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Managing Extreme Heat and Smoke: A Focus Group Study of Vulnerable People in Darwin, Australia

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Abstract: Extreme heat and poor air quality arising from landscape fires are an increasing global concern driven by anthropogenic climate change. Previous studies have shown these environmental conditions are associated with negative health outcomes for vulnerable people. Managing and adapting to these conditions in a warming climate can present substantial difficulties, especially in climates already challenging for human habitation. This study was set in the tropical city of Darwin, Australia. We recruited individuals from population groups vulnerable to outdoor hazards: outdoor workers, teachers and carers, and sportspeople, to participate in focus group discussions. We aimed to gain an understanding of the impacts of extreme heat and poor air quality and how individuals perceived and managed these environmental conditions. We identified a number of key themes relating to impacts on health, work and activity, and adaptive behaviors, while identifying gaps in policy and infrastructure that could improve the lives and protect the health of vulnerable people living, working, and playing in this region. In addition, these outcomes potentially provide direction for other regions with similar environmental challenges. Extreme heat and poor air quality place an additional burden on the lives of people in high-risk settings, such as outdoor workers, teachers and carers, and sportspeople.

Keywords: extreme heat; heatwave; air quality; bushfire smoke; heat stress; outdoor workers; teachers; sportspeople

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1. Introduction

Anthropogenic climate change is recognized as having a substantive and negative impact on human health [1,2]. A changing climate has multiple direct and indirect impacts on health that expand and amplify existing health risks [3]. One of the most significant of these includes the increased risk of mortality and morbidity as a result of the increased intensity and severity of natural events and environmental hazards, including heatwaves, bushfires, floods, droughts, increased air pollution, and increased pollen loads [4,5].

Heatwaves (also known as extreme heat events) pose a particular threat, having killed more people in Australia than all other natural disasters combined [6]. Heatwaves discriminate to identified vulnerable populations such as the very old, the very young, outdoor workers, and those with existing medical conditions [7]. Research conducted globally and nationally demonstrate that heatwaves increase rates of mortality and morbidity [8] and have a major impact on health service delivery and capacity [9–11]. Overall, there are increasing negative health outcomes as temperatures increase [12]. Extreme heat causes stress on the body via a number of physiological pathways. These include a redirection of blood flow causing organ hypoxia and ischemia, systemic inflammation, cell damage, and

cell death. This may lead to critical damage in various organs, including the heart, brain, liver, and kidneys [13].

Smoke pollution and poor air quality from landscape fires are globally significant public health problems [14]. Poor air quality provokes many immunological and stress responses, which are critical pathways for the development and exacerbation of many common diseases including ischemic heart disease, stroke, respiratory infections, and asthma [15], leading to increased community mortality and morbidity [16–18]. Research on the health impacts of the 2019–2020 Australian 'Black Summer' fire smoke emissions estimated over 400 premature deaths and over 2000 additional hospital admissions [19].

1.1. Study Setting

Located in the far north of Australia's tropical region, Darwin has the highest average temperature and relative humidity of all Australian capital cities (see Figure 1). Environmental conditions are considered extreme enough during the build-up and wet season (October–March) to cause workforce shortages in critical sectors [20]. The most recent climate projections suggest Darwin may experience up to 317 days per year of 35 °C or above by 2090 if a high-emissions scenario is followed [21]. Darwin also experiences severe smoke pollution every dry season, recording regular exceedances of the Australian air quality standard for 24 h average concentrations of particulate matter less than 2.5 µm in diameter ($PM_{2.5}$) [22]. A recently published study highlights the contribution of savanna burns in the greater Northern Territory (NT) on reductions in local air quality in Darwin [23]. Air pollution in Darwin is almost entirely caused by smoke from fires in the surrounding savannas—vehicular and industrial sources of air pollution are relatively low compared with other major cities, with 95% of Darwin's particulate pollution attributable to landscape fires [24]. Almost all early dry season fires are attributable to prescribed burning practices [25].

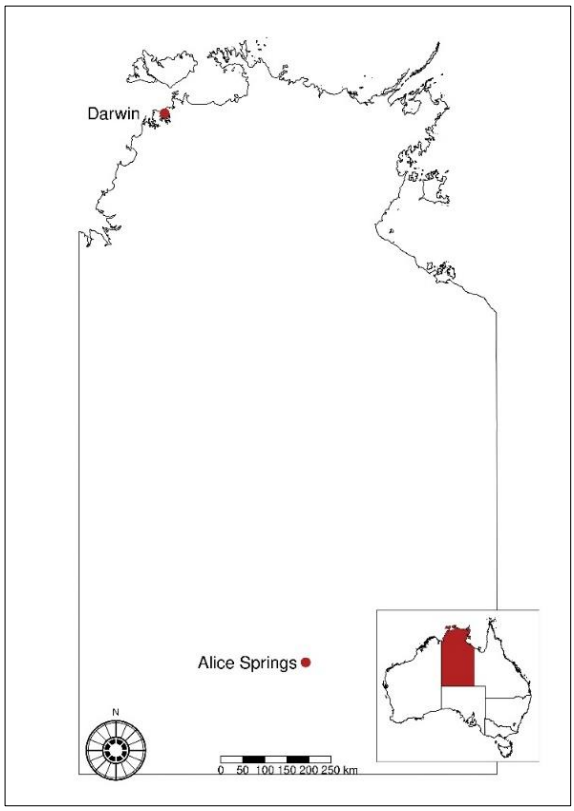

Figure 1. The location of Darwin within the Northern Territory, inset showing the location of the Northern Territory within Australia.

Given these considerations, Darwin offers an ideal location to consider the problem of climate-related environmental hazard health impacts on vulnerable populations. Local knowledge of the impact of these conditions is vital for both clinical surge capacity planning and public health promotion campaigns both preceding and during these events. Understanding how these events impact vulnerable populations increases the overall adaptive capacity of the community.

A number of current policy drivers support applied research on extreme heat risk in the NT. These include the *Northern Territory Climate Change Response: Towards 2050* document [26] and the *Darwin Heat Mitigation and Adaptation Strategy* [27]. The heat mitigation strategy highlights the risk of extreme heat on vulnerable groups, including the elderly, the very young, those who lack mobility or who are unable to adequately care for themselves, those with limited resources to prepare or adapt, and those who are homeless. The strategy also highlights outdoor workers, schools, and sports clubs as specific settings or groups worthy of adopting actions to adapt their behaviors to manage extreme heat.

1.2. Research Aim and Questions

The aim of this project was to improve the understanding of extreme heat and poor air quality impacts on vulnerable groups in the Darwin region. Therefore, our research questions were:

- What are the specific impacts of extreme heat and poor air quality on vulnerable groups in the Darwin region?
- How do vulnerable groups in the Darwin region perceive and manage episodes of extreme heat and poor air quality?

Our research also aimed to target and address a number of identified recommendations in the heat mitigation strategy, including "18. Explore and trial methods to better prevent heat stress for people working or playing sport outdoors", "21. Identify, learn from and promote actions that improve heat-related livability in Darwin", and "25. Identify, develop and test innovative heat mitigation and adaptation approaches for Darwin" [27].

1.3. Ethics Statement

The study was conducted within an ethics proposal approved by the University of Tasmania Human Research Ethics Committee (27058) with reciprocal approval from the CSIRO Human Research Ethics Committee (053/22).

2. Methods

2.1. Study Design

A focus group methodology was employed to gain a greater understanding of the impacts of heat and smoke on three specific vulnerable groups: (i) outdoor workers (OW), (ii) teachers and carers (TC), and (iii) sportspeople who play and train in the build-up and wet season (October to March) (SP). These groups were selected to provide a greater understanding of the impacts on the identified vulnerable settings highlighted in the Darwin Heat Mitigation and Adaptation Strategy.

2.2. Study Recruitment

Participants for each focus group were recruited using purposive sampling to obtain representation from the respective identified vulnerable groups: outdoor workers, teachers and carers, and sportspeople. This was achieved through social media, word-of-mouth, and existing personal and professional networks. Recruitment was facilitated by a local organization specializing in this field. Written consent was provided by each participant. Participants were gifted a AUD 50 shopping voucher to compensate for their time.

2.3. Data Collection and Analysis

A short, anonymous paper survey was conducted at the beginning of each focus group to gather participant characteristics (see Appendix A). Focus group discussions were recorded with the permission of participants (see Appendix B for focus group guiding questions). Data from the three focus group interviews were de-identified, transcribed, and analyzed with the Thomas data analysis framework [28]. Using an inductive approach, data were sorted into themes and sub-themes common across all groups that elucidated the core meaning of the data. A conceptual model based on the relevant themes and sub-themes was developed. NVivo 12 software [29] was used to assist with inductive thematic analysis.

3. Results

3.1. Characteristics of Participants

Twenty-three participants in total took part in the three focus groups. Of those, 30% were male and 70% were female. As presented in Table 1, participants in each focus group tended to cluster by gender. There was a wide variation in the number of hours spent outdoors per week (3–40 h) and the amount of time participants had lived in the Darwin region (7 months–64 years). Almost half the participants fell into the 25–34-year age group, with the remaining participants spread evenly across the age spectrum (18–65 years).

Table 1. Characteristics of participants.

Group	Count	Gender (M/F)	Hours Spent Outdoors per Week		Years Lived in the Darwin Region	
			Mean	Range	Mean	Range
Outdoor workers (OW)	7	5/2	18.8	3–40	28.6	12–64
Teachers and carers (TC)	11	1/10	21.3	3–30	18.5	3–50
Sportspeople (SP)	5	1/4	13.4	7–25	12.4	0.6–29
Total	23	7/16	17.8	3–40	13.2	0.6–64

3.2. Focus Group Content Analysis

Common themes across all focus groups were identified. These themes were:

1. Increasing temperatures;
2. Seasonal smoke;
3. Impacts on work from heat and smoke;
4. Impacts on health from heat and smoke;
5. Impacts on activity from heat and smoke;
6. Adaptive behaviors;
7. Lack of policy and infrastructure;
8. Doing the same things as usual.

There was a common perception among participants that it was getting hotter and that increased local temperatures impacted their work, health, and activity. Seasonal smoke also impacted their work, health, and activity. Adaptative behaviors were used by participants because of hotter temperatures and decreased air quality from seasonal smoke. A lack of policies around increased temperatures and seasonal smoke and of appropriate infrastructure were perceived as barriers that resulted in work practices and sporting activities not adapting to environmental changes (i.e., doing the same things as usual), which ultimately had health and activity implications. Figure 2 shows the relationships between these themes.

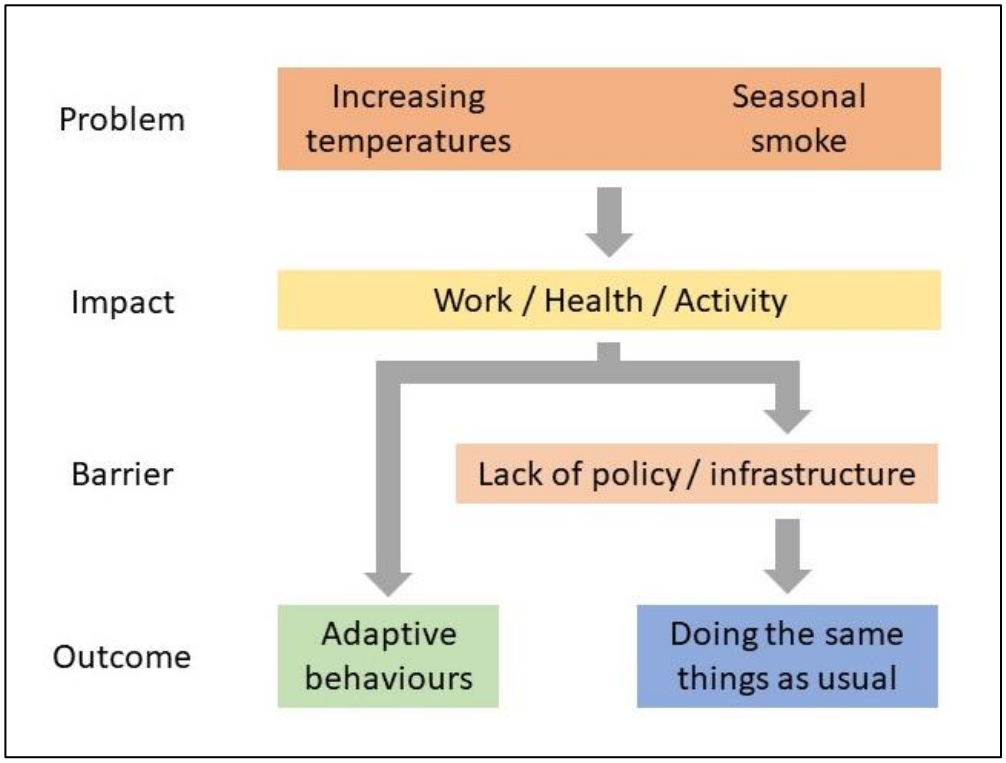

Figure 2. Interactions and relationships between key themes.

3.2.1. Increasing Temperatures

Across all focus groups, participants noticed that temperatures in Darwin were increasing over time.

> *Even having been here 20 years, we've seen exactly the same thing. The temperatures are blatantly going up*—OW
>
> *The heat policy the [sport] have brought in up here, it's only been around for four years. And so they brought it out for a reason. And they didn't have one before that. Because it's just getting hotter*—SP
>
> *I grew up here and I was 17 when Cyclone Tracey hit. I started my work life on the street gangs cleaning up the streets and Darwin was 32 [°C]. Now it's 34 and 35 [°C]*—OW

3.2.2. Seasonal Smoke

Smoke in the air was recognized as a seasonal issue, only occurring during the dry season (April–September). This also coincided with the perceived 'better weather'.

> *It's interesting to hear the wet seasons are the hottest, but we don't have smoke in a wet season. As soon as the weather comes good, the smoke starts*—OW
>
> *if you were here four or five days ago, as soon as that dry bit kicked in and the south-easterly started, that was it . . . grey skies*—OW

3.2.3. Impacts on Work from Heat and Smoke

Participants reported that heat had a substantial impact on work productivity.

> *You get more done in the first three hours of work than the rest of the day*—OW
>
> *Like, obviously safety is a massive thing when it comes to heat and smoke, regardless of people's medical conditions. It impacts everyone. I've had people who have lived in Darwin their whole life, first day on the job, they go down with heat stress. Yeah, it's a productivity thing as well . . . but it's also if you're constantly being affected by heat*

*stress, it also impacts on the relationships with the people that you work with because when you feel like s**t you treat people like s**t*—OW

Definitely as it gets hotter, yeah. I find myself making more mistakes—OW

Activities in the workplace meant special considerations were necessary to prevent heat-related injuries. For example, teachers and carers reported how heat impacted infrastructure in the workplace.

Playgrounds with climbing frames that aren't under shade sails. Climbing frames get well over 40 degrees. Then grabbing on it burns on the hands—TC

And sandpit burns—TC

Smoke impacted work as it forced day-care centers to keep children inside.

If we have a colleague having the issue with asthma, so we have to bring the kids in as well. Because otherwise you can't look after the kids. Somehow those kids in their age, they would have to play more outdoors. So, that's what happened, which made the kids to be anxious too, so "Why do we need to go inside? Why can't we play outside?"—TC

Teachers also commented on their increased workloads, as having children inside all day meant extra cleaning was needed.

So, if you've got to clean rooms or you've got kids coming out, so you've got to close down one yard and transfer children to another yard. It's like you're inside, the room is a mess and you've got to clean it all over again—TC

3.2.4. Impacts on Health from Heat and Smoke

Heat and smoke had noticeable impacts on health. These impacts were both physical and psychological. Participants complained of heat and smoke induced health problems including, but not limited to, sore throats, respiratory complaints, visual problems, anxiety, dehydration, nausea, cramps, and inability to concentrate.

Tired, dizzy and not really wanting to do anything. Wanting to drink more. Just, yeah, it's time for bed—OW

Tired. Lethargic. Can't be bothered. Irritable—TC

Sometimes your vision can be blurry if you're real dehydrated and all that—OW

I guess some light-headedness if I get really dehydrated. Yeah, just get a bit woozy, can get a bit nauseous—SP

It's anxiety causing, very much so. So, stepping out into a smoky environment, it triggers something within me anyway, where oh my goodness if I'm not getting the air in and that just exacerbates other feelings and sensations—OW

For those that don't like the smell, they can become agitated. Because you can't get away from it—TC

Headaches were linked to dehydration and smoke exposure.

Yeah, your head aches and you can't really satisfy your thirst for rehydration. I think that the more you try to rehydrate I think it almost feels like you can't do it, so you tend to not. So, there's kind of like a self-fulfilling prophecy for—and I see it all the time where people go way beyond it. Kids in sport … and I'm involved mainly in coaching … where they're way too thirsty to drink. That's a real problem—SP

Me, I find I get headaches, especially if there's a lot of tobacco or fire smoke around—OW

One outdoor worker explained how heat would affect cognition as well as fine motor skills.

It clouds your thinking as well, so when you get really hot, you're finding it hard to think straight, especially if you're dealing with anything that needs fine motor skills or coordination—OW

Smoke impacted respiratory health, especially for asthmatics. Smoke exacerbated asthma and caused asthma attacks.

> *A lot of people have asthma and they struggle to breathe normally*—TC

> *I'm asthmatic. . . . So, I'll be on the field and I'll start having symptoms before anyone else can smell the smoke. So, it impacts me significantly. And I had a real scare a few years ago where it was night-time burning off, so I could feel it happening. And I tried to get off, and my coach didn't sub me off. And then I got called back to [position]. So, I tried to breathe out and I couldn't breathe. And I was running...and I literally ran [off the field] . . . into a full-blown asthma attack. And it was a really bad season for the fires up here, and we've got a few asthmatics in our [sports] club. And I think three of us went down with asthma attacks on that round, on that day, and it was interesting the club's shift in it. So now the moment there is smoke or anything, straight away they ask us three, "Do you want to go on?"*—SP

One outdoor worker reported that smoke can cause air filters in diving equipment to become blocked and compressed air to become contaminated. The combination of blocked air filters and contaminated air is potentially life threatening for commercial divers.

> *I used to be a commercial diver and whenever there was bushfires around on the harbor, especially if we were working later in the evenings . . . if you had the compressor on board, first you had to keep a real eye on what the weather was doing. As the air cools, the smoke drops. It only takes about five minutes before the filters are chockers, even just from a normal smoky day. Then getting contaminated air, it can be catastrophic*—OW

3.2.5. Impacts on Activity from Heat and Smoke

Separate from impacts on work productivity and health, participants identified the impacts on day-to-day activity from heat and smoke.

> *I do know that often if it is too smoky outside, we bring the children back inside, so they're not exposed to that smoke. Which reduces their outside time for play and running around*—TC

> *Like really just box yourself in. You can't really escape because it just fills the whole sky*—TC

> *So what I noticed is when I'm down south, I'm a completely different person and I have so much more energy, my fatigue levels are different, I don't drink as much water, I don't feel the need for water. I'm actually really much happier down south. And I've just got a lot more energy. Where I get up here and I'm actually quite sluggish*—SP

> *The ones that tend to have asthma or reduced lung capacity, they can be really heavily affected by it whilst the person they're playing against might be non-asthmatic and they can handle it perfectly fine. So it's just finding that balance of when we stop play or when you let them keep going at their own discretion, or at the parent's discretion*—SP

It was perceived by participants that heat caused physical activity to be more difficult and was therefore less likely to be achieved.

> *I just find the air feels a lot thicker and heavier, so I find it harder to breath and work around that as well. And be motivated then to go out and go for a run, because it just seems that added layer in addition to running . . . having to breathe*—SP

3.2.6. Adaptative Behaviors

Participants highlighted that they adapted their behavior because of the heat and smoke. Behavioral adaptation strategies included, but were not limited to, cooling down behaviors, drinking more, wearing suitable clothing, and modifying work and/or activity times.

Seeking shade was mentioned as a common cooling down behavior.

And also, if they're having a break, quickly try and have a shade break. In terms of my players, I'm so aware, if it's really hot, I'll modify sessions to help or have shorter, sharp bursts and then go in the shade—SP

When we stop and talk about something, it's predominantly in the shade, so we try and find a shady spot. We don't stand out in the sun and talk about things, it's just shade—OW

We have outdoor fans. They put up shade cloth as well as we've got the trees—TC

Seeking air-conditioned buildings was noted as another adaptive behavior.

When [we have customers] we will use other people's air conditioning, so we will go into the foyer of a hotel or we will go down an arcade . . . it's deliberate, we've gone through different laneways, different big arcades for arguments sake, so there's a blast of the air-con as you're actually walking in there. This is the kind of thing we were looking for all the time, just to try and help out—OW

Ice applications were also used to decrease body temperature in the heat.

Before I go on the field . . . I fill my bra up with ice. And then I fill it up every time I sub off. I go to the ice machine and I put ice down my bra—SP

Yeah we have water coolers and an ice machine at our work—OW

From our club's point of view, like it's quite proactive . . . each team gets its own kind of heat management kit. So it's the big ice buckets and towels and that all gets distributed out to each of the teams at the start of every seasons, along with a list of what you do—SP

I guess for our higher-level events, where they can be a bit more intense and a bit longer matches, we have inflatable baths that we set up as ice baths. For the players to, like under physio supervision, they'll use the ice baths throughout the tournaments—SP

Increasing fluids and adding electrolytes was another adaptation behavior used to mitigate the effects of heat.

Drink lots of water while you're working. I've had some days where I've drunk nine liters of water—OW

If it's like really hot, I'll call up the boss and tell him to give me a purchase order for some electrolytes. But yeah, I'm willing to pay for it myself—OW

And then a couple of sips of water and a sip of Gatorade, always just keep the hydrolytes going. And then myself, if I'm really bad, I will have hydrolytes after—SP

Wearing suitable clothing was perceived as useful to adapt to working on hot days.

Yeah, so if I know it's going to be a really hot day, even though it sounds counterproductive, long sleeve shirts, long sleeve pants because of the sun—OW

Another adaptation behavior was avoiding working during the hottest part of the day by adjusting work hours.

We've started at two in the morning before, six, seven, just depends. Normally is eight—OW

We usually try and mitigate it by our [events] are all scheduled early morning, when I say early morning, 8, 10:30 and later in the afternoon. So, we try and avoid the really stinking hot part of the day—OW

To adapt to the smoky outdoor environment, closing windows and doors was seen as helpful. Once doors and windows were shut, turning on air-conditioning helped to mitigate the heat.

When you're working outside, there's not much you can do about it. But if back at home, shutting all the doors and windows and turning the aircon on, you're going to have a bit of a decent sleep and escape it—OW

Childcare centers also mentioned air filters and monitors.

Our aircons are filtered. So, they're recycling air through the center, but they're filtered. We get filters checked as well to make sure that they're giving us as clean aircon as possible—TC

We've got some air quality monitors in the school just recently. Because of COVID and I know that they've started to use those in some of the classrooms. Because of the inability to actually open classroom windows quite often—TC

3.2.7. Lack of Policies and Infrastructure

Although there was some evidence of existing policies to manage heat and smoke, there was an identified lack of policies specific to local conditions and space for improvements in policy overall, especially in sport. Lack of policies was identified as a barrier to adaptation.

I think they just put it in the too hard basket to do a policy specifically for more tropical climates. Compared to the policy for the southern climates. Because even across the NT, that would be different as well, even the Alice [Alice Springs] or the desert climate. And we're tropical up in Darwin. So, we'd need separate policies within the NT—SP

I know guys that play in Brisbane and North Queensland. It comes into effect a little bit there. They changed it, because the national policy would mean that we never played here. So the scientists who came up with it originally, what was a good number to play to not damage whatever is getting damaged, they had to adjust it because we wouldn't play [sport] above the 26th parallel. So they had to change it. There's a rule—they kind of adjusted it to make sure that we could play in northern Australia. Not just here, Cairns, the Kimberley—SP

We've got nothing. When I say 'nothing', I'm actually not a [sport] NT or [sport] Australia [administrator], but the fact is that we play [sport] while we've got ash falling on us and heavy smoke, with three people being treated . . . —SP

On game days, where the peak body has a heat policy, which changes the times of the games and the rest breaks and it allows you to be able to go into the shade or leave the field of play. So that's really good, but it gets invoked at 36 degrees and 80% humidity . . . So it's filthy way before that. And most of the kids I think 90% of our games this year are 2pm, so it was horrid—SP

. . . the heat policies and stuff, don't actually know how effective they are. They're trying. Like you've got to do something. But I do worry that the long-term effects are probably yet to be known—SP

Inconsistency with policy was evidenced by this participant's comment about rules at different childcare businesses.

It depends what center—I've been at multiple centers and at some centers it's, "No, it's time for you to go outside." So, we're all going outside. Until whoever is in power comes outside and goes, "I don't want to be out here." And other centers where people don't want to go outside even if the day is quite nice. So, it does have that opposite effect in some centers as well—TC

Natural environments were identified to be more effective in cooling the environment, with a discussion around the ineffectiveness of using man-made products to cool the environment. Policy and funding support were considered as potential solutions to include more natural environments and infrastructure to help create cool places, while greater access to shade was essential for sportspeople.

Especially outside, it has to be that natural environment. It has to be the trees, it has to be grass, it has to . . . like you were saying with the outdoor area with the water and the creeks and stuff like that. I think centers definitely need a lot more funding to go towards that outdoor environment, to keep it safe for the children. And to make it safe for the staff as well, to make it enjoyable to be outside and a lot cooler. Not sails, not Astroturf—TC

> *We should put it back to the government. So, something in the regulations through ACECQA [Australian Children's Education and Care Quality Authority] would be nice around the natural environment*—TC

> *But when they can go off for breaks, I just don't think there's—well, we don't have—we definitely don't have sufficient [shade]. I'm trying to cram them into shade whilst also being COVID safe. I'm like, "You there, you there." And it's a nightmare. I don't know whether [to prioritize] heat or COVID. So definitely more shade structures around the facility*—SP

3.2.8. Doing the Same Things as Usual

Without defined policies on heat and smoke, there was an expectation to do things the same way as had always been done, despite environmental changes in temperature and seasonal smoke. Local cultural influences were also mentioned.

> *So there definitely is that sort of well, it's hot but you're in the Territory, so get on with it*—SP

> *I think for the [sport], it's slowly changing but we touched on it before, I think the general attitude here is that it's been like this forever. We've done this forever. So, we kind of know that it's hot, but it's hot for everyone, so... we just get on with it*—SP

> *Because the standard response is, "Oh, we've been doing it here for 70 years," so it doesn't actually . . . I don't think that stacks up*—SP

> *Darwin does have—it is changing slowly, but it does have that 'we're territory tough' attitude. "Oh yeah, doesn't matter that it's 37 degrees, get out there and work."*—OW

4. Discussion

Our research found that increasing temperatures and exposure to seasonal smoke impacted the work, health, and activities of groups that live, work, and play in Darwin's outdoor settings. While these groups have developed various adaptive strategies to reduce exposure and mitigate harm, gaps in policy and infrastructure provision across all sectors limited how these strategies can be maintained and maximized. Our research also emphasized how climate change has both common and diverse impacts across a variety of different settings.

The existing literature describing the impact of environmental conditions on the vulnerable community groups we studied was relatively limited, especially for sportspeople and teachers and carers. For example, while the health impact of extreme heat on sportspeople was relatively well researched in terms of epidemiological outcomes [30,31] and some progress on implementing strategies to manage extreme heat in elite sport appears to be progressing [32], there was a paucity of published literature on sportspeople's perceptions of heat and poor air quality and how this impacts their enjoyment or participation in sport at the community level. Similarly, while the negative health impacts of extreme heat on children were well-known from a number of epidemiological studies [33,34], an understanding of the impacts of these conditions on institutions and carers was not well established, especially for warmer climates. For example, research on the impacts of heat for preschools in the cold climate of Sweden found that these institutions were exposed to extreme temperatures during heatwaves and these conditions impacted the children and educators' wellbeing [35]. However, these findings may lack relevance in the Darwin setting given the substantial differences in climate.

In contrast, there were a greater number of studies on this issue for the outdoor worker sector, with an identification of the health and productivity burdens of extreme heat and poor air quality [36–38] and a recognition that there are substantial gaps in knowledge [39]. Results of a qualitative study of outdoor workers by Singh et al. [40] demonstrated a clear correlation with our research, reporting experiences of heat stress, while working outdoors, reductions in productivity, attempted adaptive behaviors, and clear policy gaps in relation to health protection for outdoor workers. A second qualitative study by Xiang et al. [41]

demonstrated that outdoor workers are interested in increased policies and guidelines regarding working in extreme heat and are willing to change their practice to accommodate this hazard. Furthermore, studies undertaken in the Darwin region demonstrated further similarities with our findings, most notably that outdoor workers were more likely to experience chronic and severe heat stress compared to workers who did not spend the majority of their time outdoors and that outdoor workers reported that heat had a negative impact on work speed, quality, focus, quality, satisfaction, and attention to detail [42].

The existing literature on the impact of extreme heat for those from cultural and linguistic minorities shows an alternate narrative to that presented by the identified vulnerable groups in our research, with concerns over message translation, barriers to understanding social norms around heat (such as using sunscreen or drinking water), concerns over housing and power costs during events, and the discrepancies between traditional dress and clothing more suitable to hot weather [43]. Furthermore, research by Varickanickal et al. [44] demonstrated that people from a non-English speaking background experienced a number of unique barriers to understanding and responding to the risks associated with extreme heat. Similarly, research on the perceptions of heat management by the elderly highlight issues with fear and anxiety about heat, difficulties with using technology to manage hot environments, and socioeconomic factors [45]. Taken together, this research highlights that specific identified vulnerable groups may have varying concerns and each needs to be taken into consideration with regard to the development of policies and guidelines.

4.1. Study Strengths and Limitations

There were several strengths and limitations of this study. Firstly, our study focused on one location within a tropical urban setting. This created both strengths and limitations with regard to the generalizability of the findings. While these results are highly relevant for the location in question and may be relevant for locations of a similar size, density, and climate (for example, Cairns or Townsville in Queensland), these findings were not necessarily generalizable to other locations in a non-tropical environment. However, correlation with Singh et al. [40], which conducted interviews largely across the temperate eastern states of Australia, suggest there are strong synergies of issues between tropical and non-tropical climates, at least for outdoor workers.

Secondly, our study was limited by recruiting participants from a largely English-speaking background with little diversity in culture and language. Therefore, the results of this study may be less relevant for those from a culturally diverse background or for sectors within the settings in this study that recruit from a largely non-English speaking population. Furthermore, our study did not seek any specific recruitment from older age groups known to be vulnerable to heat.

4.2. Policy and Practice Implications and Priorities

Our findings highlighted a number of implications for policy and practice. These included specific gaps in knowledge and infrastructure that, if addressed, could potentially improve adaptive strategies for those exposed to adverse environmental conditions in their chosen outdoor settings.

For example, while the issue of extreme heat and workplace safety in tropical regions is relatively well explored [42], flow-on effects such as worker productivity, worker error, and the impact of heat on workplace relationships are less well understood and potentially contribute substantially to workplace health and safety concerns in addition to the direct impact of heat illness or worker mortality and morbidity. Furthermore, our study strongly aligned with findings from Gamage et al. [46] that found sports policies referencing heat illness in Victoria, Australia did not match international best practice and had substantial gaps in addressing heat definitions, recognition of signs and symptoms, cooling strategies, and acclimatization. While this is a potential area for improvement at the elite level, these strategies also need to filter through to the relevant policies at the community level of sports participation.

Findings from our study have demonstrated how extreme heat and poor air quality can reduce workplace productivity, contribute to decreased participation in sport, and to a reduction in outdoor play time for children, creating a negative impact on human capacity and productivity. These outcomes directly conflict with national policies that focus on the benefits of increasing productivity, community sports participation, and access to outdoor settings for children's play [47–49].

To protect the region from further health impacts of increasing heat and poor air quality conditions, local policymakers could use these results to seek a greater understanding of the day-to-day realities of individuals living, working, and playing in the Darwin region, and engage with these communities in developing useful and applicable adaptive solutions, beyond the current advice and warning systems. Furthermore, increased support and education for leaders in the three sectors under study may assist to improve policies and practices, make informed decisions, and manage risks appropriately. Given the impacts are happening in the present, addressing these barriers in a timely manner appears to be a high priority. There remain substantial risks from a business-as-usual approach, with negative impacts across key areas of productivity and health.

Finally, Darwin serves as a marker for the most extreme climate scenario in Australia. Policies and guidance in response to extreme heat and poor air quality in Darwin can therefore act as a national benchmark for managing these risks as they arise in other regions. In this context, collaboration between national and Darwin-based leaders may provide an effective vehicle to develop improved national heat and air quality policies for community settings.

4.3. Future Research

Our findings highlighted an immediate need for the development of solutions to manage the health burdens associated with living and working in extreme environmental conditions. Future research could potentially concentrate on a community-led co-design of responses and outcomes or a wider exploration of how these issues are managed in other similar locations worldwide. Further research into the impact of climate change on sports participation at the community level is also warranted.

Research on suitable and relevant adaptive solutions is also needed. The role of technological solutions, for example, does not appear to be well understood across the literature. Technological solutions may provide the opportunity to provide real-time information to inform a personalized approach in managing health in the face of extreme environmental hazards [50,51].

5. Conclusions

Climate change is causing an increase in the frequency and intensity of extreme heat and bushfires, leading to poor air quality. Extreme heat and poor air quality place an additional burden on the lives of people in high-risk settings, such as outdoor workers, teachers and carers, and sportspeople. Work, health, and day-to-day activities are affected, with a range of adaptive behaviors needed to accommodate for the extreme conditions. A lack of policy and infrastructure specific to managing extreme heat and poor air quality was evidenced across a range of settings in the Darwin region. This gap made it difficult to adopt behaviors that were better suited for managing these extreme environmental conditions. Future research incorporating co-design by impacted communities is paramount.

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Appendix A

The following short survey was completed for each participant prior to the focus group.

1. Please provide your gender.
    - Female
    - Male
    - Non-binary
    - Prefer not to say
2. Please provide your age group.
    - 0–18
    - 19–24
    - 25–34
    - 35–44
    - 45–54
    - 55–64
    - Over 65
3. Please provide your occupation (optional).
4. In your capacity as an outdoor worker/sportsperson/teacher or carer, please provide the number of hours you would spend outdoors on a weekly basis through the build-up and wet season in Darwin (October–March).
5. How long have you lived in the Darwin region?

Appendix B

The following questions were used to guide focus group discussions.

1. What is your personal understanding of how extreme heat can impact your health/the health of those you care for?
2. What about for poor air quality . . . what is your understanding of how this can impact your health? Follow up question if not understood: For example, when there is a lot of smoke in the air?
3. How much of a problem is this for you/those you care for when you are working/playing/training?
4. When it's very hot, what sort of things can you do to manage the heat as you work/play sport outdoors?
5. What sort of things does your employer/sports club provide for you to manage in hot weather?

6. What about when its smoky? What sorts of things do you do to manage? And does your employer/sports club provide anything to help you?
7. What sort of things would you like to do that you haven't been able to? Is there anything that might help to make this easier for you? What do others do?
8. Do you think the culture of your workplace/sports club makes it easier or harder for you to manage extreme heat? For example, is it 'normal' to just 'get on with it'? Or are their strict rules around when you can work/play/train based on temperature or air quality?
9. Is there anything else you'd like to say about this topic?

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