ORIGINAL RESEARCH

Environmental Deaths in the Northern Territory of Australia, 2003–2018

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Introduction—The Northern Territory is sparsely populated with a distinctive climate, geography, and wildlife compared with other states and territories in Australia. Environmental deaths (including drowning, heat-related deaths or environmental exposure, fatal animal attacks or envenomation, and lightning deaths) are reportable to the Northern Territory coroner for further investigation.

Methods—Databases of the Northern Territory coroner's office and the Royal Darwin Hospital Forensic Pathology Unit were searched to identify all environmental deaths over a 15-y period (July 1, 2003–June 30, 2018).

Results—A total of 4535 cases were reported to the Northern Territory coroner's office during the studied period, of which 167 (4%) were environmental deaths. Drowning was the most common type of environmental death, followed by heat-related deaths and fatal crocodile attacks. Deaths resulting from lightning and animals other than crocodiles are rare. Local resident, male victims in rural locations were the most commonly affected. Alcohol intoxication played a role in about one-third of cases, and in approximately one-third of cases a known underlying medical condition was identified.

Conclusions—The Northern Territory has a challenging environment that is hot, humid, remote, and isolated. Circumstantial information and thorough police investigations are essential in the medicolegal investigation of environmental deaths.

Keywords: forensic pathology, autopsy, drowning, heat-related death, crocodile attack, animal attack

Introduction

Australia is a large country that consists of a federation of 6 states and 10 federal territories. The Northern Territory (NT) is a federal territory in the central and northern central regions of Australia and is bordered by Western Australia, South Australia, and Queensland. Many of the geographic, demographic, climatic, and wildlife features of the NT differ from those of the other states and territories in Australia.¹

The northern regions of Australia have a more tropical climate, whereas the southern regions are more temperate, with milder summers and cool, sometimes rainy winters. Average minimum temperatures in all seasons

are the highest in northern Australia and near the coastal areas and are lowest in the elevated areas of the southeast.

More than 80% of the NT lies within the tropics, and there are 2 distinct climate patterns in the NT. At the northern end (the so-called Top End), a tropical savannah climate exists with 2 seasons—wet and dry. The wet season is from November to April, with the wettest month being January, and the dry season lasts from May to October. Very little rain falls in the dry season. The mean temperatures in Darwin are 29°C (84°F) in January and 25°C (77°F) in July; in Alice Springs, mean temperatures are 28°C (82°F) in January and 12°C (54°F) in July. The average monthly maximum temperature in Darwin remains above 30.5°C (87°F) throughout the year, with the main difference between the 2 seasons being the relative humidity and rainfall patterns.²

Before the proper onset of the wet season, a period known as the “build-up” is experienced, wherein there is increasing humidity without any relief of rain fall. Humidity levels can reach in excess of 80% in the wet

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season, and uncomfortable humidity is experienced for 8 mo a year. In the central area of the NT (the desert center of the country, which includes Uluru and Alice Springs), a desert climate exists, with semiarid conditions and little rain. The NT is prone to cyclones, tropical storms, and monsoonal rains during the wet season.²

The NT covers an area of 1.4 million km² (8.7 million mi²) with more than 6000 km (3728 mi) of coastline, which is mainly flat and fringed with mangroves, swamps, and mudflats.¹

Despite covering about one sixth of Australia's mainland, the NT is sparsely populated, with a population of $\pm 250,000$, which is less than 1% of Australia's population.³ It is a popular tourist destination; according to NT tourism data, 293,000 visitors visited the NT during 2017, of whom 133,000 were international visitors. Key source markets for international tourists were predominantly northern-hemisphere countries (United States, United Kingdom, Germany, Japan, and Greater China), with visitors arriving from cooler and less humid climatic conditions.⁴

Compared with other Australian states, the NT has a relatively underdeveloped transport system, which is a reflection of its small population base and the vast distances to be traversed. The main highway ("Stuart Highway") runs south from Darwin to the South Australian border and is paved; however, the majority of rural roads are unpaved and subject to temporary closure after heavy rainfall.¹

Regarding fauna in the NT, estuarine ("saltwater") and freshwater crocodiles are a feature of the Top End, with a population of $\pm 100,000$ estuarine crocodiles. Culling of crocodiles has been illegal and strictly regulated since the 1970s.⁵ Snakes commonly encountered in the NT include water pythons, carpet pythons, olive pythons, western brown snakes, banded tree snakes, northern brown snakes, black whip snakes, and king brown snakes. Box jellyfish have been found along Australia's northern coastline from Fraser Island in Queensland across the NT to Broome in north Western Australia, and the stinger season runs from October to May. Around 40 people per year with jellyfish stings receive attention at Top End health clinics and hospitals in the NT.⁶

No recent detailed published or accessible statistics and data on environmental deaths in the NT are available. An environmental death was defined in this study as a death due to an interaction (direct or indirect) between a human and the natural environment. The main categories of environmental deaths are deaths from drowning, environmental heat exposure, animal attacks, envenomation, fire, and lightning. In the NT, there is an obligation to report environmental deaths to the coroner because such a fatality could be a death that "appears to

have been unexpected, unnatural or violent, or to have resulted directly, or indirectly, from an accident or injury..." (Northern Territory of Australia Coroner's Act, 2017).

Methods

An observational, retrospective, descriptive study was performed of all cases reported to the NT coroner identified as environmental deaths over a 15-y period, from July 1, 2003 to June 30, 2018.

Databases of the NT coroner's office and the Royal Darwin Hospital Forensic Pathology Unit were searched to identify all possible environmental deaths. The following search terms were used to identify the relevant cases: heat stroke, heat-related death or illness, dehydration, exposure, environmental exposure, undetermined, drowning, animal, snake, insect, crocodile, jellyfish, kangaroo, buffalo, shark, allergy, anaphylaxis, envenomation, lightning, fire, burn, cyclone, and tropical storm. Swimming pool drownings, building or vehicle fires, homicides, and suicides were excluded from this study. Tropical diseases were also excluded because they are not reportable to the coroner and traditionally are seen as natural deaths in forensic pathology, even though it may be interpreted as being a result of an interaction between a human and the natural environment.

Copies of the coroner's findings, postmortem reports, contemporaneous notes, hospital records, and collateral information filed in the archives at the NT coroner's office and the Royal Darwin Hospital Forensic Pathology Unit were retrieved and studied.

Data analysis was performed by the author. All data were treated confidentially. Ethics approval was obtained from the Human Research Ethics Committee of the Northern Territory Department of Health and Menzies School of Health Research (Ref. no. HREC 18-3164), and permission for this research was granted by the NT coroner's office.

Results

A total of 4535 cases were reported to the NT coroner's office over the 15-y study period (July 1, 2003–June 30, 2018). Of these, 167 cases (4%) conformed to the definition of an environmental death. In the NT, the manner of death is determined by the coroner. The majority of cases reported to the NT coroner were deemed to be natural (48%), followed by accidental (28%), suicidal (19%), undetermined (3%), homicidal (1%), and under investigation (1%).

Environmental deaths were generally categorized as accidental deaths. However, in some cases, the manner of death was considered to be natural (eg, where a

Figure 1. Types of environmental deaths.

significant underlying medical condition was identified and believed to be the initiating cause of death, with the environmental conditions seen as a contributing factor or contextual information). An example of this is an experienced adult swimmer with severe ischemic heart disease who swam in a waterfall pool and whose body was discovered after being immersed in the water for some time. The initiating or underlying cause of death was considered to be ischemic heart disease; however, this occurred in an aquatic environment, and the possible role of terminal drowning could not be excluded.

Drowning ($n=103$, 62%) was the most common type of environmental death encountered in the study, followed by heat-related deaths ($n=36$, 22%) and fatal crocodile attacks ($n=17$, 10%), with other animal-related deaths (including snakebites, buffalo attack, jellyfish sting, road traffic accidents involving animals, complications of an insect bite, and anaphylaxis after mud crab ingestion) being rare. One death from lightning was identified (Figure 1). Four deaths were identified that were related to tropical storms or cyclones.

The demographic information of the identified cases is displayed in Table 1. Males ($n=142$, 85%) were affected more frequently than females ($n=25$, 15%), and most victims ($n=69$, 41%) were in the age group of 31 to 55 y. The majority of incidents ($n=134$, 80%) occurred in rural locations.

Case files varied in their degree of detail and completeness, and a background medical history was documented

in 112 cases (67%). Where the medical history was available, 53 decedents were known to have a significant underlying medical condition. Background medical information was not available in 59 cases (35%).

Alcohol and/or drug intoxication was proven to have played a role in death in 46 cases (28%), and in an additional 25 cases (15%) the role of intoxication was unascertainable because of limitations posed by either the state of the body or the extent of the autopsy.

The characteristic features of the most common types of environmental deaths (drowning, heat-related, and fatal crocodile attacks) are set out in Table 2. Local residents were most commonly involved in all types of fatalities, followed by interstate visitors in drowning deaths and fatal crocodile attacks and international visitors in heat-related deaths.

Four of the 6 international travelers who drowned were from Asian countries, and 6 out of 10 international travelers who died as a result of a heat-related illness were from Germany. Drowning was associated with the crossing of flooded rivers by foot or car in 12 cases (12%), and 3 (3%) of the drowning cases were in relation to cyclones or tropical storms. Drownings occurred at an inland location in 63 cases (61%) and at sea in 40 cases (39%). Documented underlying medical conditions were present in almost one third of the drowning cases ($n=35$; 34%).

With regard to overall investigative procedures, 37 cases (22%) showed moderate to advanced decomposition; in 12

Figure 2. Overall monthly occurrence of drowning cases.

cases (7%), the bodies were never recovered, and in 4 cases (2%) no autopsies were ordered.

DROWNING

When reviewing all drowning deaths over the 15-y period, 2 peaks were seen in the overall monthly occurrence of drownings (Figure 2). The first peak was in January, which is in the middle of the wet season and the wettest month with the highest rainfall when monsoonal rains, storms, and flooding typically occur. A second

peak was noted in July, which is in the middle of the dry season and during the winter school holidays. This could possibly be explained by an influx of tourists and increased outdoor activity of both local residents and visitors during the more pleasant dry weather conditions.

Inland locations for drownings included lakes, billabongs, rivers, streams, or waterfall pools. A billabong is an Australian term describing a branch of river forming a backwater or stagnant pool, made by water flowing from the main stream during a flood.⁷ Where alcohol was considered to be a contributing factor, the blood alcohol concentrations ranged from 0.02 to 0.47%. Drug use was considered to be a contributing factor either alone or in combination with alcohol in 6 cases (6%), with the identified drugs being cannabis, methamphetamine, amphetamine, and 3,4-methylenedioxymethamphetamine (“ecstasy”). Known underlying medical conditions were present in almost one third of cases, and these included neurologic diseases (cerebral palsy, epilepsy, tuberous sclerosis, and seizures), hearing impairment, ischemic heart disease, hypertension, and chronic obstructive airway disease. Three drownings were associated with extreme weather conditions (cyclone or tropical storm), and 12 cases (12%) occurred when persons crossed flooded rivers by foot or car in remote areas. This is in keeping with previous reports that there is an increased risk of fatal river drowning in remote areas, in addition to poor water clarity, currents, debris, and flooding.⁸

The crude fatal drowning incidence over this study period was 2.7 per 100,000 population. No similar data were available to compare this incidence to the overall fatal drowning incidence across Australia. A recent article looked at the burden of fatal and nonfatal drowning across Australia from 2002 to 2015, and the reported average crude drowning incidence (fatal and nonfatal) over the 13-y study period was 2.99 per 100,000 population.⁸

HEAT-RELATED DEATHS

When searching the various databases for heat-related deaths, it was clear that there was no consistency in the terminology used by the various involved pathologists. Terms used in this cohort that related to heat-related deaths included “heat stroke,” “heat exertion,” “exertion,” “exposure,” “environmental exposure,” “hyperthermia,” “dehydration,” “undetermined,” and “heat-related death.” There is clearly a need for standardization.

Heat-related effects on health and mortality have been studied in Australia before; however, most studies focused

Table 1. Demographic information of study population (n=167)

Case characteristics	No. (%) of cases		
	Male	Female	Combined
Sex	142 (85)	25 (15)	167 (100)
Age (y)			
<18	11 (6)	7 (4)	17 (10)
18–30	37 (22)	0	37 (22)
31–55	61 (36)	8 (5)	69 (41)
>55	36 (22)	8 (5)	44 (27)
Location of incident			
Rural	114 (68)	20 (12)	134 (80)
City	29 (18)	4 (2)	33 (20)
Underlying medical condition			
Documented	45 (27)	8 (5)	53 (32)
No significant condition known	45 (27)	10 (6)	55 (33)
Unknown (information unavailable)	52 (31)	7 (4)	59 (35)
Contributing role of alcohol±drugs			
Proven	40 (24)	6 (4)	46 (28)
Uncertain	22 (13)	3 (2)	25 (15)
No	80 (47)	16 (10)	96 (57)

Table 2. Characteristics of the most common type of environmental deaths in the NT

Characteristics	Type of death								
	Drowning (n=103)			Heat-related (n=36)			Crocodile attacks (n=17)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Sex, n (%)	92 (89)	12 (11)	103	28 (78)	8 (22)	36	14 (82)	3 (18)	17
Age (y)									
Range	3–85	11–63	3–85	1–78	32–73	1–78	11–62	9–12	9–62
mean±SD	40±19	40±18	40±18	55±15	50±22	52±20	33±19	10±2	29±19
Residential/Visitor status, n (%)									
Local resident	77 (74)	11 (11)	88 (85)	18 (50)	3 (8)	21 (85)	12 (71)	3 (17)	15 (88)
Interstate traveler	8 (8)	1 (1)	9 (9)	4 (11)	1 (3)	5 (14)	0	0	0
International traveler	6 (6)	0	6 (6)	6 (17)	4 (11)	10 (28)	2 (12)	0	2 (12)
Alcohol and drug use, n (%)									
Alcohol use alone	23 (22)	4 (4)	27 (26)	1 (3)	1 (3)	2 (6)	3 (18)	0	3 (18)
Combined alcohol and drug use	4 (4)	0	4 (4)	1 (3)	0	1 (3)	0	0	0
Drug use alone	2 (2)	0	2 (2)	1 (3)	0	1 (3)	0	0	0
Documented underlying medical condition, n (%)	31 (30)	4 (4)	35 (34)	12 (33)	4 (11)	16 (44)	2 (12)	0	2 (12)

NT, Northern Territory.

on other Australian states and regions, with little detail available on heat-related deaths in Darwin and the NT.^{9–11}

Heatwaves (“3 days or more of high maximum and minimum temperatures that is unusual for that location”) are Australia’s most deadly natural disasters and occur when a high-pressure system moves across the continent and pushes the hot, dry air from the outback down toward the cooler coastal regions. The worst heatwave death tolls have historically occurred in the southeast of the country.¹² However, heat-related deaths seen in the NT were not typical heatwave deaths as seen in the other parts of Australia or in the Northern Hemisphere. The heat-related deaths encountered in the NT were individual heat-related deaths of active persons who were involved in some degree of physical exertion while being exposed to the hot and humid environmental conditions. The average age of persons who succumbed to the effects of heat in the NT (52 y) was lower than that reported in other parts of Australia (Adelaide: 70 y) and in the Northern Hemisphere (France: 75 y and older).^{9,13} In this study, almost all the deaths (n=35, 97%), apart from 1 infant death, occurred at an outdoor location, which is in strong contrast with cases reported in Adelaide, South Australia, where 42 out of 54 (78%) heat-related deaths happened indoors.⁹ These heat-related deaths of younger individuals at outdoor locations in the NT are similar to those reported in southern Arizona, where climatic conditions are more comparable to those of the NT.¹⁴

The profile in the NT was that of an individual over the age of 50 y with a known underlying medical

condition in almost half of the cases. Underlying medical conditions included coronary artery disease, diabetes mellitus, hypertension, dementia (3 cases), and mental illness (2 cases). This confirms previous clinical, epidemiologic, and physiologic evidence that suggests that chronic disease increases the risk of heat stress.¹¹

Ten cases involved international tourists, all of whom arrived from northern-hemisphere countries for a holiday in the NT (Germany, Switzerland, United Kingdom, Japan, and United States). A typical scenario when reviewing the coroner’s findings would be an individual arriving in the NT for a holiday and embarking on a hike or tour within a couple of days after arriving, likely underestimating the harsh weather conditions and without allowing some time for acclimatization. In 2 separate cases, deaths were associated with vehicle breakdown; individuals were stuck in remote locations without adequate fluid supply and with no communication.

Heat-related deaths occurred most commonly in January, as expected (similar to the peak observed in the drowning cases), in the middle of the very hot and humid wet season, with another peak during October and November as part of the “build-up” period previously explained, wherein there is increasing humidity and associated physical discomfort with no relief of rainfall (Figure 3).

In the majority of cases, large search operations were undertaken to locate the bodies in remote locations, and most of the bodies were discovered after being missing for days, which allowed for advanced decomposition to develop in the warm and humid conditions. The core

Figure 3. Overall monthly occurrence of heat-related deaths.

body temperature was not measured in any of the cases. Core body temperature is sometimes measured at the scene of death in the early postmortem interval to assist in determining an estimated time since death. This is done by taking a rectal or subhepatic (probe inserted through a small subhepatic incision) temperature. The core body temperature, immediate ambient temperature, and consideration of factors that may influence the cooling rate of the body (eg, body dimensions, posture, clothing and coverings, air movement, and humidity) are used to calculate an estimated postmortem interval, using a nomogram. The best known published nomogram is that developed by Henssge and Madea; however, there are limitations to the use of the nomogram, particularly in determining the strength of the variable factors, and the nomogram does not allow for variation of the variable factors over time.¹⁵ Furthermore, these nomograms refer to research in Europe, where climatic conditions are vastly different from the NT, and are therefore not considered to be reliable for use in the NT. In addition, most of the bodies were not found in the early postmortem period.

Where environmental temperatures were recorded, the temperatures ranged from 36.5 to 43.5°C (98–110°F). The relative humidity index was only available in 1 case and was recorded as being 70%.

In the context of climate change, the future of Australia is a hotter one; that, with the predicted growth in the size and age of the population, will contribute to an increase in the number of people vulnerable to heat.^{11,16} In Darwin, the average temperature has increased by about 0.5 to 0.7°C (0.9 to 1.26°F) since 1960, and the average annual number of days with a maximum temperature of above 35°C (95°F) has increased from 7.9 during the 1940 through 1970 period to 13.1 during the 1981 through 2010 period. Under the best case scenarios, it will be 28 days by 2030 and 49 days by 2070.¹⁷ Adequate prevention measures are indicated to warn and

protect vulnerable groups (especially poorly acclimatized individuals over the age of 50 y with underlying medical conditions).

FATAL CROCODILE ATTACKS

As mentioned in the introduction, estuarine crocodiles (*Crocodylus porosus*), commonly known as “salties,” are a feature of the Top End in the NT. After previous unregulated harvesting led to a severely depleted population, strict measures were imposed that led to an almost fully recovered population in the core habitats of tidal rivers and associated flood plains. The potential for human–crocodile conflict is increasing; the crocodiles are increasing in age and becoming larger and more aggressive, and the human population in the NT is also increasing.¹⁸

Findings of a previous review of human–crocodile conflict in the NT were confirmed in this study; namely, that fatal attacks occurred year round and were unpredictable. The most common size of crocodiles responsible for attacks was 300 to 350 cm (9.8–11.5 ft) (adult males); local residents and male individuals were involved most often, and swimming and wading posed a high risk for attack.¹⁸

During this study period, 17 cases of fatal crocodile attacks were identified. Autopsy examinations in these cases were frequently impeded by decompositional changes with or without mutilation of the body. In 5 cases (29%), the bodies were never recovered, and the coroner’s findings were based on witness accounts and circumstantial evidence. Attacks occurred most frequently in rivers and billabongs (n=13, 76%), and 4 cases (24%) took place at sea.

As described in a past case series on crocodile attacks, there are distinct pattern injuries in fatal crocodile attacks: complete traumatic disruption of bodies with incomplete

and fragmented remains to examine or crush injuries of the head and torso and possible avulsion of limbs.¹⁹

DEATHS RELATED TO FAUNA OTHER THAN CROCODILES

In this study, deaths from animals other than crocodiles were rare (Table 3). Three fatal snakebite cases occurred, with brown snake venom positively identified in all 3 events.

The first case involved a 45-y-old man who was bitten by a snake outside his rural property in the Alice Springs region (Central Australia or southern half of the NT). He was taken to the hospital and died 2 d later in the intensive care unit as a result of a brainstem bleed from coagulopathy. Polyvalent antivenom was provided during the course of his treatment. The snake was never located, and visual identification was therefore not possible.

The second case involved a 38-y-old man who was discovered deceased at his residence in a Darwin suburb a day after sustaining a witnessed bite to the left hand by a snake that he kept in a cage, believing it to be a python. Serum collected at autopsy tested positive for brown snake venom, and the cause of death was venom-induced consumptive coagulopathy. A snake was subsequently located in the decedent's house and visually identified by a local snake expert as a western brown snake (*Pseudonaja nuchalis*).

The third case was that of a 26-y-old man who was reportedly bitten by a snake at a local sport stadium in Darwin. A "brown snake" was observed, and the decedent and a friend attempted to relocate when the snake bit him on the ring finger. The decedent became confused within

30 min, had a fall during which he sustained a scalp laceration, and was transferred to a hospital. Brown snake venom was detected on a urine venom detection kit, and the decedent was intubated, ventilated, and treated with polyvalent snake antivenom; however, he was declared braindead 2 d after the bite. The cause of death was brown snake envenomation resulting in coagulopathy with intracerebral hemorrhages complicated by diffuse axonal injury as a result of the fall and head strike.

The case of box jellyfish envenomation was that of a 6-y-old boy who was stung by a jellyfish while swimming in the sea in Milikapiti, a village on the northern coast of the Melville Island, which is located 105 km (65 mi) from Darwin by air. Some tentacles were removed by witnesses at the scene, and the decedent was driven to the local health clinic; however, he was unresponsive on arrival at the clinic, and resuscitative efforts were unsuccessful. At autopsy, tentacles, described as "fine serpiginous threads" with a length of 2 m (6.6 ft), were present extensively over the skin of both lower legs and both hands, and the cause of death was envenomation after a box jellyfish sting. A local expert positively confirmed the tentacles as those of *Chironex fleckeri* on wet preparations of the unfixed tentacles, and the cause of death was acute jellyfish envenomation. *C fleckeri* is the adult major box jellyfish, with a bell of 25 to 30 cm (10–12 in) in diameter and with 10 to 12 tentacles at each corner, measuring 2 m (6.6 ft) or more in length. Box jellyfish that can cause Irikandji syndrome have smaller bells of 2.5 cm (1 in) or less and a single tentacle arising from each corner, ranging in length from a few centimeters to 35 cm (14 in).⁶

Table 3. Deaths related to animals other than crocodiles (n=10; 6%)

Type of death	Short description
Snakebite (n=3)	Western brown snake involved in all 3 cases 26-, 38-, and 45-y-old men Two bites occurred in urban locations, 1 in a rural location
Crush injuries after a buffalo attack (n=1)	Remote area 45-y-old man
Envenomation from box jellyfish sting (<i>Chironex fleckeri</i>) (n=1)	6-y-old boy
Anaphylaxis after ingestion of freshly caught and cooked mud crab (n=1)	24-y-old man
Septic complications after an "insect bite" (n=1)	32-y-old woman Bitten by an unidentified insect at a rural location Developed <i>Streptococcus pyogenes</i> necrotizing fasciitis and multiple organ failure
Road traffic incidents (n=3)	Animal(s) struck by vehicles resulting in fatal road traffic incidents In 1 case, a pig was struck, in another a horse, and in the third a kangaroo and a horse were struck

OTHER ENVIRONMENTAL DEATHS AND CONDITIONS

Although spectacular lightning storms occur in the wet season, deaths from lightning were rare, with only 1 case identified in the study period. This involved an adult man who was hiking with a metal camera tripod strapped to his backpack in the Kings Canyon region, west of Alice Springs, during a sudden-onset lightning storm.

No deaths from bushfire were identified during the study period; this is in strong contrast to other states in Australia, such as New South Wales, Victoria, Queensland, South Australia, and Western Australia, where multiple fatalities in relation to bush fires frequently occur.¹²

CYCLONE AND STORM-RELATED DEATHS

Cyclones (also known as “hurricanes” or “typhoons” in the northern hemisphere) are areas of low atmospheric pressure surrounded by high wind systems that rotate in a clockwise direction. They are graded according to their severity and wind velocity on a scale of 1 to 5 (the latter being the most severe). Cyclone Tracy (1974), the most destructive cyclone recorded in Darwin, was a category 4 cyclone. The cyclone season in Northern Australia begins on November 1 and extends until April. During this time many cyclones will form, although few will cause much structural destruction.²⁰ Seven cyclones occurred in the NT over the 15-y study period (chronologically named Ingrid, Monica, Helen, Paul, Carlos, Grant, and Marcus).

Four deaths were identified in relation to tropical storms or cyclones during the study period. The first death was a drowning at sea during a tropical storm; the second was a drowning after a person crossed a flooded river by a vehicle after Cyclone Helen in January 2008. The third death was a drowning after the overturning of a houseboat on an inland lake during a tropical storm. The fourth death was only indirectly related to Cyclone Marcus, which took place in March 2018. In this case, a pedestrian was struck by a vehicle in an unlit area that was affected by the loss of electricity due to damage to power lines.

LIMITATIONS

A dedicated attempt was made to identify all relevant cases over the study period; however, cases may have been missed because of the different keywords and classifications used by changing coronial and forensic pathology staff over the 15-y period. The possibility of underreporting or nonreporting to the coroner exists and cannot be excluded, particularly in view of the vast geographic landscape of the NT with many remote outstations

and limited communication and access to larger centers, particularly during the wet season. Investigator and pathology reports varied in detail and completeness, and medical history was not available in about one third (n=59, 35%) of cases. Findings should thus be interpreted in context. The decomposed condition of many of the bodies impeded autopsy findings and further ancillary testing such as toxicologic and biochemical analyses.

Recommendations and conclusions

Drowning was the most common type of environmental death in the NT, followed by heat-related deaths and fatal crocodile attacks. Deaths resulting from lightning and animals other than crocodiles are rare. Definite trends were identified in the most common types of environmental deaths encountered in the NT, and most deaths could have been prevented. This information should be used to inform and warn local residents and tourists to the NT to take the necessary precautions to minimize these types of deaths.

The NT has challenging environmental conditions; it is hot, humid, remote, and experiences monsoonal rains. These conditions influence subsequent police investigations and the interpretation of autopsy findings, and therefore circumstantial information and thorough police investigations are essential in the medicolegal investigation of environmental deaths.

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