Deaths, Injuries, and Damages from Lightning in the United States in the 1890s in Comparison with the 1990s

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ABSTRACT

A reduction by a factor of 10 in the population-weighted rate of lightning-caused deaths over the last century has been determined in several previous studies. The reasons have been attributed to a number of factors, but none have been quantified in detail with a large dataset. Several thousand lightning-caused deaths, injuries, and reports of property damage in the United States from 1891 to 1894 were analyzed manually from descriptions provided by an 1895 data source. A similar manual analysis was made of information in the NOAA publication *Storm Data* 100 yr later, from 1991 to 1994. Comparisons show that the decrease in lightning risk to people coincides with a shift in population from rural to urban regions. Major changes in the types of property damaged by lightning between the two periods 100 yr apart are also shown. In addition, the results identify significant shifts in the kinds of incidents in which people and objects are impacted by lightning. This information can help in the development of better guidelines for lightning safety and education.

1. Introduction

The causes of temporal changes in the number or rate of human casualties caused by severe weather in the United States have been examined for phenomena whose impacts have been forecast with increasing accuracy. The significant reduction in deaths from tornadoes (Brooks and Doswell 2002) and hurricanes (Pielke and Landsea 1998; Gray 2003) has been documented. These and similar studies show that improved forecast methods, combined with public warnings and appropriate responses, have helped to reduce not only the death rate but also the absolute number of deaths in many regions. In the case of lightning, the large reduction in both the death rate and absolute number of fatalities over the last century in the United States has been documented (López and Holle 1998). Because lightning is not explicitly or routinely forecast to any extent, however, the causes for such a large decrease in lightning deaths are primarily due to factors other than improved forecasts or warning-response efforts for the lightning threat itself, while recognizing that the general awareness and knowledge of thunderstorms is now vastly greater in the United States than it was a century ago. No systematic approach has been taken to clarify the relevant factors contributing to this decline in detail, although a number of reasons have been suggested for this tenfold drop in the fatality rate in the last century.

The number, rate, activity, and/or location of lightning victims and lightning-caused damages have been described in dozens of publications from within and outside of the United States, such as those listed in Holle et al. (2001), as well as recent studies by Agoris et al. (2002), Aguado et al. (2002), Roberts and Elsom (2002), Hodanish et al. (2004), Lengyel et al. (2005), and Fieux et al. (2005). Results from these publications are usually difficult to compare, however, and only a portion of the important factors are included in each publication. It is not apparent from most of these studies which factors of human behavior, location, or activity are most critical, and so the results cannot be used easily to improve guidelines for lightning safety through education.

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For this reason, this study was undertaken to identify the factors in both the location and activity of lightning victims 100 yr apart. The critical component of this study is a book by Kretzer (1895) that has numerous reports of lightning-caused casualties and damages from 1891 to 1894 (hereinafter 1890s). For comparison, identical summaries of *Storm Data* lightning reports were compiled for a similar period a century later from 1991 to 1994 (hereinafter 1990s).

2. Lightning casualty and damage data

a. Storm data

Reports of damaging weather phenomena have been collected monthly by National Weather Service offices with essentially the same procedures since 1959. Station reports are sent to the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center in Asheville, North Carolina, where *Storm Data* is assembled. (*Storm Data* is available online at www5.ncdc.noaa.gov/pubs/publications.html#SD.) A standard report includes all or part of the following information: year, month, and day; time in local standard time (LST); state and county; number of fatalities; gender and location of fatalities; number of injuries; gender and location of injured people; and categorical amount of damage reported. Damage costs are reported in *Storm Data* by numbers from 1 to 9, where category 1 has a range of \$0–\$50, category 2 has a range of \$50–\$500, and so on.

Critical to the current study is the additional information provided by verbal narratives accompanying entries in *Storm Data*. Activities and locations of lightning deaths and injuries were extracted manually from 1991 to 1994 and were categorized in as much detail as possible. Expanded information on objects impacted by lightning was sometimes available in the verbal narratives; in a few cases, an exact dollar amount was given.

b. Kretzer's book

Newspapers across the United States were scanned for lightning entries from 1891 to 1894, and the entries were summarized in Kretzer (1895). The goals of the book were stated as determining the potential threat from lightning to people and property in the United States, documenting lightning incidents and protection, and encouraging the public to use lightning rods. The efforts of Kretzer led to the first collection of such information by federal agencies starting in 1890 (López and Holle 1998).

Standard and expanded information on lightning casualties and damages were classified from Kretzer's book. The same system was used as is described in section 2a for analyzing *Storm Data*. The 21 newspapers, in eight states, scanned by Kretzer (1895) emphasize the region around his Saint Louis, Missouri, home (Holle et al. 2001). Nevertheless, for decades before and after its publication, no publication contains as much detail on lightning impacts as this book. Kretzer sometimes lists "special reports of correspondents" as a source. There were 894 accounts from 470 cities and towns in 42 states. In addition, 16 events were entered from eight foreign countries.

It is likely that fatalities were reported in Kretzer (1895) more often than injuries for a number of reasons. Kretzer reports less than two injuries for each lightning fatality, whereas Curran et al. (1997) showed that the ratio in *Storm Data* steadily increased from 2 injuries per death in 1959 to 8:1 in 1994 in the United States. A recent study by Cherington et al. (1999) used data from medical reporting systems that have been recently automated and expanded to find a 10:1 ratio. Kretzer found that deaths were 47% of the total casualties in rural incidents but that deaths were only 15% of the total casualties in urban incidents. It is possible that lightning-caused deaths were covered frequently by newspapers in both rural and urban areas but that injuries in a rural situation were reported less often than an injury in a city. For these reasons, many of the following results will only consider fatalities.

Damages in Kretzer's book were sometimes given in exact dollar amounts. They were matched with the same categories in *Storm Data*. No inflation corrections have been applied to either Kretzer or *Storm Data* damage amounts.

c. Underreporting

Absolute values of lightning-caused casualties and damages must be considered with caution. Most of these events are less spectacular and more widely dispersed in time and space than tornadoes and hurricanes. Lightning deaths, injuries, and damages have been found to be underreported in the following studies:

- 33% more lightning deaths were found in Texas medical records than in *Storm Data* (Mogil et al. 1977),
- 28% more fatalities and 42% more injuries requiring hospitalization were identified in Colorado medical records than in *Storm Data* (López et al. 1993),
- 367 times as many personal property claims resulting from lightning were present in insurance data in three

western states than were listed in *Storm Data* (Holle et al. 1996),
- 31% more fatalities were located with Florida death certificates than in *Storm Data* (Lushine 1996),
- a ratio of 10 injuries for each fatality was found in Colorado when emergency room visits were included (Cherington et al. 1999), and
- a lightning fatality without a witness to the event was documented by Cherington et al. (2001).

A number of factors contribute to underreporting. Indirect lightning casualties are often reported by the medical system as having lightning as the secondary rather than the primary cause (Mogil et al. 1977). Issues relating to direct and indirect causes of lightning deaths were addressed in detail in López et al. (1993). Because the study presented in this paper could not reconstruct the events after the event concerning the cause, the reports in Kretzer (1895) and *Storm Data* were used as they were published. In addition, there is a reliance on newspaper clippings for lightning events entered in *Storm Data* by the National Weather Service (López et al. 1993). Also, lightning casualty events nearly always involve only one individual, so that such events do not attract as much interest from the media or reporting agencies as larger storms. Also, some lightning deaths are missed because of an incorrect medical diagnosis.

3. Classifications

a. Rural–urban setting

A significant decrease in lightning deaths over the last century was shown by López and Holle (1998). The population-weighted fatality rate decreased tenfold from about 6 deaths per million people in the early decades of the twentieth century to about 0.6 deaths per million late in the century (López and Holle 1998, their Fig. 3). The decrease was almost parallel to the decrease in the percentage of the U.S. population living in rural situations, as found by the U.S. Census Bureau. Similar results have been found over varying periods in other countries. For this study, the change in the rural–urban setting between the two datasets 100 yr apart is assumed to be similar to the steady decrease from 65% of the U.S. population living in rural settings in 1890 to 25% in 1990 (López and Holle 1998, their Fig. 4).

From these separate time series of fatality rate and percentage of population shift from rural settings, a major shift from rural to urban settings of lightning fatalities was inferred. Because this fact has not been explicitly documented in past studies over a long period, the cases were categorized into rural or urban setting when possible, without reference to other information. For this study, an overall impression was developed from each entry in Kretzer (1895) and *Storm Data* as to whether the situation was rural or urban when the situation was clearly described in the verbal narrative. It was not possible to determine the rural–urban setting in about one-third of the cases. For example, an unknown case frequently occurred in which someone was killed or injured by lightning inside a house. If nothing was mentioned about the setting external to the house, neither a rural nor an urban setting could be assigned to the casualty. There are, then, three possible settings that can be assigned to each event in this study: rural, urban, and unknown.

b. Activity and location

Storm Data includes a location for each victim. However, *Storm Data* locations are unknown in 40% of the cases, and another 27% are in "open field, ballparks, playgrounds, etc." (Curran et al. 1997, 2000). This information is not adequate to define changes in the situation of lightning victims from the 1890s to the 1990s.

Instead, a *separate* activity and a separate location were identified for each casualty from the information in the narratives. There has been a tendency in past studies to emphasize the location, such as in an open field. Instead, it was expected to be equally or more important to understand what the person was doing when killed by lightning, such as playing baseball or hiking in the open. For these reasons, it was decided to extract as much information as possible from the data to obtain a more complete understanding of the fatalities by making detailed separate categories of both location and activity.

For example, an entry reporting a lightning death could have an activity of "seeking shelter from rain" and a location of "under a tree." Such a casualty was assigned one code for activity and another code for location. Another death entry might have "camping" as activity and "under a tree" as the location. In this case, the code would be different for activity but the same for location. In many cases it was impossible to determine the location, activity, or both from Kretzer (1895) or from *Storm Data*; such a datum was coded as being unknown.

Activity and location were then coded *separately* into one of seven classes: agriculture, indoors, outdoors, recreation, sports, small structures, and unknown. These seven types apply to both activity and location, as listed alphabetically and described in Table 1. Agriculture was identified as a separate class because it was expected that 1890s fatalities were often in rural settings,

TABLE 1. Types of activities, locations, and incidents.

Type	Description of activities, locations, and incidents
Agriculture	The case took place on a farm or ranch. The agricultural location was more substantial than a garden in the backyard of a home in the city. It typically was where the livelihood of a lightning casualty and related family involved agriculture. If there was no specific mention of an agricultural setting for the casualty, it was not included here.
Indoors	The case occurred inside a building, most often a house.
Outdoors	The case occurred during a wide variety of situations in which the casualty was outside a building but the situation was not related to agriculture, recreation, small structures, or sports.
Recreation	Such cases include any recreational activity. These events occur outside, but the category does not include group sports events.
Small structures	The case occurred when the victim was in a shed, vehicle, open-sided shelter, shack, or other small, isolated building. This category does not include large structures such as homes, office buildings, or stores.
Sports	The case occurred during a group sporting event involving a team situation. If only one or a few people were fishing, for example, the case was recreation.
Unknown	When none of the above could be identified, the case was classified as unknown.

but this may not be true in the 1990s dataset. In addition, it was also expected that group sports and individual recreation events were much less common a century ago relative to the present. The small-structure class was expected to have more entries in the 1890s dataset, because such buildings can be common in rural settings. In the two examples given above, the activity of "seeking shelter from rain" would be assigned to outdoors, the activity of "camping" would be assigned to recreation, and the location for both entries of "under a tree" would be assigned to outdoors. Using this method, each case had both an activity and a location assignment to one of the seven classes.

c. Incident

The two class assignments of each case were examined to obtain the most likely overall class of the incident. Incident types were the same as the seven classes in Table 1. Thus, the first case described above would be an outdoors incident and the second would be recreation. Incident type was determined with fixed rules. When activity- and location-derived classes were the same, the incident typing was clear. For a large number of entries, however, either the activity- or location-derived class was missing so that the type was the same as the nonmissing class. In a few instances the categories differed and preference was given to the activity-derived class, as in the second example above. However, the location-derived class was dominant when the activity class was indoors but the location class was otherwise. Location class was also dominant for an outdoors activity with a location class of agriculture, recreation, small structure, or sports. These rules assured that the more-specific piece of information had a greater influence in classifying incidents.

4. Comparisons of deaths and injuries between centuries

a. Rural–urban setting and type of incident

The rural–urban settings of lightning deaths are compared from the two datasets in Fig. 1. In the 1890s, there are 3 times as many fatalities in rural as in urban settings. In the 1990s dataset, deaths in urban settings are somewhat more frequent than those in rural settings. A comparison of centuries shows that rural deaths decrease from 76% to 46% and fatalities in urban settings more than double from 24% to 54%.

The types of incidents are compared in Fig. 2, and the following three major differences are apparent: one, there is a dominance of agriculture cases in the 1890s; two, recreation and sports contribute significantly to the total number of incidents in the 1990s; and three, indoors incidents decreased from the most frequent type in the 1890s to very infrequent in the 1990s. Outdoors is the most common type of incident in the 1990s,

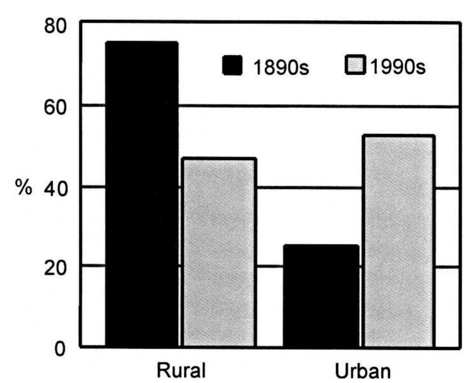

FIG. 1. Rural vs urban lightning-related deaths 100 yr apart, without unknown cases.

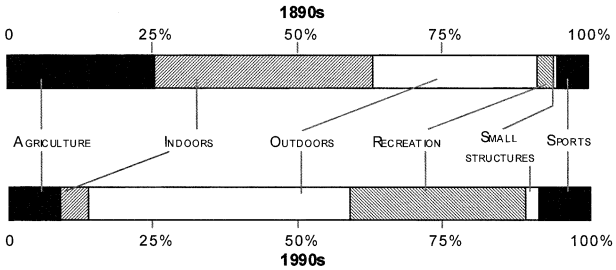

FIG. 2. Comparison of the percentage of types of lightning death incidents 100 yr apart, without unknown cases.

and was also frequent a century ago. Recreation is now the second largest category but was very infrequent a century ago. Agriculture incidents were frequent in the 1890s but now are a minor type. Lightning casualties were also found to increase since 1950 in Colorado while agricultural casualties decreased at the same time (López et al. 1995). Baker (1984) also related the reduction in lightning deaths in the United Kingdom to a reduced number of people in agricultural work.

The setting together with type of incident is compared between centuries in Fig. 3. Nearly all of the agriculture incidents are in rural settings at both times, as expected. Indoors incidents in the 1890s were evenly divided between rural and urban, but many were in unknown settings. Outdoors incidents were mainly rural in the 1890s but are now mainly in an urban setting. Recreation increased greatly during the century; most incidents are now in a rural setting.

The combination of these results profiles the most common lightning deaths. In the 1890s, a lightning fatality was most often an agriculture, outdoors, or indoors incident in a rural setting. In the 1990s, a victim was most often involved in an outdoors incident in an urban setting or a recreation incident in a rural setting.

b. *Changes within type of incident*

Detailed descriptions of the activities and locations of lightning casualties are given in the following list by alphabetical order. Only entries with at least 1.0% in one of the columns are included. The comparisons are made according to the percentage of the entire sample of reports within each period's dataset. The tables provide details of activities and locations so that potential users of this information can assemble categories appropriate to each situation. Past casualty studies often developed classifications in advance, such as "in the open," but such a grouping does not provide information that adequately describes the situation.

1) AGRICULTURE

Agriculture activities and locations are compared in Table 2. The agricultural activity group in the 1890s accounts for 6.6% of deaths from 1891 to 1894, and 2.8% of injuries. Other large categories include caring for horses and animals and plowing. The 1890s locations of open fields, farm and ranch, and barn account for nearly 17% of all deaths in that period. None of the 1990s agriculture categories reaches 3% of the deaths or injuries.

2) INDOORS

Indoors activities and locations are compared in Table 3. Recall that in the 1890s, indoors incidents are the most frequent type for both deaths and injuries. During the 1890s, the largest indoors lightning death activity was bed/sleeping; other routine activities inside houses occurred less often. Most of these activities are infrequent in the 1990s dataset. House fires were a consistent source of casualties; they accounted for 2.1% of deaths and injuries in the 1890s and 2.4% in the 1990s. Telephones were identified as the cause of 0.4% of deaths and 2.5% of injuries in the 1990s. A similar rate of 2.4% of U.S. casualties from 1959 to 1994 was related to telephones, using the *Storm Data* categorization (Curran et al. 1997).

In terms of location, the combination of all types of dwellings accounted for over 20% of all indoors deaths

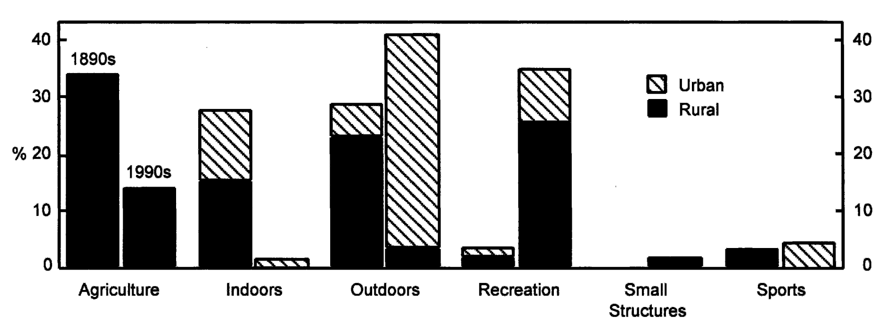

FIG. 3. Comparison of the percentage of types of lightning death settings and incidents 100 yr apart, without unknown cases.

TABLE 2. Comparison of activities and locations during agriculture incidents organized by large groups in the 1890s and 1990s by percentage of the total for each dataset.

	1890s		1990s	
	Deaths	Injuries	Deaths	Injuries
Agriculture activity				
Agricultural	6.6	2.8	2.5	0.6
Plowing	3.7	0.5	—	—
Horses/animals	3.2	1.1	2.5	0.1
Cotton	1.3	1.1	—	—
Agriculture location				
Open field	7.2	1.8	1.3	0.5
Farm/ranch	4.8	2.0	1.7	0.2
Barn	4.8	2.4	—	0.3

and injuries in the 1890s. In the 1990s, dwellings account for substantially fewer deaths and injuries than 100 yr earlier. Not included in Table 3 is an 1890s case in which 200 people were injured (no deaths) inside a church that was heavily damaged.

It is probable that the large decrease of casualties in indoors dwelling locations is due to better-grounded structures now than a century ago. With the installation of power, plumbing, and telephones, a lightning strike to a home now has a path to ground that greatly reduces the impact on the building and its occupants. In the 1890s these structural improvements were only beginning to be installed in the United States.

3) OUTDOORS

Outdoors activities and locations are compared in Table 4. The most frequent activities for outdoors lightning deaths during the 1890s involved wagons and horses in various situations; these activities are few in the 1990s. People who were walking were lightning victims at nearly the same rate in both centuries, whereas more people were sitting or standing when they became lightning victims in the 1990s. Military activities accounted for quite a few injuries in both periods.

TABLE 3. Same as Table 2, but for indoors.

	1890s		1990s	
	Deaths	Injuries	Deaths	Injuries
Indoors activity				
Bed/sleeping	3.7	2.3	—	0.1
Routine household	3.5	4.4	—	1.9
Near window/doorway	2.1	2.7	—	1.2
House fire	1.6	0.5	2.1	0.3
Near chimney	1.3	0.8	—	—
Telephone/telegraph	—	0.5	0.4	2.5
Indoors location				
House/home/cabin/mobile home	24.1	20.4	2.9	6.2
Work/store/factory	2.4	7.4	0.8	1.5
School	1.6	0.6	—	0.2

TABLE 4. Same as Table 2, but for outdoors.

	1890s		1990s	
	Deaths	Injuries	Deaths	Injuries
Outdoors activity				
Riding a wagon	3.5	1.5	—	—
Riding/harnessing horses/pony	3.2	0.5	—	0.7
Walking	2.4	1.8	2.5	1.1
Garden/yard related	1.1	0.3	0.4	0.4
Sitting/standing	1.1	0.9	4.2	2.9
Repairing ship	0.8	1.8	—	0.1
Military related/training	0.3	2.3	0.8	5.7
Getting in/getting out/loading/unloading vehicle	—	—	2.1	2.4
Mowing/raking lawn/leaves	—	—	1.7	0.4
Construction	—	—	0.8	1.2
Working on vehicle	—	—	—	1.0
Outdoors location				
Under/near tree	6.6	1.5	15.1	6.3
Road/travel	3.7	3.2	—	—
Porch/awning/porch near tree	1.3	1.1	—	1.0
Open field	1.3	0.2	1.3	1.1
On horse/horse lot	1.3	0.2	—	—
House doorway	1.1	0.6	—	—
Near/touching wire fence	0.8	1.1	—	0.2
Garden/yard	0.8	0.9	2.5	1.2
In water/near ship/under boat	0.8	1.8	—	—
Tent	0.3	2.4	0.8	3.9
Near vehicles	—	—	3.3	3.5
Approaching/near building	—	—	1.7	1.4

Outdoors locations frequently involve people located under or near a tree. The 1990s death rate in the vicinity of trees of 15.1% is more than 2 times that in the 1890s. Curran et al. (1997, 2000) found from *Storm Data* categories that a similar percentage of 13.7% of U.S. lightning casualties from 1959 to 1994 were under trees. Such results indicate the need for continued education of the lightning hazard associated with being in the vicinity of trees.

In the 1890s, 3%–4% of victims of lightning were on the road or were engaged in travel, which was not in metal-topped enclosed vehicles. The 1990s dataset did not have any such entries, but there is a similar frequency of 3%–4% near vehicles of all types.

4) RECREATION

Recreation activities and locations are compared in Table 5. The most frequent activities for recreation involve the category of water, which includes fishing and on watercraft of all types. These percentages are much larger in the 1990s relative to the 1890s dataset. In the 1990s, 12.1% of the deaths are in such situations. Curran et al. (1997, 2000) used *Storm Data* categories to show that 8.1% of U.S. casualties from 1959 to 1994 were in locations related to water. Over 4% of these 1959–94 injuries occurred during camping.

The most frequent 1990s location for the recreation entry is 18% of the deaths occurring on the beach or in or on the water. Some recreation casualties occurred under or near trees; this percentage has increased.

5) SMALL STRUCTURES

The only small-structure activity or location that reached the 1% threshold for these comparisons is 1990s injuries in or near a vehicle (table not shown).

6) SPORTS

Sports activities and locations are compared in Table 6. The most frequent activities in the 1890s were attending a circus and playing baseball, but these did not appear in the recent dataset. Several other activities are evident in the 1990s. The most frequent sports locations were tents and open fields in the 1890s, which are replaced by golf and sporting events in the 1990s. Table 6 shows that 3.3% of deaths and 3.7% of injuries were during golf activity in the 1990s. A similar value of 4.9% was found by Curran et al. (1997, 2000) from *Storm Data* for casualties that were related to golf from 1959 to 1994. Sports locations follow the activities closely.

7) ALL ACTIVITIES

All activities are combined in Fig. 4. A 2% death threshold was used. The most frequent 1890s activities were agriculture, inside a house, in bed/sleeping, plowing, and riding a wagon or horse. In the 1990s, the most frequent activities are boating, golfing, and camping, as well as walking and standing.

TABLE 5. Same as Table 2, but for recreation.

	1890s		1990s	
	Deaths	Injuries	Deaths	Injuries
Recreation activity				
Fishing from shore/boat/dock	0.5	0.5	5.0	0.9
Camping	0.3	1.1	0.3	4.2
Picnic	0.3	0.6	1.3	0.8
Boat/canoe/kayak/jet ski/water ski/wind surfing	—	—	7.1	1.9
Walking	—	—	1.7	0.5
Hiking	—	—	1.3	0.7
Riding bike/motorcycle	—	—	1.3	0.5
Jogging	—	—	1.3	0.1
Recreation location				
Beach/water	1.1	0.5	18.0	7.2
Under/near tree	0.3	1.1	2.5	1.9
Mountain	—	—	2.1	1.3

TABLE 6. Same as Table 2, but for sports.

	1890s		1990s	
	Deaths	Injuries	Deaths	Injuries
Sports activity				
Attending circus	2.1	3.0	—	—
Playing baseball	2.1	1.8	—	—
At/observing sporting event	—	0.5	0.1	5.7
Golf	—	—	3.3	3.7
Playing sports	—	—	0.1	3.4
Sports location				
Tent	2.1	3.0	—	—
Open field	2.1	1.8	<0.1	—
Golf	—	—	3.3	4.1
Recreation (sports)	—	—	2.9	9.0

8) ALL LOCATIONS

All locations are combined in Fig. 5. House and home deaths and those in open fields decreased greatly over the century. Deaths under or near a tree more than doubled. Casualties occurring in farms, barns, school, and work were down, but beach, water, and recreation casualties increased significantly in the 1990s.

c. *Comparisons of additional casualty information*

1) SHELTER TAKEN BY PEOPLE

For all locations combined, the types of shelters deliberately taken by people are compared in Fig. 6; a 1% threshold was applied for entries. Taking shelter under trees is a consistent killer during both centuries. As compared with the 1990s, in the 1890s more people took no shelter from lightning at all or were in agricultural sheds that can be assumed to have been ungrounded.

2) TRANSPORTATION

The transportation context of lightning casualties is compared in Table 7. During the 1890s, victims involved in transportation were most likely to have been on a wagon or buggy being pulled by animals or were on an animal. A few lightning victims were on a horse in the 1990s, usually in a recreation setting. During the 1990s, the most frequent transportation context was on a boat or ship or inside a motor vehicle or tractor.

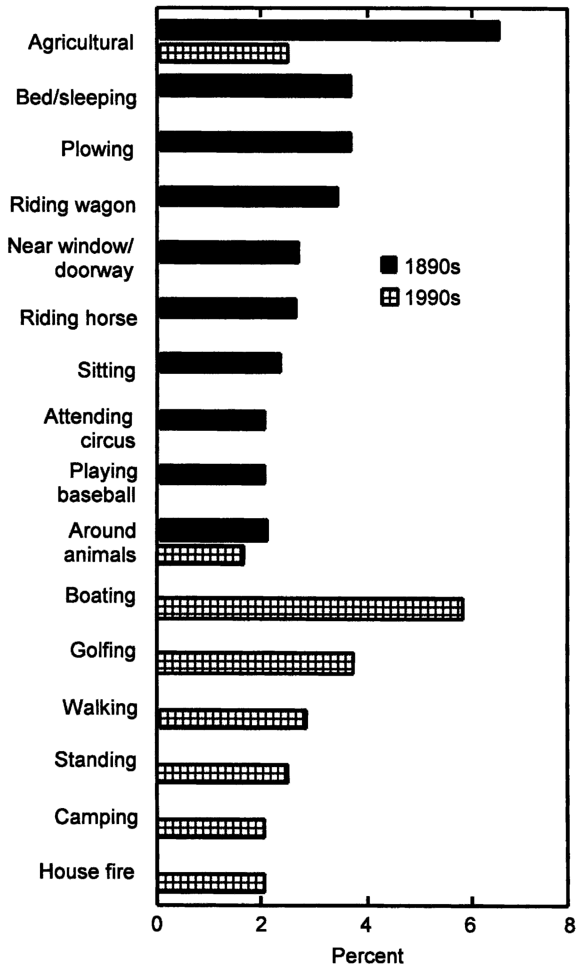

FIG. 4. Comparison of the percentage of the most common lightning death activities 100 yr apart.

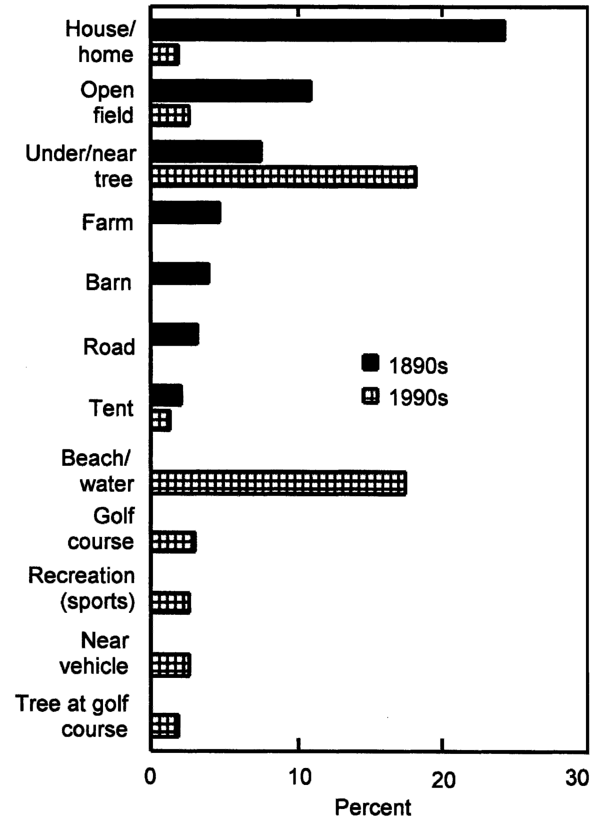

FIG. 5. Comparison of the percentage of the most common lightning death locations 100 yr apart.

3) ANIMALS NEARBY

The presence of animals near lightning victims was also identified. The only entries that exceeded 1% in either century were 11% people killed and 34% injured near or on horses in the 1890s (table not shown).

4) GENDER

The gender of victims is compared in Fig. 7, without unknown cases. The "male and female" category refers to at least one male and one female killed during the same event. In both centuries, males were a dominant part of the deaths. Similar large percentages of male victims were found in the United States by Curran et al. (2000) and Duclos and Sanderson (1990), in Florida by Duclos et al. (1990) and Holle et al. (1993), and in North Carolina by Langley et al. (1991). The same was also found in Singapore by Pakiam et al. (1981), Great Britain and Ireland by Baker (1984), Australia by Coates et al. (1993), England and Wales by Elsom (1993), and Navarra (Spain) by Aguado et al. (2000).

5. Comparisons of damages between centuries

Storm Data from 1991 to 1994 contains many damage entries. When an entry described more than one object being impacted on the same date or in the same region, each description of a damaged object was listed separately, for a total of 3242 descriptions. The utilities category includes the distribution of power and water, as

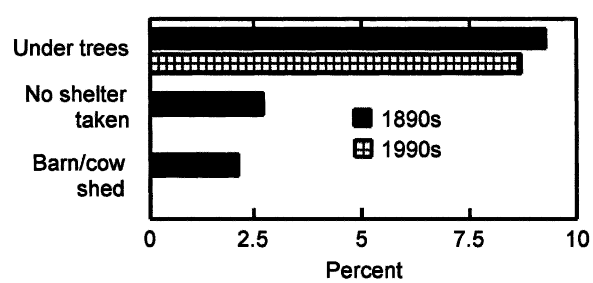

FIG. 6. Comparison of the main types of shelter taken by lightning fatalities 100 yr apart.

TABLE 7. Same as Table 2, but for transportation being taken by lightning casualties.

	1890s		1990s	
	Deaths	Injuries	Deaths	Injuries
Pulled by animals	5.0	2.0	—	—
On an animal	3.0	0.5	0.4	0.9
Boat/ship	—	0.8	6.7	2.0
In motor vehicle	—	—	0.4	1.7
Tractor	—	—	1.3	0.4

well as telephone and cable systems, and the collection of wastewater. The major types of lightning damages are compared in Fig. 8. Farms and animals were the categories most often mentioned for the 1890s. Dwellings account for one-half of the 1990s entries in *Storm Data*, yet the lightning death rate in indoors settings has greatly decreased (Fig. 5). Many other categories are relatively infrequent and similar, although utilities now account for many more entries than in the 1890s. The sampling of damages in both datasets is probably very irregular. Kretzer (1895) tended to mention damages to farm and rural situations, which were probably the most common situations for lightning impact. The importance of animals was shown by Henry (1900) with a state-by-state list of the number and value of thousands of livestock killed by lightning in 1899. In recent years, *Storm Data* has reported lightning damages to utilities and other public facilities that affect a wide population. These widespread impacts are somewhat similar to the other broad impacts of storms, such as floods and tornadoes, for which *Storm Data* is well suited.

The dollar amounts of some of these losses were noted in Kretzer (1895). The reported losses appear to include relatively expensive impacts for that time. Both samples peak in the same category of $500–$5000 (Fig. 9). However, recent losses tend to be larger, which is consistent with an increase resulting from inflation in value during the 1990s relative to the 1890s. Note that these 1990s costs are lower than in *Storm Data*, summarized by Curran et al. (1997) from 1959 to 1994. Insured losses that are better documented in the United

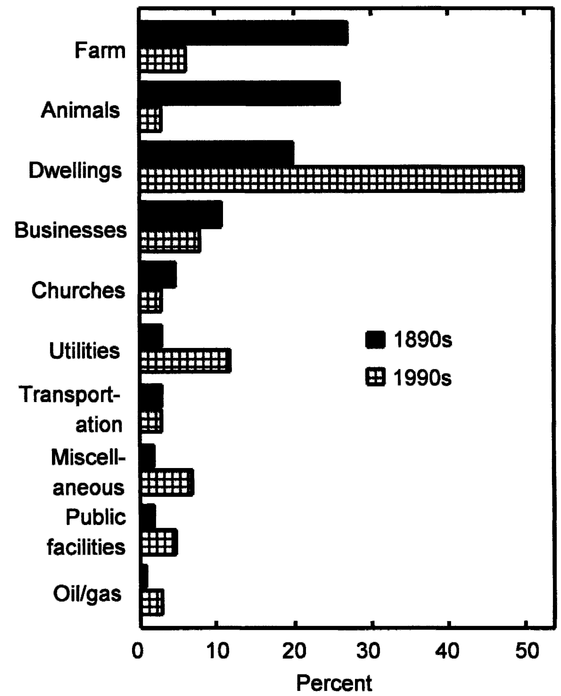

FIG. 8. Comparison of the types of lightning damages 100 yr apart.

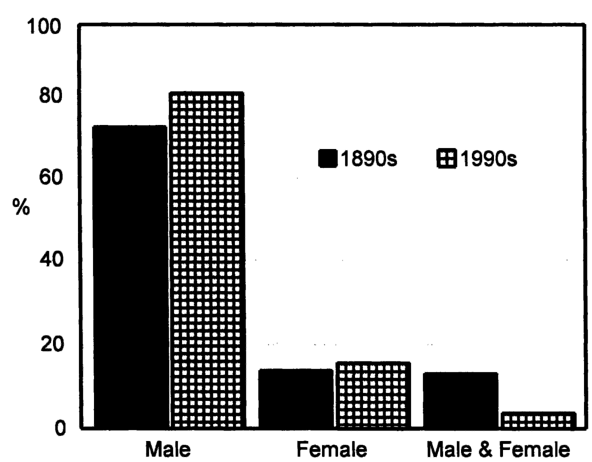

FIG. 7. Comparison of the gender of lightning fatalities 100 yr apart. The rightmost category refers to at least one male and one female killed during the same event.

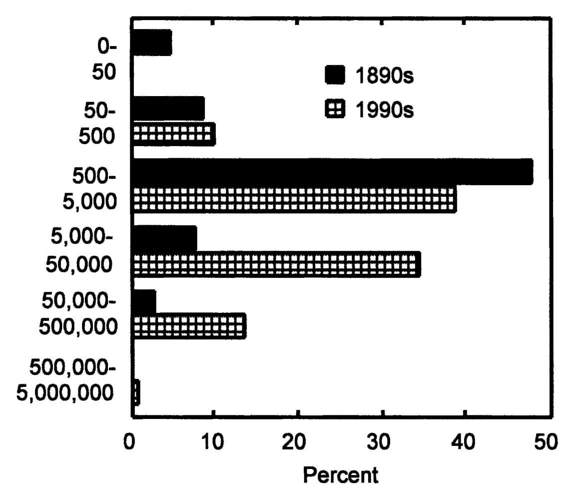

FIG. 9. Comparison, in dollars, of the amounts of lightning losses 100 yr apart (inflation not taken into account).

States from 1987 to 1992 (Holle et al. 1996) are less than those shown for the 1990s dataset in *Storm Data* because this publication tends to include more widely publicized cases with larger costs.

6. Discussion and conclusions

Lightning-related fatality, injury, and damage reports for the United States from 1891 to 1894 were compared with those from 1991 to 1994. The reports were classified by manual analysis of all entries in Kretzer (1895) and *Storm Data* from 1991 to 1994. This detailed inspection of lightning victims profiles separate populations a century apart.

After removing the many unknown entries, the characteristics of the remaining cases were clearly defined. Comparisons of numbers and rates were made only with fatality information, because injuries in the 1890s in rural areas were greatly underreported. Several methods were used to subdivide the features of lightning casualties:

- Three settings were defined—rural, urban, and unknown.
- Seven activities, locations, and types of incidents were defined—agriculture, indoors, outdoors, outdoor recreation, small structures, sports, and unknown.

Major changes were found among the characteristics of lightning victims between the two centuries in many categories:

- A major shift from rural to urban deaths occurred from the 1890s to the 1990s.
- A large reduction in the number of agricultural and indoors incidents took place from the 1890s to 1990s.
- Many more cases involve outdoor recreation and sports in the 1990s. Many of the outdoor recreation activities and locations involved fishing, boating, and proximity to the beach or water in the 1990s.

The change concerning indoors victims consisted mainly of incidents inside dwellings. Houses are now better grounded than a century ago because of the installation of power, plumbing, and telephones over this time period. A lightning strike to a dwelling in the 1890s often resulted in a fire or killed people during routine household activities. In recent years, however, such a strike usually caused a casualty only when a person was in direct contact with power, telephone, or plumbing that brings the lightning's current into a building.

Three interesting similarities were found:

1) Outdoor deaths occurred often in both periods, and grew from 29% in the 1890s to 45% in the 1990s.
2) About 9% of the deaths occurred when people took shelter under trees in both centuries.
3) Males accounted for 73% of the deaths in the 1890s and 81% in the 1990s dataset.

In summary, a U.S. lightning fatality in the 1890s most often was in an indoors, outdoors, or agriculture activity/location in a rural setting. In the 1990s, a victim was most often in an outdoors or recreation activity/location in an urban setting. As a result, current U.S. lightning avoidance education programs should place less emphasis on indoor and agricultural situations and more emphasis on behavior in outdoor and recreation situations, including the danger of seeking safety under trees and being in or near water.

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