the vulnerability concept, adaptation is also recieving more attention in sport and leisure management literature (e.g. Dawson, Scott, & Havitz, 2013; Dingle & Stewart, 2018; Fairley et al., 2015; McDonald, Stewart, & Dingle, 2014; Orr & Inoue, 2018).

Climate-dependence refers to the degree to which an industrial sector relies upon “climate resources” (Amelung & Moreno, 2009). These resources include temperatures, rainfall, snow and soil moisture (Willows, Reynard, Meadowcroft, & Connell, 2003). The term overlaps with others such as “climate-exposed” (Linnenluecke, Birt, & Griffiths, 2015) and “climate-sensitive” (Berkhout, Hertin, & Gann, 2006). In this paper, we argue that grass turf used in sport is a natural resource—and an organisational asset—that is dependent on a further natural resource: the atmospheric climate system. In the next section of this paper, we review literature relevant to where sport and climate intersect.

2.3 Research on sport and climate

Existing studies in the field of sport and climate are limited in terms of foci, sports, geography and levels of analysis. Beginning with how the sport-climate relationship is conceptualized, significant advances have been uncommon, with Orr and Inoue’s (2018) Climate Vulnerability of Sport Organisations (CVSO) framework a rare example of this. The CVSO framework progresses existing understanding of sport-climate research by highlighting the range of risks to sport facilities posed by climate, and by integrating key climate concepts—vulnerability, impacts, exposure, sensitivity, adaptive capacity—whose origins lie in the climate science literature that has evolved of the past two decades. By extending these concepts to sport, and casting them within a risk framework, sport management scholars now have a sport and climate-specific construct which can be used for the purposes of climate risk assessment and management.

Other sport management research may be characterized as adopting an “inside-out” perspective of organisations (Porter & Kramer, 2006). That is, focused on the impacts of the organization (the “inside”) on the natural environment in which they operate (the “outside”). Examples of *inside-out* work include studies on carbon emissions through sport (Chard & Mallen, 2012, 2013; Dolf & Teehan, 2015; Otto & Heath, 2010).

While such studies are important, they do not consider external impacts on an organization’s activities, something that Porter & Kramer (2006) described as an “outside-in” perspective. Such research considers the potential of the climate system (the “outside”) to disrupt sport competitions and the activities of organisations (the “inside) who manage sport facilities. In an era of global climate change, we argue that our study is an example of outside-in research with the potential to add breadth and depth to sport management literature, and offer guidance to industry practice.

Much of the outside-in research has focused on skiing and ski industries in the northern hemisphere (e.g. Hopkins & Maclean, 2014; Rutty et al., 2015; Rutty et al., 2017; Rutty et al., 2014; Scott & McBoyle, 2007; Wolfsegger, Gössling, & Scott, 2008). Other climate change-specific research has investigated the Olympic Games (Rutty et al., 2014; Scott et al., 2015), and heat impacts on sports tourists (Matzarakis & Fröhlich, 2015). Studies of golf in Canada remain rare examples of climate change research that includes grass turf sports, and yet these were focused on participation (Scott & Jones, 2006), or future impacts (Scott & Jones, 2007), rather than direct climate impacts on sport facilities.

While it has been acknowledged that, “climate and weather conditions can have a large influence on the playing conditions of natural turf” (Stiles, James, Dixon, & Guisasola, 2009), research including climate impacts on major participation sports with grass turf playing surfaces (e.g. football codes, baseball, tennis & cricket) is rarer still. Two Australian studies widened the scope of sport-climate investigation by including impacts of drought in the southern hemisphere (Kellett & Turner, 2011; Phillips & Turner, 2014), yet these focused on implications for stakeholders and Corporate Social Responsibility (CSR) and did not apply the vulnerability, resilience or adaptation concepts. Wicker et al.’s (2013) study made significant inroads into understanding of organisational resilience in response to the impacts of floods and cyclones, but did not consider heat or drought impacts, and paid limited attention to adaptation. These authors also noted the absence of qualitative research.

Despite arguments that organisations need to anticipate and initiate adaptations for climate variability and climate change (Arnell, 2010; Berkhout, 2012; Linnenluecke & Griffiths, 2010; Tompkins et al., 2010), and a proliferation of research on the topic outside of sport (e.g. Carr-Cornish, Linnenluecke, & Griffiths, 2013; Haigh & Griffiths, 2012; Kolk, Levy, & Pinkse, 2008), in an era of climate change a limited number of studies have considered sport facilities and sport organisations. Again, those that have been published focused only on the northern hemisphere, and qualitative research on current impacts is also noticeably absent. Comparative studies are yet to be developed.

There is, thus, a knowledge gap on sport and climate impacts with respect to CLSCs and grass turf fields. This study seeks to address that gap, in part, by focusing on any climate impacts in regions of Australia and Canada, their vulnerability and/or resilience to such impacts, and any adaptive management responses.

2.4 Natural resources and the sport-climate relationship

To aid conceptualisation of the sport-climate relationship, we used concepts articulated in the *Natural-Resource-Based View* (NRBV) (Hart, 1995; Hart & Dowell, 2011), a perspective that extends Resource-Based View (RBV)/Resource-Based Theory (RBT). Central to the NRBV's value to researchers is that it offers a better understanding of "the firm's relationship to the natural environment" (Hart & Dowell, 2011, p. 1008). It also takes into account that the natural environment is at times a "serious constraint on firms' attempts to create sustainable advantage" (Hart & Dowell, 2011, p. 1464). In other words, the NRBV allows natural resources to be understood as both enablers of an organisations activities, and potential threats.

Two key assumptions of the NRBV help with interpreting the sport-climate relationship. The first assumption is that there is an important relationship between organisations and natural resources. This is significant because, as management theorists have argued, systems of the natural world—such as the climate system—are typically externalized in organisational thinking and this makes it difficult for, "economic and management theories to recognize (and theorize) the co-dependency between firms and the natural environment" (Winn et al., 2011, p. 158). We argue that many CLSCs manage outdoor sport assets that are both part of nature, and dependent on other eco-systems/ natural resources. Specifically, we contend that the grass turf playing surfaces of sports fields themselves are living eco-systems (i.e. a natural resource), and that such turf also depends on atmospheric climate—a second eco-system/natural resource—for rainfall inputs that are needed to maintain good condition.

The second assumption is that “ecosystem degradation and resource depletion” can “create discontinuities that threaten firms’ existing resources and capabilities” (Hart & Dowell, 2011, p. 10). Specifically, there is potential for grass turf playing surfaces of sports fields to be degraded and depleted through extreme climatic events, such as droughts and floods. That is, the grass turf natural resource is vulnerable to the behaviour of the climate natural resource. As a result, a paradox appears to exist: nature is both a resource for sport organisations *and* potentially a threat to the assets on which their competitions are staged.

For this study, the assumptions pertaining to the NRBV presented above articulate our interpretation of the relationship between climate-dependent sport facilities at the community level, and natural resources. We began interpreting this relationship with an *a priori* conceptualisation which represented our initial understanding of the research problem, an approach advocated by qualitative researchers (e.g. Cepeda & Martin, 2005; Miles, Huberman, & Saldana, 2014). Our conceptualisationwas informed by the meteorological concepts considered previously in this paper, and the climate concepts we have also considered previously—impacts, vulnerability, resilience, adaptation and dependence. Consistent with Research Questions 1, 2 and 3, the objective of our a priori conceptualisation was to integrate the climate impacts/vulnerability/resilience/adaptation/ dependence concepts for the purpose of further clarifying the paths of our enquiry.

3. Research design and methods

For this study, a qualitative research methodology underpinned the use of a multiple-case research design (Yin, 2014). Qualitative research methodology is appropriate for sport management research because it enables phenomena to be described, and because it facilitates deeper understanding of the issues through direct interaction with research participants (Edwards & Skinner, 2010; Andrew, Pedersen & McEvoy, 2011). Case study method was deemed suitable because it is used widely in management research, and because case studies are well suited to "real-life events" (Yin, 2014), such as the climate impacts discussed in this paper.

Multiple-case designs are appropriate because they allow more powerful and valid conclusions to be drawn than single-case designs (Andrew, Pedersen, & McEvoy, 2011; Miles et al., 2014; Yin, 2009), and expand external generalisability (Creswell, 2013). Creswell's (2013) five stage process guided our data collection and analysis: (1) devising the research questions; (2) selecting the country, region and sport facilities; (3) selecting interview participants; (4) designing and conducting the in-depth interviews, and; (5) data analysis & conclusions.

3.1 Sampling: selecting the countries, regions and sport organisations

Selective sampling (Coyne, 1997; Sandelowski, Holditch-Davis, & Harris, 1992), a form of purposeful sampling (Miles et al., 2014; Sarantakos, 2013), was used to identify the sports fields through a, "preconceived, but reasonable initial set of criteria" (Sandelowski et al., 1992, p. 628). These criteria were: (1) CLSCs situated in either the northern hemisphere nation, or the southern hemisphere; (2) CLSC sectors that are exposed to climate impacts and accessible to the researchers; (3) a broadly equivalent climate zone (i.e. temperate zone c/w temperate zone). Both Australia and Canada were appropriate choices as they each have well-established outdoor, community-level natural grass sports sectors that are exposed to significant climate variations and long-term change. As each nation had a range of human contexts (i.e. capital cities, urban, rural & regional areas), they offered comparable study populations with the potential to illustrate any climate impacts on CLSCs in temperate climate zones of both the northern and southern hemispheres.

According to the Australian Bureau of Meteorology, *the State of Victoria* in Australia is located in a broadly temperate climate zone (Bureau of Meteorology, 2018a). Victorian climate divides into five climate sub-zones ranging from persistently dry with hot summers, to no dry season with warm summers. Victoria was an appropriate site to choose for studying climate impacts on community sports fields partly because the state's climate has changed beyond natural climate variability. Victoria has experienced a warming trend over the last century averaging 0.06 °C per decade (1911 to 2014), in line with global warming (Timbal et al., 2016). Further, seven of the 10 warmest years in Australia have occurred since 2005 (Bureau of Meteorology, 2017a). Impacts of this climatic change include more frequent and hotter days, lower average rainfall, more frequent severe droughts, harsher fire weather, and reduced alpine snowfall (Commonwealth Scientific and Industrial Research Organisation & Bureau of Meteorology, 2015; Hennessy, 2011; Reisinger et al., 2014). Victoria's "unprecedented" 13-year "Millennium Drought" of 1996-2010 was the worst in 110 years of meteorological records (Commonwealth Scientific and Industrial Research Organisation, 2010, p. 1; Timbal, 2009). All Victorian climate sub-zones have been impacted by climate change as the, “severity, duration and frequency of heatwaves have increased” (Auty, 2013, p. 36).

The *Golden Horseshoe Region of Ontario* in southern Canada is also in a temperate climate zone: summers are generally warm and humid, with cold and drier winters (Cowie, 2011, p. 10). Municipal sports fields in this region were selected as the climate has also changed beyond normal climate variability, with average surface temperatures rising 1.3 ºC. in the past 40 years (Penney, 2012). Impacts of this climatic change include, “economic damage from severe weather [that] has increased dramatically” (Romero-Lankao et al., 2014) from, more rain events and “more heat waves of 3 or more consecutive hot days”, and, “more summer droughts and dry spells” (Penney, 2012, p. 8). These climatic changes have occurred within a wider national context where impacts include sea-level rise, storm surges, diminished snowpack, increased evaporation, wildfire activity and insect outbreaks (Romero-Lankao et al., 2014).

3.2 Selection of organisations and interview participants

A total of 23 organisations participated in our study. These were mainly local governments who owned and/or managed grass turf sport facilities. In the case of Victoria, three State Sporting Associations (SSOs) plus a consultant with expertise in climate impacts on community sport also participated. A summary of participant organisations, interviewees, sports, and climate impacts is provided in Table 3 below.

INSERT TABLE 3 HERE

Interview participants were chosen using “typical instance” sampling (Tracy, 2013). Participants typically responsible for managing community-level outdoor natural grass sports fields were selected including senior facility managers, senior facility maintenance managers, and senior recreational programming managers. Using Martino's (1983) framework, participants were deemed experts based on their knowledge of the topic that is advanced beyond what most people know.

Participants were solicited using Okoli and Pawlowski's (2004) five-step process: (1) dividing the Australian and Canadian sites into four areas (north, south, east and west), and ensuring metropolitan, regional, rural communities were represented; (2) developing a worksheet of municipalities in each of the four areas in both countries; (3) populating the worksheet with the names of the potential participants using public information; (4) assessing candidates were for participation; and, (5) inviting potential participants via telephone and email to participate in the study.

3.3 Data collection

A total of 28 in-depth semi-structured, face-to-face interviews were completed: 17 in Victoria, Australia, and 11 in the Golden Horseshoe region of Canada. In this paper, the participants are referred to as *Australian Participant (AP)*, and *Canadian Participant (CP).*

Following approaches employed in earlier research that investigated climate impacts on climate-dependent assets (i.e. Kiem & Austin, 2013; Scott & McBoyle, 2007), an interview guide was developed with questions that were designed to elicit each organization's perspective on any climatic impacts on community grass turf sports fields. Drafted by one member of the research team, and then reviewed by the other, the interview guide was crafted with open-ended questions in order to allow interviewees to share their own story.

All interviews were held at the organisations employing each participant, and ranged between 45 and 90 minutes. Each interview was audiotaped, and transcribed verbatim. Participants remained anonymous throughout course of the study (Blincoe et al., 2009; Costa, 2005), and were assigned alphanumeric identifiers. The university research ethics boards/committees in both Australia and Canada approved the research process.

3.4 Data analysis

As a qualitative study, a five phase approach (Yin, 2011) was adopted to analyze the interview transcript and documents data: (1) compiling data into a database; (2) disassembling data into smaller fragments; (3) reassembling data into themes; (4) interpreting the data themes that emerged and creating a narrative, and; (5) developing conclusions. Content analysis, a method used widely in sport management research (Andrew et al., 2011), was employed to analyze relevant documents provided by the organisations (e.g. Annual reports). Interpreting the data involved three readings of the Australian and Canadian interview transcripts by one of the researchers, with each reading focused on one of the research questions. The second researcher then verified the data analysis. “Intercoder reliability” (MacPhail, Khoza, Abler, & Ranganathan, 2016, p. 199) was achieved by developing a “code frame” followed by iterative discussion until agreement was reached. With coding as a precursor to identifying themes in the data, the central themes and subthemes (Wolfe, Hoeber, & Babiak, 2002) then emerged.

4. Results and discussion

In this section, the results of our study are presented as they relate to the research questions. For each research question, themes are provided to organize the data, and address each question.

RQ 1: What, if any, climate impacts are there on community-level sport fields in regions of Australia and Canada?

RQ 2: How do any climate impacts, vulnerability or resilience of community sports fields in the Australian state of Victoria compare with those in the Canadian "Golden Horseshoe" region?

Participants in both Australia and Canada indicated that climate impacts were adversely affecting CLSC grass sports fields. While acknowledging they were not climate scientists (AP's $n = 2$; CP's $n = 1$), participants consistently reported that the climate was not the same as in previous decades. For some participants from both countries, "huge" climate impacts on their fields were evident (AP-2; AP-3; CP-6).

The major theme emerging from participant responses was *disruption from extreme weather*. An extreme weather event has been defined as one that is, "rare at a particular place and time of year" (Bureau of Meteorology, 2018b), and involve extremes of temperatures (high and low), and of rainfall (i.e. droughts and floods). Furthermore, three key sub-themes fleshed out the major theme: (1) *extreme heat events*; (2) *extreme rain events*, and; (3) an *increased demand for irrigated water.* An Australian-only sub-theme was bush fires, while Canadian only sub-themes were severe winds and new pests (i.e. weeds and mold on the sport fields' grass). A summary of these impact themes is presented in Table 4.

INSERT TABLE 4 HERE

The impacts of climate in both countries have been categorized according to the theme and sub-themes emerging from the data. Each sub-theme will now be considered.

4.1 Extreme heat events

4.1.1 Similarities between Australia and Canada concerning extreme heat

Participants from both countries reported they were now dealing with extreme heat events that impacted the condition of their sport fields, as well as player safety. Australian participants stated that they had to manage, for example: “a week of over 35 degrees (AP-2), with no rain in sight (AP-2; AP-4). Temperatures of up to “40 degrees [Celsius]” were also reported (AP’s *n* = 4). So serious are the overall impacts of these droughts on CLSC fields, one local government managing such fields had developed six “drought proofing strategies for turf playing surfaces” (Holland, Quayle, Corr, Robinson, & McCartney, 2011, pp. 81-96).

A major problem resulting from the extended extreme heat events was the compaction of the fields’ playing surfaces. Soil compaction has been defined as an increase in soil density (Alakukku, 2012), a phenomenon that can be caused by external loads (i.e. from people or animals) but is also associated with inadequate soil moisture. Australian participants reported that extreme heat and associated drought led to greater field compaction (AP’s *n* = 5). A consequence of compaction and hardening of the soils underneath the turf on these playing fields was a significantly reduced capacity to cushion players from the impact of falling on the grass. This in turn posed safety risks to participants.

Australian participants reported compacted fields caused by drought had a higher incidence of impact injuries (AP’s *n* = 10). In particular, impact injuries in football, and facial injuries in cricket, were reported (AP’s *n* = 4). In the words of one participant: “it is a safety risk … [including] a player risk, a user [group] risk, and then there is an asset risk” (AP-3). Consequently, compacted and hardened fields across Victoria were closed as a safety precaution during the Millennium Drought, but also because it was difficult to obtain public liability insurance for them. Extreme heat also caused games to be cancelled because of higher risk to player health.

Similarly, Canadian participants also confirmed severe heat as a major issue, with less summer rainfall (CP's n = 3), and summer maximum temperatures regularly exceeding 35 degrees Celsius. However, while Canadian participants also noted more field compaction due to the heat, and the associated safety risk, (CP's n = 4), closure of sport fields was not reported. A summary of impacts associated with extreme heat is presented in Table 5.

INSERT TABLE 5 HERE

4.1.2 Differences between Australia and Canada

While the province of Ontario and state of Victoria both experienced extreme heat events, extreme heat events in Victoria were greater in intensity and duration. The temperate Victorian climate is generally hotter and drier than the temperate climate of the Golden Horseshoe region of Ontario, and so the climate impacts were more severe. Summer maximum temperatures in Victoria regularly exceed 40 degrees Celsius, while the summer maximum temperatures in Ontario are not as great. Less compaction and cracking of grass surfaces was reported, and injury risks to participants was therefore not as severe.

4.2 Extreme rain events

4.2.1 Similarities between Australia and Canada concerning extreme rain events

Participants from both countries stated that they were now dealing with severe rain events that affected the conditions of their sport fields and their maintenance. Australian extreme rain included, “downpours” (AP-7), or “25 to 50 milliliters of rain in one day” (AP-2). These extreme rain events had caused floods (AP’s $n = 2$), “significant damage to infrastructure” (AP-8), and caused the grass to die (AP-5). Canadian participants also reported issues with extreme rainfall (CP’s $n = 3$), or “torrential downpours” (CP-1). Participants noted that they had to, “be in a position to manage [heavy rain] quickly because when the fields wash out they become unsafe” (CP-5). Additionally, there were field maintenance interruptions due to the extreme rain.

4.2.2 Differences between Australia and Canada concerning extreme rain events

While the province of Ontario and state of Victoria both experience extreme rain events, the key difference is the reported flood events in Victoria. Flood events, such as those in the Victorian summer of 2010-11, caused major damage to the surfaces of some cricket/football fields. Some were inundated for weeks and even months, and required major repairs afterwards totaling hundreds of 000’s of dollars (Frost, 2013).

INSERT TABLE 6 HERE

4.3 Increased demand for irrigated water

4.3.1 Similarities between Australia and Canada concerning irrigated water demand

Participants from both countries reported an increased demand for irrigated water for the sports fields, as rainfall was no longer providing enough. Reliance on water irrigation to maintain fields was reported by most participants (AP’s $n = 6$), and in the words of one Australian participant, their water consumption had “significantly changed” (AP-5). Water availability was a particular problem during periods of government-mandated water restrictions during the mid-to-late 2000’s due to the Millennium Drought (AP’s $n =$

8). Where water allocations were exceeded, some CLSC users had—during drought periods—paid for water to be "carted" in (i.e. delivered by truck) (AP's *n* = 4).

Australian water is typically metered (measured) and is expensive with one participant reporting that an annual water allocation for the fields of 11 mega-litres costing approximately AUD$2,500 (AP-5). When purchasing additional water, "it's traditionally $50.00 or $60.00 a mega-litre, but the cost had increased $220.00 to $240.00 a mega-litre" (AP-5). It was thought that market forces of supply and demand were causing this. Purchasing and trucking/carting water to a field was noted as not an "efficient use of [government] funding" (AP-1). During the Millennium Drought, "some communities raised over $250,000 to pay for carted water for their sport fields" (AP-1; AP-3).

Purchasing extra water was a choice for some clubs however, was essential for most to avoid the risk of compacted sports fields that increased the incidence of injury. In the words of one participant: "an insurance company has to guarantee that the player is playing on a standard and fit surface. So if you're not providing that fit surface …[it is a] risk" (AP-5). Communities that could afford the extra water had useable fields; those that could not afford water were more likely to have their fields closed during drought.

Canadian participants also reported that their water consumption had risen in the process of maintaining the sports fields (CP's *n* = 6). They also reported that "water budgets" had increased significantly in the last 3-5 years (CP-10) and the higher cost of watering the sport fields had budget implications (AP's *n* = 3). The actual cost to water the fields was an unknown with respect to the Canadian participants, as the water usage information did not channel through their department (CP-10). Instead, a key Canadian issue involved the cost of installing irrigation equipment on the premier fields to distribute water (CP-2). Irrigation costs were as high as CAD$200,000.00 for each system, and “there are additional costs as you add new fields onto the system” (CP-6).

4.3.2 Differences between Australia and Canada concerning irrigated water demand

The Australian participants had a more advanced understanding of their water use and the cost implications compared to their Canadian counterparts. Canadian participants also did not report any issues with being able to access to water.

INSERT TABLE 7 HERE

4.4 Impacts limited to one country: Australia or Canada

4.4.1 Impacts limited to Australia

Australian participants reported that an additional impact of drought was bush fires that led to some sports fields being burned, or damaged when used as refuges (AP-1; AP-3).

4.4.2 Impacts limited to Canada

None of the Canadian participants mentioned the issue of fires. This result suggests that the Australian participants have experienced more severe droughts than their Canadian counterparts. Also, the Canadian participants reported impacts of severe wind and new pests, including weeds and mold. Severe winds during extreme weather events were affecting “trees around the sports fields and ensuring safety was, thus, a huge impact” (CP-1). Invasive weed species (CP-2; CP-11) on the sports fields were linked to drought conditions. Molds (CP-3; CP-5) on the grass fields were also reported and linked to extreme rainfall. A summary of impacts limited to one country is presented in Table 8.

INSERT TABLE 8 HERE

Overall, the results for RQ 1 indicate that the climate impacts on these sport fields fell into a single major theme: disruption from climatic extremes. This theme divided into three sub-themes, including extreme heat events, extreme rain events and an increased demand for irrigated water. A summary of illustrative quotes pertaining to RQ1 is in Table 9.

INSERT TABLE 9 HERE

5. Discussion of results for Research Questions 1 and 2

The results demonstrate that the CLSC fields were adversely affected by climatic extremes in both Australia and Canada. Climatic extremes of heat compacted the soils underneath the grass turf fields in both Victoria and the Golden Horseshoe region of Canada. This compaction was more extreme in Victoria, but was still a problem in Canada. Compaction was central to a rise in injury problems in Australia, and so insurance problems were evident. In contrast, insurance problems were not evident in Canada. Overall, the maximum temperatures in Australia are higher and more frequent, and so arguably the Australian fields are more exposed to extremes of heat. For extremes of rainfall, flood damage for some Victorian fields and disruption lasting months was significantly higher than anything experienced in Canada where flooding was rare.

Overall, the results of our study suggest that CLSC grass turf fields in these temperate climate zones of the northern and southern hemispheres have significant vulnerability to climate impacts. This is consistent with earlier work which argued that impacts of temperatures and soil moisture play a part in the success of some industrial sectors (Willows et al., 2003).

With regard to the resilience of these sports fields to climate impacts, the degree of vulnerability appears to be a critical factor. The more exposed these fields were to extremes of heat and low or high rainfall, the more vulnerable—and less resilient—they were to the damage flowing from these impacts. In general terms, the climatic extremes experienced in Australia suggest higher vulnerability and lower resilence than those in Canada. However, while the resilience of the fields in Australia and Canada is a function of *exposure* to climate extremes, *adaptation* of management practices is also crucial. For example, the end of the Millennium Drought in Victoria brought rainfall closer to the long-term average and thus played a role in the recovery of CLSC fields, and so a degree of natural resilience is evident. And yet the recovery of the Australian fields was also, in part, a function of the management adaptations discussed in the next section of this paper.

No matter the degrees of vulnerability or resilience of these fields, a more fundamental question deserves an answer: should the impacts reported in this paper be attributed to natural climate variability, or to the broader phenomenon of climate change? To address this question, it is helpful to acknowledge that there is an overwhelming scientific consensus about the evidence for, and causes of, climate change (Cook et al., 2013; Intergovernmental Panel on Climate Change, 2014c; Mastrandrea & Schneider, 2010). It is also true that other studies have attributed adverse impacts on climate-dependent sport facilities specifically to climate change (e.g. Fairley et al., 2015; Hopkins & Maclean, 2014). However, we argue that for CLSC fields, some caution may be necessary.

This is because climate variability is a naturally occurring process (Bureau of Meteorology, 2017b; Bureau of Meteorology & Commonwealth Scientific and Industrial Research Organisation, 2016; Kiem et al., 2016). Specifically, droughts and floods are a routine feature of Victorian climate; extreme rain also happens in the Niagara region. Attributing the climatic impacts on the fields of these CLSCs specifically to climate change likely requires an Attribution Study (e.g. Angélil et al., 2014; Perkins-Kirkpatrick et al., 2016). However, attribution studies are complex scientific tasks performed by climate scientists, and so are outside the expertise of sport management researchers alone.

Nevertheless, it is also unlikely that these impacts can be attributed to extremes occurring within natural climate variability alone (Bureau of Meteorology, 2015). As the climate science literature reminds us, climate change is a long-term process. In Australia, the climate has warmed 0.87 ºC. since 1910 (Commonwealth Scientific and Industrial Research Organisation & Bureau of Meteorology, 2015), and is projected to warm a further 0.6-1.3 ºC. by 2030 (Commonwealth Scientific and Industrial Research Organisation & Bureau of Meteorology, 2015; Reisinger et al., 2014). Similarly, Canadian climate has warmed 1-3 ºC. between 1948-2012, with warming in Canada almost twice the global rate (Government of Canada, 2015). Therefore, the impacts on CLSC fields observed in this study have all occurred during an era of climate change, and are consistent with a warming global climate. In summary, these findings address RQ 2.

RQ 3: If there are any organisational responses to such impacts,* why *are they occurring, and how do they* compare *between Australia and Canada?

The results demonstrate that the organisations managing CLSC grass turf fields from both countries do what the research literature suggests is typical of systems faced with climatic extremes: they adjust their actions in order better cope with, and recover from, such impacts. In the next section of this paper, we discuss adaptation themes that emerged from the data.

5.1 Organisational adaptation to climate impacts

Participants from both countries reported organisational responses to the various climate impacts on their sports fields. The three response themes were: (1) *adaptation of grass* *varieties*, (2) *adaptation of water management*, and (3) *adaptation of organisational policy*. A summary of these responses to climate impacts is presented in Table 10 below.

INSERT TABLE 10 HERE

5.1.1 Adaptation of water management

Water management practices at the organisational-level were adapted by participants from both countries to cope better with climatic impacts. It was clear that Australian participants had adjusted their water management regimes partly in response to government-mandated restrictions during the over-a-decade-long “Millennium Drought”, and now had a greater understanding of the need to ensure adequate water supply for their fields. A reflection of this was the state-wide practice of installing on-site water storage tanks of 20,000-50,000 litre capacity. However, these tanks were only a supplement for irrigated water, not a substitute (AP-3). As the volume of water required to irrigate the fields was large, some Australian participants had also turned to storm water as, “there’s a lot of it available” (AP-2).

Additionally, Australian participants also reported a, “drought-proofing strategy” (AP-7); or a “drought relief program” (AP-4) involving money earmarked for a potential future drought (AP-4). Intriguingly, participants stated that all of the strategies were to be updated regularly, but sensed that this had lapsed somewhat as the focus moved to other immediate daily pressures (AP-6; AP-8). This is possibly because as the Millennium Drought abated, addressing climate impacts became less urgent.

Canadian participants did not report water capture and storage, but raised this as a future option, once it became more affordable. The barriers to adopting water capture and storage were the high cost (CP-12), and the need to make it potable (CP-6; CP-7) to avoid bacterial infections for users. Interestingly, as one Canadian participant indicated, a competing priority was the need to safeguard community water supply: “we are looking at it [the fields] having to be more natural” (CP-7). This meant that their field users played on brown grass during times of drought.

5.1.2 Adaptation of grass varieties

Complementing adaptation of water management was adaptation of the grass varieties used on the sports fields in both Australia and Canada. Participants in both countries adopted drought-tolerant grasses in order to address compaction, safety issues, and reduce water inputs. The Australians adopted “couch” grass (AP’s n = 6) which was thought to be drought-tolerant and required less water. Canadian participants moved away from native grasses that were now much more difficult to keep alive (CP-10), and switched to a combination of grass types (CP-4; CP-5). Drought-tolerant grasses were also thought to cope better with extreme rainfall (CP-6).

Supporting mandated water restrictions in Australia was another management adaptation: a substitution strategy involving the installation of synthetic turf fields. In Victoria, “five years ago there were none” (AP-1), yet now there is a movement towards installing synthetic turf for sports fields (AP-7) as part of the field mix, albeit in limited numbers, “to alleviate load from other [grass] turf facilities” (AP-1). In Canada, some participants reported either an increased need for synthetic turf, or thought more synthetic turf was inevitable in a warming climate (CP-7, CP-8, CP-9, CP-10). Similar to Australia, synthetic turf was thought by these participants to better cope with wear and tear to playing surfaces, particular where usage loads had increased or diversified.

Whilst the data from this study around adaptation of grass turf was clear, this was not reflected in the research literature. Although switching to drought-tolerant grasses had been contemplated by Kellett & Turner (2011), no studies in the northern or southern hemispheres had reported its implementation for CLSCs, or at the elite-level.

5.1.3 Adaptations of policy

Participants from both countries stated that policy adaptations were occurring. This was particularly true for water-related policies. For example, the issuing of "best practice guidelines for [field] irrigation" (AP-2) such as avoiding irrigation during the hottest times of the day (AP's $n = 2$; CP's $n = 2$). Also, advancing the number of aeration practices due to compaction to ensure the water seeps into the soil (AP's $n = 1$; CP's $n = 2$), and adaptations in soil to more sand for efficiencies in field drainage (CP-9; CP-10). Policies were also evident focused on implementing water saving measures (AP-7), using low-volume nozzles on hoses (CP-7). A summary of illustrative quotes for adaptation is presented in Table 11.

INSERT TABLE 11 HERE

5.2 Implications for sport management

A number of implications are evident for managers of CLSCs with grass turf sports fields in these temperate climate zones of Australia and Canada. First, vulnerability to extreme heat events and extended drought conditions demand adaptation of the management of CLSC sports fields. As organisations with climate-dependent assets, a new reality is clear: atmospheric climate is less reliable in providing the water resources that are a traditional and critical enabler of high quality community sports fields. This creates higher operating costs, which in turn has triggered adaptations of water resource management, grass turf, and organisational policy. Capital costs, of the water infrastructure needed to offset the lack of reliable rainfall, are a new management reality. Replacing the grass playing surfaces with drought-tolerant grass varieties added to capital costs, and for those organisations who had replaced natural grass fields with synthetic turf, further capital costs were incurred. Climate is thus a cost issue for these CLSCs, rather than revenue opportunity. This finding is consistent with Dingle & Stewart's (2018) cost finding for major sport stadia.

Second, the results of our study demonstrate that extreme levels of rain/water resources are risks to CLSC grass playing surfaces in these temperate climate zones of Australia and Canada. Whilst adequate supply of rainwater is crucial for the growth and maintenance of the CLSC fields, extreme rain events can be highly destructive. This finding reinforces the view of Wicker et al. (2013) and Filo et al. (2015) that extreme rain events can have devastating consequences for CLSCs. Such impacts illustrate the duality of the relationship that these sports fields have with nature: enough rainwater protects & enhances; too much rain is damaging. Planning to mitigate the impacts of extreme rainfall events is thus another new management reality.

CLSC field managers in these climate zones are thus confronted with a paradox: nature is both a resource for CLSCs, *and* a threat to the assets on which their competitions are staged. Climate risk management is therefore an important organization capability for them.

As Hart & Dowell (2011, p. 2) have argued, organisations need to be cognisant of, and able to manage, "the interaction between an organization and its natural environment". For the organisations managing grass turf CLSC fields in these temperate zones of Australia and Canada, strategies are needed to develop a degree of resilience to climate impacts. Fortunately, their adaptations to water and turf resources, and organisational policies, were effective in developing a degree of resilience to future impacts. The community users of these fields rely upon them to be sufficiently resilient in order to reap important social and health benefits.

Third, existing sport management theory needs to evolve to reflect the shifting realities and unpredictability of atmospheric climate, and the risks this natural resource poses for sport assets. As various researchers have argued (e.g. Meyer, Gaba, & Colwell, 2005; Santos & Eisenhardt, 2005; Winn et al., 2011, p. 158), organization science has a bias toward "the predominance of stable states and the linearity of change processes in organisations and their environments." Theory needs to capture the non-linear reality of how nature functions, and how organisations are compelled to adapt in response.

In summary, organisations with climate-dependent sports fields will likely benefit from including in their organisational thinking concepts of climate-dependence, climate impacts, vulnerability, resilience, and climate change. Adaptation capabilities, of the kind indicated earlier in this paper, are likely to be part of the suite of management functions. Just as airlines, banks and insurance companies have included climate change in their strategic thinking (Burns & Cowlishaw, 2014; Mills, 2009; Mishra, 2013), organisations with climate impacted sport facilities can do the same. For example, municipal governments responsible for CLSCs could include climate change in their strategic plans, with cascading levels of responsibility for climate risk management down to the level of sports field turf managers.

5.3 Revised conceptualisation of natural resources for climate-dependent, natural grass community sport

In light of our results and findings, it was clear that our *a priori conceptual* conceptualisation needed revision. In retrospect, we concluded that our initial assumptions were partially correct. The initial conceptualisation was able to identify grasses as climate-dependent natural resources for community sports fields. It also identified water as a crucial natural resource input. However, the initial conceptualisation failed to anticipate the extent and effectiveness of organisational adaptation in generating degrees of resilience to climate impacts in both countries, particularly to droughts. The inclusion of the "resilience" concept in the second iteration of our conceptualisation illustrates the potential of adaptive responses to enhance capacity of CLSC fields to withstand, and recover from, adverse climate impacts.

We argue, therefore, that our revised conceptualisation offers insights into the relationship between CLSC fields, natural resources, and vulnerability, resilience, and adaptation. Our findings suggest that sport management for CLSCs is a more complex process than previously thought, and points to the importance of including these concepts in organisational thinking.

5.4 Limitations of this study and avenues for future research.

A number of limitations of our study should be acknowledged. First, this study was confined to CLSC fields in temperate climate zones of Australia and Canada. Given that climate impacts can be location-specific, caution should be applied to generalising our results to all CLSC fields in these nations where climate zones range from tropical to temperate (Australia), and sub-arctic to temperate (Canada). National-level studies are therefore needed. Second, caution must be applied in generalising these results to other countries. Nation-specific studies are needed to fully understand impacts, and adaptations that are also specific to national contexts. Research in Europe, Asia, Central and South America, and Africa all remain important sites for investigation.

Third, this study was confined to qualitative methods. Mixed-methods and further quantitative studies would add depth and nuance to this field of research. For example, quantitative methods could be used to measure financial costs climate impacts on CLSCs, while mixed-methods could be used as part of future location-specific studies. Fourth, sport management researchers can also extend their knowledge of the relationship between CLSC fields, natural resources, and vulnerability, resilience, and adaptation through analysis of CLSC-level field management practices. In particular, the efficiency and efficacy of natural resource use may yield insights into how successful adaptation to, and resilience from, climatic extremes can be achieved. Fifth, this study was confined to fields of CLSCs. Any vulnerability to climate impacts for other natural grass sports contexts (professional, semi-professional) remain poorly understood, and so require further investigation.

6. Conclusions

This study sought to understand impacts of atmospheric climate on natural grass sports fields of CLSCs in the southern hemisphere state of Victoria, Australia, and the northern hemisphere Golden Horseshoe region of Ontario, Canada. This study considered the full range of climate impacts, and addresses limitations in existing research focused on either extreme heat and low rainfall, or extreme rainfall.

First, the results confirm the climate-dependence of community-level natural grass sports fields in these regions of both the northern and southern hemispheres. This renders them vulnerable to extreme climate impacts, and particularly so in an era of climate change when such impacts are likely to become more extreme and/or frequent.

Second, the results demonstrate that climate extremes are disrupting CLSCs in temperate zones of both the northern and southern hemispheres, and that this is a contemporary—and not just a future—management issue. The results demonstrate significant vulnerability of community sport to climate impacts, particularly in Australia. This is also evident for sports that have previously been thought to be unaffected. This challenges previous assumptions about the extent of climate impacts on sport management at the community-level sport, the level of sports systems that involve by far the biggest number of participants and facilities. Sport management at this level is therefore more complex than previously understood.

Third, despite the sport fields' general vulnerability to climatic extremes in both Australia and Canada, a degree of resilience to such impacts appears to be possible principally through adaptations by the organisations that manage these fields. These adaptations focused on how water resources and the grass turf resources are managed. To date, it is unknown if the adaptations provide short-term relief or evidence of long-term resilience to climate impacts. Finally, while our study demonstrates the value of an "outside-in" perspective to underpin sport-climate research, much work remains to be done on sports facilities whose playing surfaces depend on complex interactions with natural resources. It is hoped that this study leads to further sport-climate research.

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