ENVIRONMENTAL RESEARCH 10, 1–13 (1975)

Mortality during Heat Waves in New York City July, 1972 and August and September, 1973

F. P. ELLIS,[1] F. NELSON, AND L. PINCUS

Medical Research Council's Environmental Physiology Unit, London and Department of Health, New York City

Received April 25, 1974

Analysis of the causes of death by day of occurrence during two heat waves in New York City in 1972 and 1973 established that there was a great increase in the numbers of deaths in each heat wave after several days of excessively warm weather and on the day which followed the hottest day.

On both these days deaths from ischaemic heart disease were far and away the most prominent cause of death and the great majority of those who died were 65 years of age or older.

The observation that deaths from ischaemic heart disease in New York City heavily outnumbered deaths from cerebrovascular accidents on the two days which followed the hottest day of each of these heat waves is at variance with earlier observations which indicated that deaths from cerebrovascular accidents during months when severe heat waves occurred in the United States as a whole, and in certain states particularly affected by the heat waves, were a more prominent cause of death than ischaemic heart disease. The reason is obscure.

The number of homicides in July, 1972 were significantly greater than the numbers for any of the first 8 months of the year; but the increase occurred after the heat wave was over not during the heat wave. This increase was not apparent after the shorter, though warmer, period of hot weather in 1973.

Scrutiny of death certificates showed that despite the large excess of deaths above expected numbers during the heat wave in 1973 heat effects were shown on only 30 death certificates during the entire summer and on each certificate this was only one of a number of multiple causes of death. If the tabulation of deaths due to organic disease were to take precedence over deaths due to environmental causes in health reports it is possible that not even these deaths would have been shown as deaths due to excessive heat.

Both heat waves were less severe than others which have occurred in New York during the past century and very much less severe than heat waves in other cities in the United States during the last twenty years.

If conditions comparable to those which occurred in August, 1896, were to recur today (and this is always a possibility) and the power supplies failed to keep the city's electrically powered services operating at or near to maximum capacity, there could be an environmental disaster of unprecedented proportions.

Sporadic heat waves are an occasional and dramatic feature of the climate in the United States but there have been few prospective attempts to assess the impact on mortality and morbidity. A recent review of statistical and meteorological data published up to 1967, from the John B. Pierce Foundation Laboratory and Yale University School of Medicine, New Haven, was made possible

Requests for reprints to F. P. Ellis, M.R.C. Environmental Physiology Unit, London School of Hygiene and Tropical Medicine, Keppel St., London WCIE, 7HT.

from 1952 onwards by the inclusion in the General Mortality Tables by Month of the Annual Reports of the National Center for Vital Statistics, of deaths from "excessive heat and insolation (E 931)," the generic grouping (World Health Organization, 1967) under which deaths from acute heat illness are tabulated (Ellis, 1972). There were severe heat waves, involving more than half the states in some years, in the summers of 1952, 1953, 1954 and 1955 and the next did not occur until 1966. Thus, by 1971 these had been five heat waves of considerable magnitude in 20 years for which there were available monthly mortality figures for more than 250 common causes of death, including deaths due to excessive heat.

In months when unusually large numbers of heat deaths appeared in the tables, deaths from all causes provided a more reliable measure of the effect of hot weather than deaths tabulated to be due to heat alone. The validity of the latter varied with certification and coding instructions from state to state and from year to year. The majority of excess deaths were deaths of people who already had cerebrovascular or cardiovascular disease as observed earlier in Detroit, Michigan, by Schuman, Anderson, and Oliver (1964), in New Haven by Florey, Senter and Acheson (1967) and in 11 eastern and midwestern states by Helfand and Bridger (1971).

There was a requirement for further investigation at the national level and in cities where heat illness occurs during the summer months. New York City was an obvious candidate for a pilot study. Heat waves are relatively common; the serious impact of the 1966 heat wave had been reported by Schuman (1967), Levine (1969) and Buechley (1971), and the City's Department of Health records deaths from all causes and selected prominent causes by day of occurrence. Even during a mild 5-day hot spell, which was little more than an Indian Summer, towards the end of September, 1971, there were significantly more deaths from all causes (276) on the third day, which followed the day with the highest maximum temperature (92°F, 33.3°C), than on any other day in the month for which the average daily number of deaths was 224. The daily deaths did not exceed 276 on any day during four winter months which followed except for two excessively cold days during Christmas week (Nelson, 1970, 1971; Ellis, 1972). In July, 1972, a more prolonged warm spell provided a better opportunity to examine the daily climate–mortality relationship and just as we were about to report on this another heat wave occurred at the end of August and during the first week of September, 1973.

JULY, 1972

The climate. The hot weather lasted from 14–25 July inclusive. An abstract from the Climatological Data Sheets for Central Park (National Oceanic and Atmospheric Administrations's Environmental Data Service (NOAA), 1972a) together with the daily deaths, is included in Table 1. The highest maximum air temperature (which was also equalled on 19 July), the highest minimal (night) temperature and nearly the maximal hours of sunshine occurred on 23 July, although the dew-point temperature was lower than it was on some other days and the wind speed was higher than usual. The Annual Summary for the Central

TABLE 1
DAILY DEATHS AND METEOROLOGICAL DATA, NEW YORK CITY 14–26 JULY, 1972
(CENTRAL PARK OBSERVATORY)

Date	Daily deaths	Maximum air temperature (°F)	Maximum air temperature (°C)	Minimum air temperature (°F)	Minimum air temperature (°C)	Average air temperature (°F)	Average air temperature (°C)	Departure from normal (°F)	Average dew-point temperature (°F)	Average dew-point temperature (°C)	Degree days cooling**	Percent of possible sunshine	Average wind speed* (mph)	Average wind speed* (ft/s)
July														
14	225	89	31.7	73	22.8	81	27.2	+4	69	20.6	16	82	7.3	3.3
15	246	93	33.9	76	24.4	85	29.4	+8	70	21.1	20	97	8.2	3.7
16	249	90	32.2	75	23.9	83	28.3	+6	71	21.7	18	71	7.1	3.2
17	293	92	33.3	74	23.3	83	28.3	+5	70	21.1	18	62	4.6	2.1
18	294	89	31.7	76	24.4	83	28.3	+5	72	22.2	18	59	5.5	2.5
19	280	94	34.4	76	24.4	85	29.4	+7	72	22.2	20	100	4.9	2.2
20	313	88	31.1	72	22.2	80	26.7	+2	70	21.1	15	37	7.3	3.3
21	240	92	33.3	72	22.2	82	27.8	+4	72	22.2	17	22	6.3	2.7
22	246	92	33.3	75	23.9	84	28.9	+6	68	20.0	19	99	6.5	2.9
23	325	94	34.4	79	26.1	87	30.6	+9	70	21.1	22	99	9.5	4.2
24	390	91	32.8	78	25.6	85	29.4	+7	63	17.2	20	100	9.1	4.1
25	303	91	32.8	73	22.8	82	27.8	+4	62	16.7	17	52	7.8	3.5
26	251	80	26.7	66	18.9	73	22.8	−5	56	13.3	8	76	10.1	4.5
Average for July	239	85.1	29.4	69.2	19.6	77.2	25.1	+0.4	63	17.2	—	63	7.0	3.1

* 1 mph = 0.447 m/s.
** Base 65°F (18.3°C).

Park Observatory (NOAA, 1972b) shows July, 1972, to have been the hottest month of the year. The average daily maximum and minimum temperatures were 85.1°F (29.5°C) and 69.2°F (20.6°C). The average relative humidity (at 0700) was 77% and the temperature–humidity index (Thom, 1957) reached the high value of 384 "degree days cooling." However the average daily air temperature, for the month, 77.2°F (25.1°C), was not exceptionally high. It was exceeded in 10 of the preceding 29 years and equalled on one occasion.

Mortality. The average number of deaths by day in July, 1972, was 239 (S E = 15.5). This was a high average as the numbers from which it is derived include abnormally high numbers of deaths during the heat wave. Even so, on 24 July there was a notable increase of 151 deaths above this inflated average figure. During heat waves the day with the maximum number of heat deaths frequently follows the day with the maximum temperature with a 1-day lag (Kutschenreuter, 1956; Oechsli and Buechley, 1970). The increase in the number of deaths on 20 July, following the second highest air temperature recorded on 19 July, shows a similar, but much less clearly demarcated, trend.

A total of 2,319 deaths were reported during the week ending 28 July, in marked contrast with 1,428 deaths during the same week in 1971 and 1,592 deaths in 1970. This was the greatest number of deaths reported in 1 week since December, 1968, when New York was in the throes of an epidemic of upper respiratory tract disease. Only 10 of these deaths were reported to be due to the effects of heat. The assumption made earlier that the "excess" deaths from all causes during heat waves was at least 10 times as great as the numbers of deaths

TABLE 2
DAILY DEATHS DUE TO CARDIOVASCULAR RENAL DISEASE (CVR) AND TO HYPERTENSIVE, ISCHAEMIC AND CEREBROVASCULAR DISEASE, NEW YORK CITY

Date	Total CVR	Hypertensive	Ischaemic	Cerebrovascular
14	123	2	100	11
15	123	3	95	12
16	139	2	103	18
17	148	2	96	30
18	151	4	120	12
19	142	1	104	23
20	154	4	111	28
21	126	1	95	13
22	128	0	99	13
23	164	4	120	22
24	240	4	190	30
25	168	1	131	18
26	132	2	104	19
July average	127	2.4	95.5	16.1
SE	11.3	1.5	9.8	4

reported to be due to excessive heat alone (Ellis, 1972) was certainly too conservative on this particular day.

Cardiovascular renal disease. The deaths attributed to all cardiovascular renal disease (CVR), including cerebrovascular disorders, are given above in Table 2. On 24 July there were 190 deaths from ischaemic heart disease alone. This enormous increase, the July average for this cause was only 95.5 deaths per day, was not reflected by deaths from hypertensive or cerebrovascular disease, and there was not a similar large increase, although there was an increase, after the first temperature peak on 19 July.

Homicides. Schuman (1967) observed that homicides contributed significantly to the excess deaths in New York City in July, 1966. In the United States that year there were 300 more homicides in July than in June (Ellis, 1972). In July, 1972 there were 199 homicides in New York City, in contrast with an average monthly rate of 142 for the first 8 months of the year. The next highest number occurred in August when there were 158 homicidal deaths. If excessive warmth is indeed a factor which aggravates homicidal tendencies, it is remarkable that on the 24 July, the warmest day, there were only two homicides, less than on any other day in the month, for which the daily rate was 6.6. On average there were only about four homicides daily from January to August inclusive. The greatest number (18) were reported on 29 July, four days after the heat wave ended and the second greatest number (12) on 15 July, the second day of the heat wave when the maximum temperature rose into the 90's for the first time. Thus an increase in the number of homicides was not related obviously to the peak temperatures. There was only one other day in the first eight months of 1972 with more than 9 homicides, the 17 June, when 12 were reported, and although the weather was warm the conditions were not remarkable that day.

Age and race. Scrutiny of the General Mortality Tables for the United States since 1952 indicated that "below 50 years of age the heat-death rate was higher in infants than in any other age group; above 50 years of age the rate becomes higher in adults and progressively so with advancing age" (Ellis, 1972). On 24 July in New York City 8 infants (6 white, 2 nonwhite) below the age of 1 year died. Only two young children (both white) between the ages of 1 and 5, 2(1 white, 1 nonwhite) in the 5–14 age group, 11 young adults (5 white, 6 nonwhite) in the 15–24 age group and 24 adults (12 white, 12 nonwhite) aged 25–44 succumbed. The effects of increasing age then became more prominent with 90 deaths (80 white, 10 nonwhite) from 45 to 64 years of age and 253 (225 white, 28 nonwhite) were 65 or older, significantly more than the average daily death rate for the month for all other age groups.

However, scrutiny of the figures for other days of the month showed that the 8 infant deaths on 24 July did not differ significantly from the infant mortality on other days when the weather was not unduly warm. Thus under the conditions of this heat wave it would appear that this age group was not susceptible to heat stress although there were more deaths from all causes in infants than in the young children, adolescent and young adult age groups as there were on other days also. On the other hand there were certainly more deaths in the 45–64 age group on 24 July than on any other day in the month and there were many more deaths of persons who were 65 or older, the daily average for this group for the month being 153 with 205 deaths on 25 July the greatest number on any other day.

There were 331 deaths of white persons and only 59 of nonwhite persons on 24 July and, as the ratio for whites to nonwhites in New York City was approximately 3.3 : 1, the proportion of white people who died from all causes that day was appreciably greater than for the nonwhite population, in contrast with the general trend in recent years observed during heat waves in the United States as a whole (Ellis, 1972).

AUGUST–SEPTEMBER, 1973

The climate. The heat wave lasted from 28 August to 4 September inclusive, with maximum temperatures in excess of 93°F (33.9°C) every day. On 30 August the minimum temperature was 78°F (25.6°C) and the maximum 98°F (36.7°C). This was a hotter heat wave than in July 1972 but it did not last so long.

Mortality. During August there were on average 219 deaths each day. On 31 August, the day after the hottest day, a maximum of 332 deaths for the month was reported. During the first six days of September there were 264, 294, 277, 308, 268, and 238 deaths, respectively, all above the average of 226 for September but well below the figure for 31 August.

There were 1,910 deaths during the week ending 7 September, 1973, about 25% more than the expected number and this did not include the day with the greatest number of deaths, 31 August. In spite of this large number of excess deaths scrutiny of the death certificates for the whole summer showed that death was only certified to be due in part to the effects of heat, variously certified as

heat stroke, heat prostration, heat exhaustion or hyperpyrexia, in 30 cases between 11 June and 21 October. Twenty-two occurred during 8 days, 31 August–7 September, when the maximum daily air temperature exceeded 90°F (32.2°C). The vulnerability of ageing persons to excessive environmental warmth was evident. Only 5 were under 50 years of age, the youngest being 35; 4 were between 51 and 64, 7 between 65 and 75, and 14 were over 75 years of age.

Multiple causes of death were shown on every one of these certificates, and comprised, in addition to the effects of heat, arteriosclerotic heart disease (10), pneumonia (7), cardiac arrest (6), diabetes (5) congestive heart failure (3), urinary infection (3), arthritis or inability to ambulate (3), sepsis (5), cerebro-vascular accidents (2), hypertension (2), pulmonary embolism (2), pulmonary oedema (1), hepatitis (1), renal failure (1), pulmonary aspiration (1), generalised arteriosclerosis (1), hyperthyroidism (1), sequelae of poliomyelitis (1), decubitus ulcer (1) and obesity (1). The last was a man only 48 years of age. Very obese people rarely reach old age. If the practice of tabulating organic disease as the primary cause of death when organic disease and environmental causes appear together on a death certificate were followed, none of these deaths would appear as heat deaths in mortality tables.

Cardiovascular renal disease. The pattern was similar to that for 1972. Deaths from ischaemic heart disease overshadowed all other causes. On average there were 74.6 deaths daily during August, but on the fourth day of the heat wave (31 August) deaths from ischaemic heart disease jumped from 94 deaths on 30 August to 141, to be followed by 96, 117, 102, 116, 106, and 107 on the first six days of September; the number falling to 81 on 7 September when the heat wave was over. During September there were on average 78.5 deaths from ischaemic heart disease daily so that the figures for September are not so remarkable as those for August.

On average, 14 deaths were attributed to cerebrovascular accidents during July and August. During the 8 days when the maximum daily temperature exceeded 93°F (33.9°C), this figure was always exceeded (15, 19, 17, 19, 19, 21, 21, 27, respectively). The figures on 31 August were not remarkable but they were on 4 September, the last day of the heat wave, when 27 deaths were reported, 22 on 18 September being the largest number on any other day.

Deaths associated with hypertensive disease as a primary cause were even less remarkable, the average daily number being 1.6 for the 2-month period and 4 the largest number on any one day.

Homicides. There were on average 4.7 homicides daily during the two months. On the 8 days when the maximum temperature exceeded 90°F (32.2°C) there were 3, 8, 6, 2, 1, 6, 7, and 5 homicides. The increase after the heat wave observed in 1972 was not observed in 1973.

Age and race. The age distribution on 31 August was very similar to the distribution following the hottest day in 1972 (24 July). There were 5 deaths in infants under 1 year of age, 80 from 45 to 64 and 207 deaths of persons of 65 years of age and over. There were only 5 deaths in the 1–4 age group, 2 in the 5–14 age group, 9 between 15 and 24 and only 24 between 25 and 44, which again emphasises that ageing people comprise the bulk of the heat fatalities in civil populations.

There were 269 deaths of white persons and 63 deaths of nonwhite persons on 31 August. Thus the proportion of white persons who died after the hottest day in 1973 was greater than the proportion of nonwhite persons as in 1972.

DISCUSSION

July, 1972. The most notable features were that the maximum air temperature remained above 88°F (32.1°C) without respite for 14 days with temperature peaks on 19 and 23 July. If the heat wave had terminated on 22 July the numbers of deaths on any one day would not have been extraordinary. On 11 and 12 July the maximum temperatures were 89°F (31.7°C) and 90°F (32.2°C) but the maximum air temperature did not exceed 75°F (23.9°C) on 13 July and the numbers of deaths for these three days were below the average for the month (213, 215 and 216).

The difference between 390 deaths on 24 July and only 313 on 20 July is remarkable as the maximum air temperatures and average dew-point temperatures on the previous days were identical and they were both very sunny days; but by 23 July there had been 4 more days of continuing hot weather and the minimum ("night") temperature on 23 July was 3°F (1.7°C) higher than on 19 July. Such a difference in the average 24-hour air temperature has an appreciable effect on thermal comfort and on cardiac output at these levels of warmth, especially for persons with myocardial disease, and in many homes the temperatures were probably considerably higher than the levels recorded in Central Park. This added heat burden after 14 days of hot weather proved utterly intolerable for about 151 people who would not have died if the heat wave had ended earlier. The number of deaths from ischaemic heart disease on 24 July was twice the daily average for the month and this was certified to be the outstanding cause of the heavy mortality on that day, largely in persons aged 65 or older.

An unpublished vacation study made with the City Department of Health by Nacht, Schub and McClurg (1973) eliminated air pollution by sulphur dioxide, carbon monoxide and smoke as associated causes of deaths during this heat wave. These investigators found that the causes which "showed a percent increase greater than the increase from all causes" were respiratory tuberculosis, pneumonia and total cardiovascular renal disease, and that as the number of consecutive days with a maximum air temperature above 90°F (32.2°C) increased so did the number of deaths. Thus, with one day with the temperature in the 90's there were 224 deaths, with three consecutive days 252 deaths and with five consecutive days 301 deaths. They also found that the daily mortality during the post-heat wave period was no less than it was during the pre-heat wave period. In other words the majority of those who died in the heat wave were not persons who would have died anyway about that time if the heat wave had not occurred as some have suggested when other similar episodes have been described.

August–September, 1973. This heat wave was less prolonged than that of July, 1972, although the maximum daily air temperatures were higher. In July, 1972, the highest daily maximum was 94°F (34.4°C) recorded on only two days. This air temperature was equalled or exceeded on 6 days in 1973 on 28, 29, 30, 31 August, and 2 and 3 September, respectively. It would appear that August, 1973, was also a warmer month overall than July, 1972, as there were 401

"degree days cooling" compared to 384 in the previous year, yet the mortality was much lower. September, 1973, was a much cooler month; there were only 171 degree days cooling (NOAA, 1973 a, b). It is probable that the lower mortality in 1973 was primarily due to the shorter duration and also the nonoccurrence of the second late very warm day which proved so disastrous in 1972. Otherwise the pattern was similar. Deaths of ageing persons accounted for most of the excess deaths and ischaemic heart disease was the most prominent cause of death on the day following the hottest day.

General comments. The unexpected increase in deaths from ischaemic heart disease in comparison with the increase from vascular disorders of the brain which was observed in both heat waves on the day after the hottest day is at variance with the findings of earlier studies on heat deaths by month for the United States as a whole, and also for a large group of states during the 1966 heat wave, which identified vascular lesions of the central nervous system as the most prominent cause of excess deaths rather than heart disease (Helfand and Bridger, 1971; Ellis, 1972). In the former study there was an increase in mortality from arteriosclerotic heart disease and "other" diseases of the heart in 1955 and 1966, but on nothing like the scale to suggest the complete overshadowing of deaths from cerebrovascular accidents, "other" cardiac disease and hypertension by ischaemic heart disease which occurred on these two days in 1972 and 1973 in New York City.

Perhaps, more than anything else, this confirms the scientific importance and practical value of the continuous scrutiny of causes of death by day-of-occurrence in urban and rural areas by retrospective examination of death certificates and possibly, in future, by the prospective examination of the findings of medical examiners whose enquiries into the causes of death now embrace almost 50% of all the deaths which occur in certain areas and provide more accurate information than that entered on death certificates in cases not reported to the examiner.

The value of the average daily air temperature as a guide to the severity of climatic stress has been stressed recently by Rogot (1973). He examined the association between mortality and cardiovascular disease and the weather at Midway Airport in Chicago for each day in 1967. He found that the daily average temperature was the variable most strongly associated with mortality due to cardiovascular disease, the other variables being high and low temperatures, precipitation, snowfall, snow on the ground at 6 A.M., average wind speed, total sunshine, percent of possible sunshine and maximum and minimum relative humidity. There was an inverse relationship for temperature versus arteriosclerotic heart disease (ASHD), which includes deaths from ischaemic heart disease, but no clear-cut pattern was observed for temperature versus deaths from vascular lesions effecting the central nervous system. The impact of excessively warm weather upon vascular diseases of the heart and the central nervous system is thus highly complex and requires further study; but the adverse effect on total mortality, especially in ageing persons, is undoubted and profound.

Burch and his colleagues have directed attention repeatedly to the vulnerability to thermal stress of persons with myocardial damage or cardiac failure (Burch and DePasquale, 1962; Burch and Miller, 1969; Burch and Giles, 1970),

and Burch and Ansari (1968) reported that patients with congestive heart disease do not acclimatise so well as normal controls. An air-conditioned room can be life-saving for such persons when they are exposed to unseasonal warmth.

The relatively small numbers of homicides on the day when the greatest numbers of heat death occurred in July, 1972 does not support the thesis that homicidal tendencies are aggravated directly by unseasonal warmth but the spate of 58 homicides which occurred on the last six days of the month after the heat wave is suggestive of a possible indirect effect of unduly prolonged thermal stress. It is of interest that this post-heat wave upsurge in homicides in 1972 did not recur after the shorter heat wave in 1973.

This was not the most severe heat wave New York City has experienced during the past century as the Annual Report of the New York City Health Department for 1896 bears witness. The more relevant sections of this excellent account are abstracted below:

> The most remarkable item in the Table 3 is the extraordinary and altogether unprecedented number of deaths from sunstroke, viz., 765, or 680 more than the number in 1895. The largest number of deaths from this cause ever previously recorded in this city was 320 in 1872, and again in 1892. In 1866 there were 310. With these exceptions, the number has never risen as high as 200 but four times since the records were first made up in 1804, viz., 211 in 1853, 238 in 1870, 206 in 1876, and 216 in 1887. It will be of interest here to compare the three extremely hot periods of 1872, 1892 and 1896.
>
> It will be observed that the week preceding the week of greatest mortality was a week of very moderate temperature in 1872 and 1892, while in 1896 there were five days when the temperature rose to 90 degrees or upwards. Notwithstanding this continued high temperature, however, the mortality for the week was low, only 809 deaths having been reported. In the week of the highest mortality there were five days in each year in which the temperature rose to 90 degrees or more, the average of the maximum temperature being 93.4 degrees in 1872, 92.7 degrees in 1892 and 91 degrees in 1896; and the mean temperature for the week being, in 1872, 83.7 degrees; in 1892, 82.9 degrees, and in 1896, 84.2 degrees, the very high mean of 1896 being due to the fact that the nights were very warm, adding very materially to the oppressiveness of the heat. The week of the greatest mortality in 1896 was, therefore, not only a week of very high temperatures, fairly comparable with those of 1972 and 1892, but was even more oppressive, and was itself preceded by a week of very high temperature, the average of the maximum temperatures for the preceding week having been, in 1872, 79 degrees; in 1892, 82.6 degrees, and in

TABLE 3

Cause of death	Deaths 1895	Deaths 1896	Increase in 1896	Decrease in 1896
Pneumonia	5,751	5,383	—	368
Phthisis	5,205	4,994	—	211
Bright's disease and nephritis	2,519	2,685	166	—
Sunstroke	85	765	680	—
Accidents	1,960	1,876	—	84
Suicides	376	384	8	—
Homicides	76	71	—	5
All others	15,097	14,714	—	383
Totals	43,420	41,622	975	2,773

TABLE 4

Date			Maximum temperature			Deaths reported daily			Deaths reported weekly		
1872	1892	1896	1872	1892	1896	1872	1892	1896	1872	1892	1896
			Degrees	Degrees	Degrees						
June 23	July 17	Aug 2	83	76	82	115	158	78			
24	18	3	73	82	86	102	149	112			
25	19	4	67	80	90	133	154	139			
26	20	5	74	83	94	96	164	108	769	1,081	809
27	21	6	78	82	92	105	138	109			
28	22	7	88	86	97	117	151	131			
29	23	8	90	89	95	101	167	132			
June 30	July 24	Aug	96	89	98	149	179	146			
July 1	25	10	96	93	94	184	190	129			
2	26	11	97	96	96	210	187	240			
3	27	12	94	91	93	302	171	335	1,569	1,434	1,810
4	28	13	95	97	90	267	198	374			
5	29	14	89	97	81	236	223	321			
6	30	15	87	86	86	221	286	265			
July 7	July 31	Aug 16	87	74	85	170	302	127			
8	Aug 1	17	83	79	77	150	210	124			
9	2	18	84	73	75	157	159	151			
10	3	19	87	83	72	150	125	114	1,056	1,181	822
11	4	20	89	88	72	162	107	92			
12	5	21	84	81	75	130	125	108			
13	6	22	83	85	72	137	153	106			

1896, 90.9 degrees, and the mean temperature having been, in 1872, 72.6 degrees; in 1892, 71.7 degrees, and in 1896, 82.2 degrees.

The mean temperature of the hot week of 1896 having been so high and that of the preceding week so much higher than in 1872 or 1892, it is very remarkable that the mortality should have increased so slowly. In 1872 there were six successive days on which the temperature rose to 90 degrees or more, and the greatest number of deaths reported was on the fifth day; in 1892 there were five successive days with a maximum temperature of 90 degrees or more, and the greatest number of deaths was reported on the seventh day from the first; in 1896 there were ten days when the maximum temperature reached 90 degrees or upward, and the greatest number of deaths was reported on the tenth day, while as soon as the hot spell came to an end, the mortality immediately dropped to the normal number, the deaths reported for the succeeding week having been only 822.

The figures which are given in Table 4 represent the reported mortality, i.e., the number of certificates of death presented daily at the burial permit office. The actual number of deaths occurring each day has been ascertained for the hot week alone of each year and is given in Table 5.

It will be seen that in each week the greatest number of deaths for one day coincides with the greatest number of deaths from sunstroke, and, on comparing this table with the previous one, it will be seen that in 1872 the greatest mortality was on the fourth day of extreme heat, in 1892 it was on the fifth day, and in 1896 it was on the eighth day.

In 1872 and 1892 the period of extreme heat was entirely included in the week named in the last preceding table, but this week comprised only one-half of the hot period of 1896, and it will

TABLE 5

Date			Actual no. of deaths daily			Deaths from sunstroke		
1872	1894	1896	1872	1892	1896	1872	1892	1896
June 30	July 24	August 9	191	175	233	7	—	62
July 1	25	10	247	177	325	34	2	133
2	26	11	351	199	386	68	6	181
3	27	12	238	201	313	43	16	151
4	28	13	227	285	234	44	50	86
5	29	14	184	350	177	12	106	47
6	30	15	153	228	113	4	51	11
			1,591	1,615	1,781	212	231	671

be of interest to observe the very gradual increase of the actual mortality for the first five days of the hot spell, as follows:

Table 6 clearly shows that the continued high temperature did not appreciably affect the mortality until the fifth day of its continuance.

These alarming figures received added emphasis from the fact that in terms of mortality, apart from this episode, 1896 was the healthiest year on record since the first Report in 1804. This outstanding account anticipated by nearly 80 years the observation concerning the adverse effect of unduly hot nights as well as hot days. Rogot's identification of the average daily air temperature as the meteorological variable with the most significant effects on mortality and the observation by Nacht, Schub and McClurg that the more numerous the consecutive days of severe heat the higher the death toll.

Air temperatures as high as 112°F (44.4°C) were recorded in the City Hall Plaza where ten people died and there were 386 deaths on 11 August (in the much smaller population of those days) of which 181 were due to "sunstroke" (Greenberg and Field, 1965).

The havoc which resulted provides a warning of the grave emergency with which the authorities might have to cope if conditions of similar severity were to occur today, with the present critical balance between power supplies and the consumption of power by the wide use of air conditioning, which constitutes the first line of defence for many people who are no longer as well acclimatised to

TABLE 6

Date	Actual deaths	Sunstrokes
August 3	98	—
4	120	1
5	137	3
6	139	6
7	122	3
8	172	22
Total	788	35

summer warmth as earlier generations because they have become reliant on air cooling and dehumidification in their homes, workplaces, stores, motor cars and public transport. Further, if the air conditioning should fail, few people living an air-conditioned existence are prepared, as their forebears were, to offset the deleterious effects of unexpected excessive warmth by increasing air movement, and thus evaporative cooling of the body, with cross ventilation draughts through large doors and windows sited for the purpose and a wide variety of ventilation fans and fans for circulating the air within compartments. The conflicting priorities for reducing fuel consumption and the power output of generating stations to control air pollution, which frequently accompanies heat waves, instead of augmenting power supplies to ensure the maximal use of electricallypowered air-conditioning installations, fans and refrigeration systems raises complex questions for the policy makers which are vitally important to the conservation of health and indeed of life itself and to which they do not yet appear to have found the answers.

ACKNOWLEDGMENTS

We wish to acknowledge the permission of Dr. Joseph A. Cimino, Commissioner for Health, New York City to publish the mortality data, the most helpful cooperation of Mr. William H. Haggard, Director National Climatic Center, Ashville, North Carolina, for providing the meteorological data, advice from Dr. Isadore Rossman, Assistant Director for Chronic Disease, New York City Health Department and the assistance of Mr. K. Llewellyn, Royal Marines, for careful typing of numerous drafts. The study was completed while one of us (FPE) was a consultant to the American Institute of Biological Sciences on an Office of Naval Research Contract (N00014-70-A-0104-0002).

REFERENCES

Buechley, R. W. (1971a). Heat island equals death island? Report from the Epidemiological Section, Ecological Research Brance, Division of Health Effects Research, Air Pollution Control Office, North Carolina.

Burch, G. E., and Depasquale, N. P. (1962). Hot climates; man and his heart. Thomas, Springfield, IL

Burch, G. E., and Miller, G. C. (1969). Effects of warm, humid environment on patients with congestive heart failure. *Southern Med. J.* **62,** 816.

Burch, G. E. and Giles, T. D. (1970). The burden of a hot and humid environment on the heart. *Modern Concepts of Cardiovascular Disease* **8,** 115.

Burch, G. E., and Ansari, A. (1968). Artificial acclimatisation to heat in control subjects and patients with chronic heart failure at bed rest. *Amer. J. Med. Sci.* **256,** 180.

Ellis, F. P. (1972). Mortality from heat illness and heat-aggravated illness in the United States. *Environ. Res.* **5,** 1–58.

Florey, C. DuV., Senter, M., and Acheson, R. (1967). A study of the validity of the diagnosis of stroke in mortality data. *YALE J. Biol. Med.* **40,** 148.

Greenberg, L. and Field, F. (1965). The deadly heat wave of '96. *In Reader's Digest,* August.

Helfand, L. A. and Bridger, C. A. (1971). Hippocrates, thermal stress and stroke mortality. *Weatherwise,* in press.

Kutschenreuter, P. H. (1959). A study of the effect of weather on mortality. *Trans. N.Y. Acad. Sci.* **22,** 126–138.

Levine, J. A. (1969). Heat stroke in the aged. *Amer. J. Med.* **47,** 251–256.

Nacht, C., Schub, A., and McClurg, S. (1973). A study of heat-associated deaths in New York City during July–August, 1972. Unpublished.

National Center for Health Statistics U.S. Department of Health Education and Welfare. (1952–1967). Reports on Vital Statistics of the United States. Vol. II.

National Oceanic and Atmospheric Environmental Data Service U.S. Dept. of Commerce (NOAA) Central Park Observatory, New York City Local Climatological Data (a) July, 1972.

National Oceanic and Atmospheric Environmental Data Service U.S. Dept of Commerce (NOAA) Central Park Observatory, New York City Local Climatological Data (a) August, 1973.

National Oceanic and Atmospheric Environmental Data Service U.S. Dept. of Commerce (NOAA) Central Park Observatory, New York City Local Climatological Data (b) September, 1973.

National Oceanic and Atmospheric Environmental Data Service U.S. Dept. of Commerce (NOAA) Central Park Observatory, New York City, (1972 b). Annual Summary With Comparative Data.

New York City Department of Health. (1896). Annual Report.

Nelson, F. (1970). New York City Dept. of Health., personal communication.

Nelson, F. (1971). New York City Dept. of Health., personal communication.

Oechsli, F. W., and Buechley, W. B. (1970). Excess mortality associated with three Los Angeles September hot spells. *Environ. Res.* **3**, 277.

Pincus, L. (1972). City of New York Vital Statistics. Week Ending July 28, 1972.

Rogot, E. (1973). Association of cardiovascular mortality with weather-Chicago 1967. ASHRAE Symposium on Air-conditioning, Climatology and Public Health. 22–25 August, 1971.

Schuman, S. H., Anderson, C. P., and Oliver, J. T. (1964). Epidemiology of successive heat waves in Michigan in 1962 and 1963. *J. Amer. Med. Ass.* 733–738.

Schuman, S. H. (1967). Effects of heat waves on mortality in St. Louis, New York and the Midwest in 1966. *Abstr. Joint Ann. Meet. Amer. Meteor. Soc. Amer. Geophys. Union Trans. Amer. Geophys. Union* **48**, 118.

Thom, H. C. S. (1957). A new concept for cooling degree days. *Air Cond. Heat. Vent.* **54**, 73.

World Health Organization. (1957). "International Classification of Diseases, Injuries and Causes of Death," 1957 Revision, World Health Organization, Geneva, Switzerland.