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Distribution of Extreme Heat Days across Louisiana

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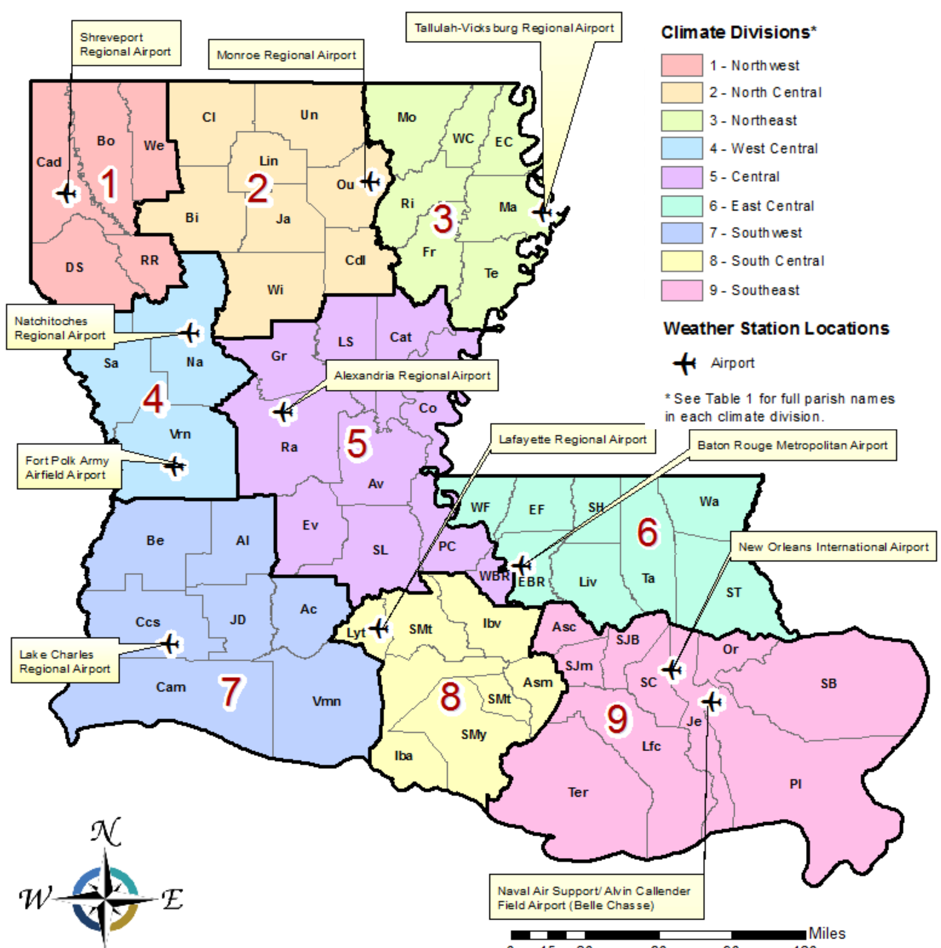
In August 2018, Louisiana summer weather made national news when Forbes published a blog post by climate scientist Brian Brettschneider titled "Who Has the Most Oppressive Weather?" The author determined that Louisiana "is the epicenter of summertime oppressive weather." This was based on the evaluation of temperature data from 380 weather stations across the country between noon and 6 p.m. from 1998-2017. Oppressiveness was defined as either a temperature or heat index ≥ 95°F or a dew point ≥ 75°F coupled with a wind speed ≤ 10 mph. Based on these parameters, Louisiana spent 40-70% of the summers from 1998-2017 between the hours of noon and 6 p.m. in oppressive heat. Conditions that promote oppressive summer heat are very light winds and a consistently high dew point in the Lower Mississippi River Valley. Even if the temperature does not reach 95°F, the heat index or dew point criteria are usually met.

This issue of the Louisiana Morbidity Report discusses extreme heat and heat-stress illness (HSI). Two articles in this edition report on HSI for the state and by climate division from 2010-2016. One article examines HSI in the entire population while the other focuses on workers. Both articles examine the relationship between temperature and heat index and HSI emergency department visits. This article discusses extreme heat in Louisiana's climate divisions. Information is provided about temperature normals, actual temperature and heat index data for 2010-2016 as well as extreme temperature and heat index thresholds utilized in both of the above-mentioned studies.

Methods

Louisiana has nine climate divisions. The parishes within each climate division have nearly homogenous characteristics regarding temperature, precipitation and humidity. We chose one weather station in each climate division to represent the entire cli-

Figure 1. Louisiana Climate Divisions, Parishes, and Respresentative Weather Station Locations



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mate division. Figure 1 is a map of the state divided into climate divisions with the parishes (names abbreviated) and each weather station location labeled. Table 1 provides the full name of the parishes in each climate division. In the West Central and Southeast climate divisions, there were gaps in the primary weather station data (Fort Polk Army Airfield and New Orleans International Airport, respectively); therefore, data from a secondary weather station was used to fill in the gaps.

A climatological normal is the 30-year average value of a meteorological element. The normal describes the climate and serves as a base to compare current conditions. The normal monthly maximum temperature (T_{max}) data for 1981-2010 for each weather station was obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information. In climate divisions where data from two weather stations was used the normal data were averaged. Temperature, heat index and precipitation data were obtained from the Southern Regional Climate Center's climate data portal and from Iowa State University's Iowa Environmental Mesonet ASOS-AWOS-METAR Data Download Page (https://mesonet.agron.iastate.edu/request/download.phtml). Historical data (1895-2019) were obtained from NOAA's "Climate at a Glance: Statewide Time Series" (https://www.ncdc.noaa.gov/cag/).

Heat index is a measure of how hot it feels temperature-wise when relative humidity is factored in with the actual air temperature. We defined extreme heat as a T_{max} or a maximum heat index (HI_{max}) ≥ 95°F; however, because the northern parts of Louisiana

Table 1. Parishes within each Climate Division

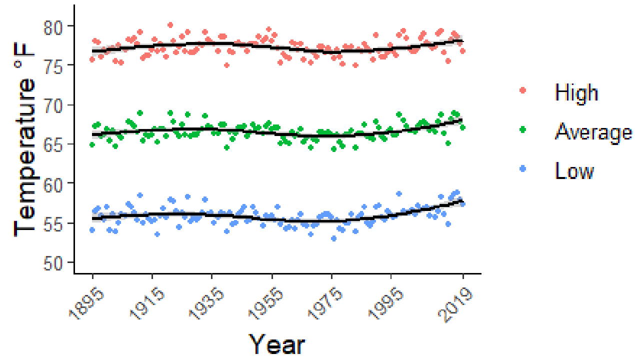
Climate Division (#)	Parishes (Parish name abbreviation)
Northwest (1)	Bossier (Bo), Caddo (Cad), DeSoto (DS), Red River (RR), Webster (We)
North Central (2)	Bienville (Bi), Caldwell (Cdl), Claiborne (Cl), Jackson (Ja), Lincoln (Lin), Ouachita (Ou), Union (Un), Winn (Wi)
Northeast (3)	East Carroll (EC), Franklin (Fr), Madison (Ma), Morehouse (Mo), Richland (Ri), Tensas (Te), West Carroll (WC)
West Central (4)	Natchitoches (Na), Sabine (Sa), Vernon (Vrn)
Central (5)	Avoyelles (Av), Catahoula (Cat), Concordia (Co), Evangeline (Ev), Grant (Gr), La Salle (LS), Pointe Coupee (PC), Rapides (Ra), St. Landry (SL), West Baton Rouge (WBR)
East Central (6)	East Baton Rouge (EBR), East Feliciana (EF), Livingston (Liv), St. Helena (SH), St. Tammany (ST), Tangipahoa (Ta), Washington (Wa), West
Southwest (7)	Acadia (Ac), Allen (Al), Beauregard (Be), Calcasieu (Ccs), Cameron (Cam), Jefferson Davis (JD), Vermilion (Vmn)
South Central (8)	Assumption (Asm), Iberia (Iba), Iberville (Ibv), Lafayette (Lyt), St. Martin (SMt), St. Mary (SMy)
Southeast (9)	Ascension (Asc), Jefferson (Je), Lafourche (Lfc), Orleans (Or), Plaquemines (Pl), St. Bernard (SB), St. Charles (SC), St. James (SJm), St. John the Baptist (SJB), Terrebonne (Ter)

often see triple-digit temperatures in summer, we also examined a threshold of T_{max} or HI_{max} ≥ 100°F. Additionally, a daily low temperature that is too high can promote heat illness. Thresholds for the daily low temperature were investigated at 75°F and 80°F to identify their risk to Louisiana residents.

Results and Discussion

Figure 2 shows the average summer temperatures from the years 1895-2019 for the whole state. Using a locally estimated scatterplot smoothing regression (LOESS) it can be seen that

Figure 2. Average Summer (May-Sep) Temperatures, Louisiana, 1895-2019



the average temperatures are reasonably stable during this time period with a slight dip around 1975 and an increase since 1995. Currently, the daily low temperatures are increasing faster than the daily high temperatures.

In all climate divisions, the normal T_{max} for May is in the mid-80s and enters the low-90s by June (Table 2). In July and August, the normal T_{max} ranges from the low- to mid-90s, and is slightly higher for the Northwest and North Central climate divisions than it is for the other climate divisions. By September, the summer season is starting to wane, and the normal T_{max} falls to the

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upper-80s.

Across climate divisions, the difference between the average monthly T_{max} for 2010-2016 and the normal T_{max} for each climate division ranged from 0°F-4°F (Table 2). On average, the normal T_{max} has a standard deviation (SD) of 2°F across the months of May-September. Using the average SD as a threshold for substantial deviation from the normal T_{max}, the Northwest climate division had the most substantial increases in average monthly T_{max} compared to normal monthly T_{max}. The T_{max} was 2°F or higher than normal for June through September in the Northwest climate division. The Northeast and Central climate divisions experienced an increased T_{max} in the months of June, August and September. The T_{max} in the North Central and Southwest climate divisions was higher than normal in September. In the East Central, South Central, and Southeast climate divisions, T_{max} did not rise above normal.

For the most part, from 2010-2016, the average HI_{max} is not substantially different among climate divisions (Table 2). The degrees increase between T_{max} and HI_{max} in each climate division is where differences emerge. Generally, the largest increases occurred in the more southern climate divisions, and the smallest increases occurred in the more northern climate division. For example, in August, the average T_{max} was 91°F in the Southeast climate division and 97°F in the Northwest climate division, and the HI_{max} was 101°F in both climate divisions. This means that in the Southeast climate division there was a 10-degree difference between the T_{max} of 91°F and the "feels like" temperature or HI_{max} of 101°F versus a 4-degree difference between the T_{max} of 97°F in the Northwest and the "feels like" temperature or HI_{max} of 101°F in the Northwest climate division.

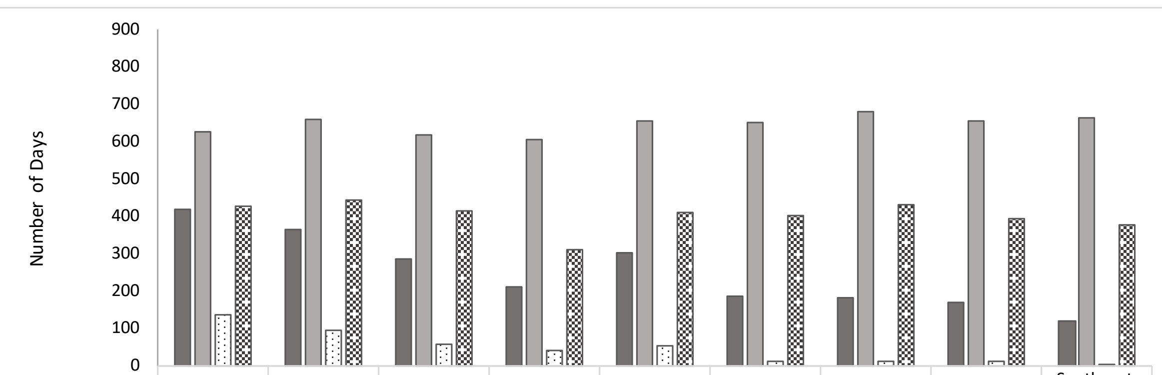
Figure 3 presents the number of days from 2010-2016 where T_{max} and HI_{max} reached or exceeded the thresholds of at least 95°F or at least 100°F. The southern and East Central climate

Table 2. Average Maximum Temperature (T_{max}), Maximum Heat Index (HI_{max}) and Normal* T_{max} by Month and Location, 2010-2016

Climate	May	June	July	August	September
Northwest: Shreveport Regional Airport					
Normal T_{max}	84	90	93	94	88
T_{max}	85	93	95	97	92
HI_{max}	86	97	100	101	94
North Central: Monroe Regional Airport					
Normal T_{max}	85	92	94	94	89
T_{max}	85	93	94	95	91
HI_{max}	87	98	101	102	94
Northeast: Tallulah-Vicksburg Regional Airport					
Normal T_{max}	84	90	92	92	87
T_{max}	85	92	93	94	90
HI_{max}	86	98	100	101	93
West Central: Fort Polk Army Airfield/ Natchitoches Regional Airport					
Normal T_{max}	85	91	93	94	88
T_{max}	84	91	92	93	89
HI_{max}	86	96	98	99	92
Central: Alexandria Regional Airport					
Normal T_{max}	85	90	92	93	88
T_{max}	86	92	93	95	90
HI_{max}	87	98	100	101	93
East Central: Baton Rouge Metropolitan Airport					
Normal T_{max}	86	91	92	93	89
T_{max}	86	91	92	93	89
HI_{max}	87	97	100	101	93
Southwest: Lake Charles Regional Airport					
Normal T_{max}	85	89	91	92	88
T_{max}	85	91	92	93	90
HI_{max}	88	98	100	102	94
South Central: Lafayette Regional Airport					
Normal T_{max}	86	91	92	93	89
T_{max}	86	91	91	93	90
HI_{max}	88	98	99	101	94
Southeast: New Orleans International Airport/ Alvin Callender Field Airport (Belle Chasse)					
Normal T_{max}	85	90	91	91	88
T_{max}	85	90	91	91	89
HI_{max}	88	97	100	101	94

All temperatures are in degrees Fahrenheit; * Normal temperature maximums are 30-year averages for the years 1981-2010 as calculated by the the National Oceanic and Atmospheric Adminstration's National Centers for Environmental Information

Figure 3. Number of Days Daily Maximum Temperature (T_{max}) and Heat Index (HI_{max}) Exceeded Threshold by Location, 2010-2016



	Northwest: Shreveport	North Central: Monroe	Northeast: Tallulah-Vicksburg	W. Central: Fort Polk/ Natchitoches	Central: Alexandria	East Central: Baton Rouge	Southwest: Lake Charles	South Central: Lafayette	Southeast: New Orleans/ Belle Chasse
Tmax ≥ 95	417	365	286	213	302	185	182	170	119
HImax ≥ 95	625	658	620	605	657	650	680	655	666
Tmax ≥ 100	136	93	58	40	55	11	11	12	4
HImax ≥ 100	428	444	413	310	412	401	431	392	377

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Table 3. Average Minimum Temperature (T_{min}), Minimum Heat Index (HI_{min}) and Normal* T_{min} by Month and Location, 2010-2016

Climate Division: Weather Station Location	May	June	July	August	September
Northwest: Shreveport Regional Airport					
Normal T_{min}	63	70	73	72	66
T_{min}	64	73	74	75	68
HI_{min}	64	73	75	76	69
North Central: Monroe Regional Airport					
Normal T_{min}	63	70	72	71	64
T_{min}	63	72	73	73	66
HI_{min}	64	73	74	74	67
Northeast: Tallulah-Vicksburg Regional Airport					
Normal T_{min}	62	68	71	70	63
T_{min}	61	70	72	71	64
HI_{min}	62	71	72	72	65
West Central: Fort Polk Army Airfield/ Natchitoches Regional Airport					
Normal T_{min}	64	72	75	74	67
T_{min}	65	72	74	74	69
HI_{min}	65	72	74	75	69
Central: Alexandria Regional Airport					
Normal T_{min}	64	70	73	72	66
T_{min}	64	72	73	73	67
HI_{min}	64	72	74	74	68
East Central: Baton Rouge Metropolitan Airport					
Normal T_{min}	65	71	74	73	69
T_{min}	65	73	74	74	69
HI_{min}	66	73	75	75	70
Southwest: Lake Charles Regional Airport					
Normal T_{min}	67	73	75	74	69
T_{min}	67	74	76	76	71
HI_{min}	67	75	76	77	71
South Central: Lafayette Regional Airport					
Normal T_{min}	67	73	75	75	70
T_{min}	67	74	75	75	71
HI_{min}	68	75	76	76	71
Southeast: New Orleans International Airport/ Alvin Callender Field Airport (Belle Chasse)					
Normal T_{min}	68	74	75	75	72
T_{min}	68	75	76	77	73
HI_{min}	69	76	77	78	74

All temperatures are in degrees Fahrenheit; * Normal temperature minimums are 30-year averages for the years 1981-2010 as calculated by the the National Oceanic and Atmospheric Adminstration's National Centers for Environmental Information

divisions had fewer than 200 (18.6%) days where $T_{max} \geq$ 95°F, and the Northwest climate division had over 400 (37.3%) days; however, all climate divisions had well over 600 (56%) days where the $HI_{max} \geq$ 95°F, with the greatest number occurring in the Southwest climate division. With the exception of the Northwest climate division, all of the climate divisions had less than 100 (9.3%) days where $T_{max} \geq$ 100°F, the East Central and southern climate divisions had fewer than 20 (1.8%) days; however, most climate divisions experienced over 400 days where $HI_{max} \geq$ 100°F.

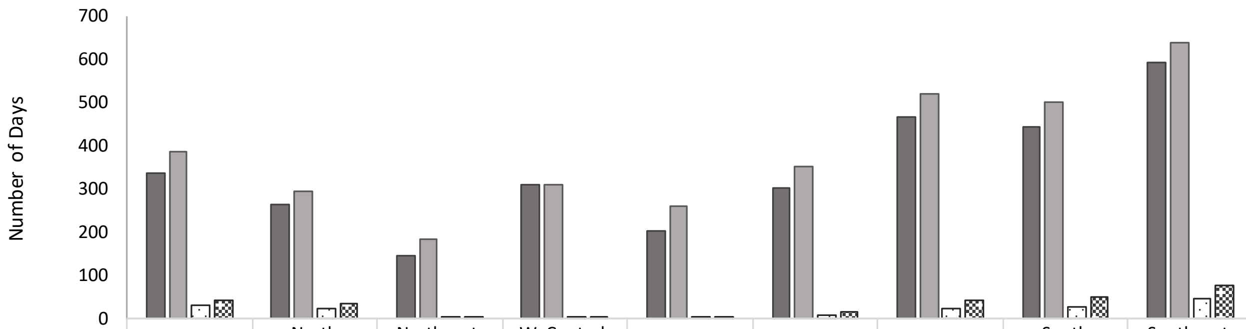
Days with extreme high temperatures are often accompanied by low temperatures that are high as well. In all climate divisions, the normal T_{min} for May is in the low- to mid-60s and enters the low- to mid-70s by June until falling to the mid-60s to low-70s in September (Table 3). In contrast to high temperatures, minimum temperatures are higher in the Southwest, South Central, and Southeast climate divisions. Differences between normal T_{min} and average monthly T_{min} and HI_{min} were less pronounced than normal T_{max} and average monthly T_{max}. The largest deviations from normal T_{min} were in the Southeast climate division where T_{min} and HI_{min} were 2-3°F higher. In general, T_{min} and HI_{min} did not differ significantly.

Figure 4 presents the number of days from 2010-2016 where daily T_{min} and HI_{min} reached or exceeded the thresholds of at least 75°F or at least 80°F. Overall, there were not many days with a T_{min} or HI_{min} over 80°F with the range being between 0 and 79 days. Days with a T_{min} or HI_{min} over 75°F ranged from a low of ~200 days in the Northeast and Central climate divisions while the southern climate divisions had the highest counts at 444-640 days.

The southern (and often the Central) climate divisions, in particular the Southeast climate division, have lower average monthly T_{max} than the northern climate divisions, this trend is reversed for T_{min}. In addition, the southern climate divisions have far fewer days where the $T_{max} \geq$ 95°F or 100°F than climate divisions further north. The primary reason that south Louisiana rarely sees temperatures ≥ 100°F is due to the amount of water around the region. These bodies of water absorb heat through the process of evaporation, which in turn leads to high humidity. High humidity can make it feel like the temperature is in the triple-digits; however, it also produces clouds and thunderstorms, which act to reduce the temperature. If the temperature climbs into the upper 90s, the atmosphere generally responds by creating thunderstorms. In this way, thunderstorms are regulators that, for the most part, prevent the temperature from reaching triple-digits in south Louisiana. Before the cooling effect of the thunderstorm, the heat index can reach the 100s. The northern parts of the state do not have the same insulating bodies of water surrounding them; therefore, they tend to experience a higher average monthly T_{max} and many more

(Distribution of Extreme Heat Days ... continued from page 4)

Figure 4. Number of Days Daily Minimum Temperature (Tmin) and Heat Index (HImin) Exceeded Threshold by Location, 2010-2016



	Northwest: Shreveport	North Central: Monroe	Northeast: Tallulah-Vicksburg	W. Central: Fort Polk/ Natchitoches	Central: Alexandria	East Central: Baton Rouge	Southwest: Lake Charles	South Central: Lafayette	Southeast: New Orleans/ Belle Chasse
Tmin ≥ 75	337	264	148	312	203	305	468	444	593
HImin ≥ 75	389	296	187	312	263	352	522	501	640
Tmin ≥ 80	34	24	4	6	1	11	25	30	47
HImin ≥ 80	45	37	5	6	5	18	44	51	79

days where the T_{max} ≥ 95°F or 100°F than the more southern parts of the state.

Humidity, which is a main determinant of heat index, is a measure of the amount of water vapor in the air. Humidity plays an important role in sweating, the body's primary cooling mechanism. When humidity is high, heat exchange efficiency is impaired which reduces the rate of moisture evaporation from the surface of the skin. As anyone living in south Louisiana knows, when humidity is high, sweat does not evaporate very quickly and you feel hotter than the actual temperature. While prolonged or intense exposure to hot temperatures are obvious risk factors for heat-stress illness, anything that interferes with the body's ability to cool itself, including high humidity, increases the risk for heat-stress illness. While certain areas of the state tend to experience higher actual temperatures and other areas experience higher humidity, the risk of heat-stress illness is high for all of Louisiana.

Occupational Heat-Stress Illness Emergency Department Visits and Hospitalizations in Louisiana and its Climate Divisions, 2010-2016

Anna Reilly, Ph.D., M.P.H.

Working in a hot environment, whether indoors or outdoors, can be dangerous. Core body temperature must be maintained within a very narrow range (97.7-99.5°F). A 2°F increase in body temperature can affect mental functioning; a 5°F increase can result in serious injury or death. Exposure to extreme heat can interfere with sweating, the body's primary cooling mechanism, putting workers at risk of heat-stress illness (HSI). Milder forms of HSI include heat rash, heat cramps and heat exhaustion, which often lead to worker irritability, low morale, absenteeism and shortcuts in procedures. The most serious form of HSI, heat stroke, is a medical emergency that can be fatal. HSI may be an underlying cause of other types of injuries such as heart attacks, falls and equipment accidents. Accidents leading to injuries can occur due to sweaty palms and fogged-up safety glasses; burns can occur from accidental contact with hot surfaces or steam.

Occupations considered high-risk for HSI include firefighters, bakery and kitchen workers, laundry workers, landscapers, agricultural workers, construction workers, oil and gas workers, electrical utility (especially boiler room) workers, mail and package deliverers, and factory workers. These workers are exposed to occupational risk factors for HSI such as heavy physical activity (produces metabolic heat from physical exertion of energy), having to wear personal protective equipment (PPE; may interfere with the body's ability to sweat effectively), and/or hot environmental conditions (e.g., high temperature, humidity, radiant heat sources, and/or limited air movement). Additional personal factors that can increase the risk for HSI include obesity, advanced age (≥ 65 years), poor cardiovascular fitness, underlying health problems, existing burns (may damage or destroy sweat glands), use of certain medications, pregnancy, previous HSI, and lack of acclimatization (heat tolerance).

Thousands of workers in Louisiana are at risk of HSI. Many industries and occupations are vulnerable to HSI, but the industries most affected by HSI due to outdoor heat are construction,