HEAT DEATHS AMONG UNDOCUMENTED US-MEXICO BORDER CROSSERS

IN PIMA COUNTY, ARIZONA

By

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ABSTRACT

Widespread media reports have described an increase in heat-related deaths among undocumented immigrant border crossers in Southern Arizona in recent years. The factual basis and important risk factors associated with these deaths have not been well studied. Although, the most common cause of heat fatalities is environmental exposure during heat waves, deserts of the southwestern USA are known for temperatures that exceed this threshold for 30 days or more. Heat-related fatalities, however, have been and continue to be rare among residents of the region. Undocumented immigration across the US-Mexico border into Arizona has likely been robust for decades, although accurate measures of the volume are not available due to its covert nature. This thesis research focuses on the occurrence and distribution of heat deaths among undocumented US-Mexico border crossers in Pima County, Arizona. Implications of this work include improving future research, informing public health policy and planning of prevention strategies.

BACKGROUND

Media Reports

Widespread news reports have described an increase in heat-related deaths among undocumented immigrant border crossers in Southern Arizona.(3-10) Concern over the frequency and distribution of these heat deaths suggests more information is needed to help determine the best estimate of the incidence, major factors associated with risk, and effective prevention strategies.(11-19)

Local news releases regarding immigrant heat deaths were rare until the last ten years. A 1991, Arizona Daily Star article pointed out that “deserts of Southern Arizona have been fatal for at least 20 people since 1980.”(20) By 1993, reports of increasing deaths appeared along with news of United States Border Patrol (USBP) measures to communicate risk along both sides of the border.(21) A 1997 Associated Press release quoted the director for the University of Houston's Center for Immigration Research that “almost 1,200 people died between 1993 and 1996 trying to cross illegally into the United States from Mexico.” Only five percent of these deaths were attributed to environmental conditions.(22) By 2001, Southern Arizona citizens had become accustomed to repeated media stories of immigrant heat deaths. Some civic leaders even pointed to the 1996 Illegal Immigration and Immigrant Responsibility Act as a partial causal factor.(23) The contended that because the Act funded a large increase in border agents that were distributed mainly at major entry ports, undocumented border crossers may have chosen more risky crossings in desert wilderness areas. In mid-summer 2003, as news reports of the annual numbers dying of heat stroke in Southern Arizona exceeded

100, the media also detailed ruthless actions committed by crossing guides, also known as coyotes.(24) It was also in 2003, that increasing national media attention increasingly turned to this seemingly increasing problem in Arizona.(3-7)

Heat Stroke in the United States

Heat stroke in the United States has been documented to occur primarily in urban areas during heat waves. Well documented deadly heat waves struck Chicago in 1995 and 1999.(25) Approximately 400 people die on average each year in the United States from heat-related illness according to the Centers for Disease Control (CDC). Heat waves have been defined commonly in the literature as "three or more consecutive days with high temperatures that exceed 90°F (32.2°C)."(17, 25-33) The Southwestern United States deserts are known for summer daily high temperatures that are above even 100°F (37.8°C) for 30 days or more. Heat-related deaths in this region, however, have been uncommon compared to other regions with more temperate climates. Heat stroke deaths are, however, also known to occur in relatively mild environmental conditions when associated with exertion, dehydration, predisposing illnesses or medications, and in the non-acclimatized.(34-42) Most heat-related deaths in the United States are known to occur in the very young or elderly, poor, socially isolated and especially those who have no access to home air conditioning.(19, 43-45)

Incidence data for heat stroke are inaccurate because the disease is probably under-diagnosed and entry of death data into vital statistics databases may be inconsistent and imprecise. Additionally, the definitions of heat-related death vary. (13, 15, 26, 43, 46-50) An epidemiological study during heat waves estimated the incidence of heat stroke to be between 17.6 and 26.5 per 100,000 population.(43) During the Hajj, in Saudi Arabia, where many heat stroke victims perish while walking through similar temperatures to Southern Arizona, the crude mortality for those with heat stroke has been estimated at 50%.(51)

The CDC sponsored Health Studies Program of the National Center for Environmental Health (NCEH) is responsible for investigating human health effects associated with exposure to environmental hazards and to natural and technological disasters. This includes a division focused on Natural Disasters and Extreme Weather. The division published a report in 2005 revealing an increase in Arizona heat deaths compared to the national average. The report did not mention undocumented border crossers or other unusual demographics.(52) An editorial that accompanies the report details the significant limitations of heat death reporting. Heat-related illnesses can be closely linked and indeed exacerbate existing medical conditions. They are therefore difficult to identify when not witnessed by a clinician. Additionally, the criteria used to determine heat-related causes of death vary among the states. This can, and likely does, lead to underreporting heat-related deaths.(47)

Climatic Change

In descending order, the five years with the highest global average annual temperatures were 2005, 1998, 2002, 2003 and 2004, said Drew Shindell of the NASA Institute for Space Studies. "I think it's even fair to say that [2005 had] the warmest... temperatures the world has experienced probably in the last million years.(53) Because cause of death record keeping has not been accurate historically, it is very unlikely that an association can yet be made between current global warming trends and deaths in heat waves. Nonetheless, Europe's summer of 2003 seared itself into the record books as the hottest, deadliest summer the continent has endured in at least 500 years.(54) Recently, the United Nations' Intergovernmental Panel on Climate Change, a group of over a thousand esteemed scientists, released two of an eventual four reports that reviewed the science to date on the issue. The reports conclude that the Earth's average temperature will rise between 2 and 4.5 degrees Celsius by 2100. The authors stated that "the harmful effects of global warming on daily life are already showing up…" (55-57) Although actual average temperature increases appear to be small, the variation in temperatures and weather patterns may be much larger. The future impact on human civilization is not clear. It is also not the intent of this thesis to address possible regional implications of global climate change and is therefore offered as background only.

Pathophysiology of Heat Stroke

Heatstroke is a potentially lethal disorder that results from extreme elevations of body temperature.(26, 32, 58-61) A great deal of research has been conducted on the pathophysiology of heat stroke that reveals an underlying failure of the body's thermoregulatory system. This is accompanied by an exaggerated immune modulation response with altered expression of heat-shock proteins. This expression of heat-shock proteins may be responsible for the transition from heat stress to heat stroke. The cardiovascular response to heat stress includes an increase of cardiac output and redistribution of heated blood away from the core to the periphery. Any inhibition of these changes because of dehydration, salt depletion, cardiovascular disease, or interfering medications would increase susceptibility to heat stroke.(26) Ultimately, multi-organ failure ensues in a final common pathway not dissimilar to that encountered by critically-ill sepsis and trauma patients. (26, 47, 59, 62-85)

Two fundamental clinical characteristics must be present for a diagnosis of heat stroke – hyperthermia (core temperature greater than 40° C) and central nervous system dysfunction.(26, 58, 59) Brain dysfunction may be manifested by inappropriate behavior or confusion or even seizures. This would be an unfortunate challenge to someone already lost in a wilderness setting.

Undocumented Immigration from Mexico

Estimates derived from the U.S. Census Bureau's Current Population Survey suggest that the unauthorized resident alien population has risen from 3.2 million in 1986 to 10.3 million in 2004. A variety of factors is claimed to have resulted in the increase, including the "push-pull" of the United States' economy, border enforcement policies that have curbed the fluid movement of migrant workers, and the delays in processing immigrant petitions.(86) The last major law that allowed undocumented immigrants living in the United States to legalize their status was the Immigration Reform and Control Act (IRCA) of 1986 (P.L. 99-603). Among the main provisions of that law was a time-limited legalization option, known as § 245A of the Immigration and Nationality Act, that allowed certain undocumented immigrants who had entered the United States before January 1, 1982, to become legal permanent residents. Nearly 2.7 million individuals established legal status through the provisions of IRCA. Since then, the political debate has become increasingly volatile, with legal immigration caps remaining essentially stable.(86) According to a 2005 Pew Hispanic Center report, Mexicans make up over half of undocumented immigrants — 57 % of the total, or about 5.9 million. The report estimates that another 2.5 million (23%) are from other Latin American countries. It also found that almost two-thirds (68 %) live in eight states: California (24%), Texas (14%), Florida (9%), New York (7%), Arizona (5%), Illinois (4%), New Jersey (4%), and North Carolina (3%).(87) Debate related to "immigration reform" continues to rage as this thesis is written with a House bill introduced March 22, 2007 by Representatives Luis Gutierrez, D-Ill., and Jeff Flake, R-Arizona. Named the "Security Through Regularized Immigration and a Vibrant Economy Act, or STRIVE Act, it claims to provide a pathway to citizenship for 12 million undocumented residents and their families and more than double the number of employment-based visas. The act also includes provisions for a guest-worker program and stepped-up surveillance, detention and deportation of undocumented immigrants who do not opt for legalized status.(88)

The distribution of United States Border Patrol (USBP) apprehensions has changed somewhat but the Tucson Sector has seen the greatest increase and total volume in recent years.(3, 6-8, 89, 90) It has been unclear whether increased deaths along the border are simply a result of increased volume across the border. Without any possible accurate mechanism to count border crossings, this relationship can only be estimated. USBP activities related to safety in the Southwest are clarified in a 1998 program called the Border Safety Initiative. According to Customs and Border Protection, the Border Safety Initiative (BSI) has two main objectives: the reduction of injuries and the prevention of deaths in the southwest border region. In particular, the BSI states their intention is to educate and inform potential migrants of the dangers and hazards of crossing the border illegally and to respond to those who are in life-threatening situations. Over the years, Border Patrol Agents have rescued over 7,500 persons from dangerous high-risk areas.(91)

Prior reports of Heat Death in Arizona

The Arizona Department of Health (ADHS) claimed that a substantial increase in the number of heat fatalities was occurring among border crossers in 2002. The increase was attributed in an ADHS newsletter to the rise in undocumented immigration across the Mexican border (92). The newsletter piece, however, provided no evidence to substantiate the claim. Similarly, undocumented immigrants are presumed to be at higher risk of heatstroke but the scientific basis for this presumption has not been published. Plausible explanations for increased risk include that they may underestimate the scarcity of viable cover from the heat, the length of time they will be exposed, the exertion that will be required to walk across the desert, and the amount of food and water that will be required.

Research Question and Proposal

The research question and purpose of this thesis is to determine the occurrence and distribution of heat deaths among undocumented US-Mexico border crossers in Pima County, Arizona. This will be attempted via analysis of a descriptive medical examiner consecutive case series provided by the Pima County Medical Examiner and statistical associations with data from the National Weather Service and United States Border

Patrol. This study was exempted from full-committee review by the University of Arizona Human Subjects Protection Program (see appendix).

METHODS

Medical Examiner Heat Death Data

All heat-related death cases from 1998 to 2005 reported in the Pima County Office of the Medical Examiner (OME) were reviewed. The Chief Medical Examiner for the OME identified or verified the cases. Undocumented immigrant border crossers were also defined by OME as individuals who appeared, based on case investigation, to be individuals who crossed the US – Mexico border without legal admission. Criteria used by the OME for case identification included body discovery locations, autopsy information provided by the OME forensic pathologists, data from USBP or other law enforcement agencies, a dedicated forensic anthropologist, articles found with the body, and on occasion witness reports from individuals accompanying the immigrants. Individual deaths constituted the unit of analysis. The designation of heat-related death was made in each case when environmental heat exposure appeared to be the most significant underlying cause for death. Demographic information in the case files was often obtained from the USBP or other law enforcement agency discovering the body. Cases were first identified from the electronic OME database by keyword searching before paper files were hand-searched to complete the explicit record review.

Data were extracted on the underlying cause of death, place of death, date of death or discovery of body, age, gender, nationality (if available) and whether the case was presumed to be a border crosser by OME. Data were transferred into an electronic database (Excel).

United States Border Patrol Apprehension Data

USBP apprehension data for the Tucson Sector were obtained as it provided the best available estimate of the at-risk population of these immigrants. Although analyses of immigrant populations share common obstacles, a study of undocumented individuals crossing an international border is especially challenging. For estimating the undocumented immigration across the United States – Mexico border, most authorities have relied upon USBP apprehension data. Annual border crosser apprehension data for 1998 – 2003 were obtained from the USBP Tucson Sector Public Affairs office and were entered into the study database.(89) These data were used to create an estimate of border crosser volume. USBP apprehension data were available only for the entire USBP Tucson Sector and not available by county (**See Figure 1**). Although Pima County is comprised of ~ 9,000 square miles compared to the ~ 100,000 square mile "Tucson Sector," a 2002 report by the Arizona Department of Health Services showed that the vast majority of heat deaths in the Tucson Sector occurred in Pima County (see Figure 2).(10)

Figure 1. Tucson sector of United States Border Patrol

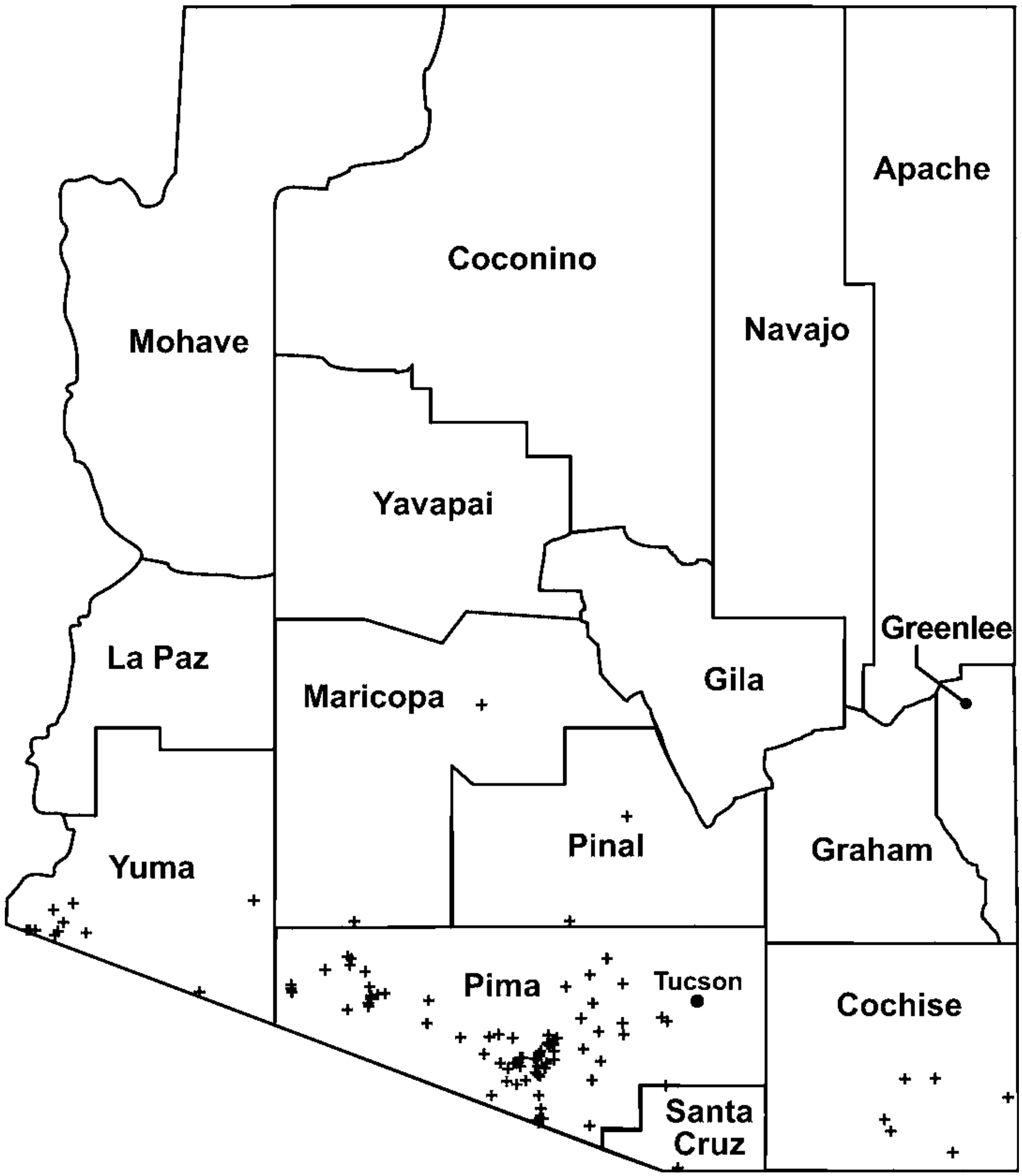

Figure 2. Heat death locations in Southern Arizona 2002(10)

National Weather Service Data

Weather data were obtained from the National Weather Service (NWS). Daily ambient high temperature (DAHT) and heat index were obtained from the five regional reporting stations within Pima County for the years 2002 to 2005. The correlation between DAHTs in Tucson and those of the other four stations exceeded 0.93 in each case and the difference between the average annual DAHT for Tucson and the other four stations ranged from −0.27 to 0.33 standard deviations. Thus, DAHT data from the Tucson reporting station were used to represent Pima County DAHT in all analyses. Although, the heat index is commonly used at temperatures above 26º C to account for the role played by relative humidity in increasing the perception and impact of high heat, it is not useful in arid climates. Heat index data were available from the Tucson station on 99% of the 227 days in 2002 for which the DAHT exceeded 26º C. The correlation between ambient temperature and heat index was 0.97. On average, the heat index value was lower than the DAHT, not higher as it would commonly be in a less arid climate. It exceeded the DAHT on only 5% of the days. Thus, the unadjusted DAHT was used in all analyses.

Estimating the date of lethal heat exposure

The following heuristic was used to estimate the date on which the lethal heat exposure (DLE) occurred. The DLE was the day the individual was admitted to the hospital, if (s)he died in the hospital. The DLE was the day the individual was rescued if (s)he died in the field prior to admission to the hospital. When the Medical Examiner

(ME) estimated from the remains that death had occurred in the 72 hours prior to discovery of the remains, the DLE was defined as the date the remains were found minus 1 day. The DLE was defined as the date the remains were found minus 4 days, when the ME estimated that death had occurred between 72 hours and 1 week prior to discovery. No estimate of the DLE was made when the ME estimated the age of the remains to exceed 1 week.

Database Construction and Data Analysis

Each heat death reported to the Medical Examiner, each apprehension reported by the USBP and the Daily Ambient High Temperature for Tucson reported by the National Weather Service served as units for analysis. Descriptive statistics were used to characterize the demographics of the cases. Heat-related death proportions and rates were calculated as the number of reported heat-related deaths per number of apprehensions by USBP. Excel database files were checked, cleaned and integrated into an SPSS analytical database. Data were analyzed with SPSS (version 11.5.2.1; SPSS Inc, Chicago, Ill). A logistic regression as well as a polynomial curvilinear regression model was constructed using days of the year in Pima County, Arizona without or with one or more reported heat deaths as the dependent variable. The "individuals at risk" were, therefore, the days of the year rather than actual humans. The rationale is based in the fact that the actual border crosser volume is not accessible secondary to covert behavior. The dichotomous outcome of interest was the presence of a day with or without one or more heat deaths reported to the Medical Examiner. In this model, only the daily ambient high temperature (DAHT) was used as the independent variable as other human variables were thought to be uncertain.

RESULTS

Characteristics, Patterns and Geographic Distribution of Heat-Related Death Cases

Table 1 summarizes the demographic characteristics of the cases identified for 2002 - 2005. These deaths are all those documented by the Pima County Medical Examiner. All deaths were verified by forensic pathologists at the Pima County Forensic Science Center. Overall, 83% of the 384 deaths were male and 95% were over the age of 17. Nationality was known for 84% of the cases and 91% of these were non-US nationality. Demographics for 1998 – 2001 were similar and release in a prior publication.(1) The number of total heat-related deaths reported in Pima County rose from 1998 to 2002. The vast majority of the deaths were persons of non-United States origin and occurred in remote wilderness deserts (**Figure 2**). The 99 deaths in 2002 represent a 98% increase from the previous year **(Figure 3**).

Table 1. Demographic characteristics of heat death cases Pima County, Arizona 2002 - 2005

Year	Number of Heat-related Fatalities	Males	Age Available	Age > 17	Age	Nationality Known	Non-US Nationality	Date of Lethal Exposure Estimated
		n (%)	n (%)	n (%)	M (SD)	n (%)	n (%)	n (%)
2002	99	69 (70)	72 (73)	67 (93)	34 (16)	84 (84)	75 (89)	63 (64)
2003	100	74 (74)	85 (85)	80 (94)	34 (14)	83 (83)	76 (92)	75 (75)
2004	75	54 (72)	74 (99)	73 (99)	33 (15)	68 (91)	60 (88)	44 (59)
2005	110	82 (75)	102 (93)	95 (93)	32 (12)	87 (79)	83 (95)	75 (68)
Total	384	279 (83)	333 (87)	315 (95)	33 (14)	322 (84)	294 (91)	257(67)

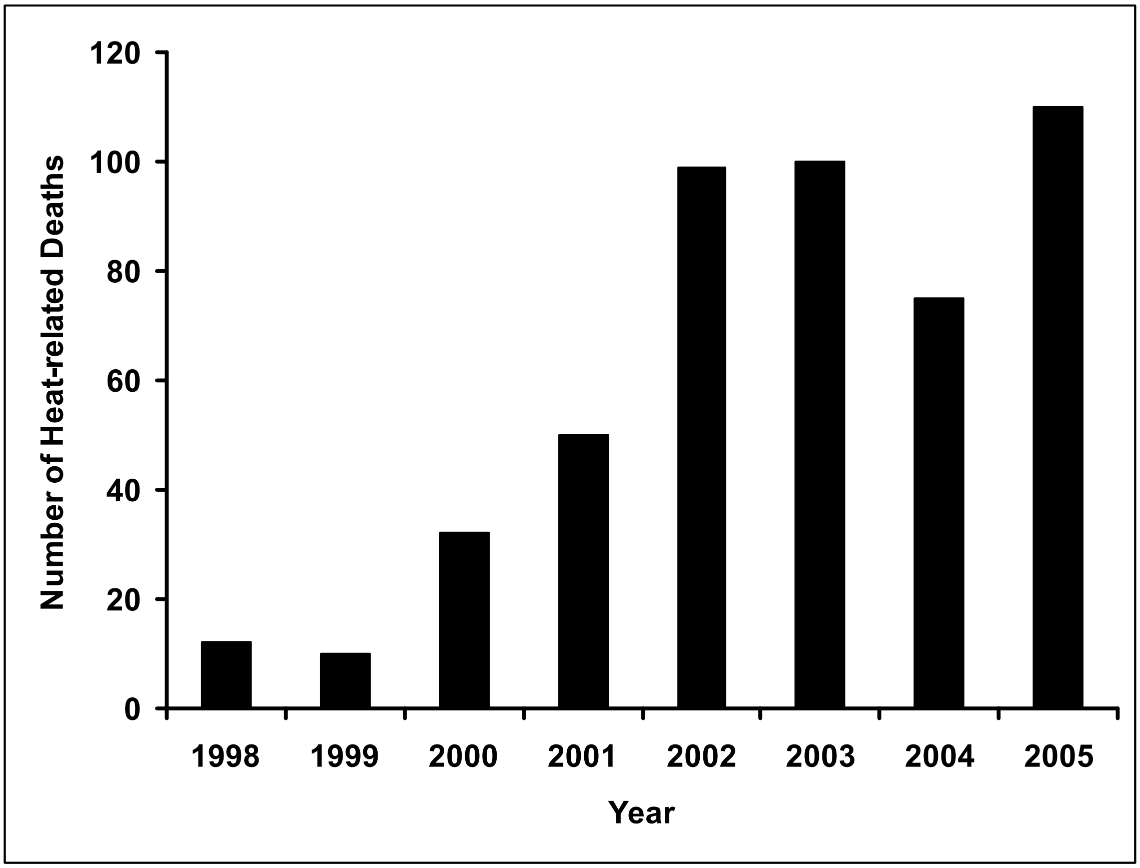

Figure 3. Number of heat death cases in Pima County, Arizona 1998 – 2005

Association with Border Patrol Apprehensions

Table 2 shows the number of USBP apprehensions for the Tucson Sector 1998 - 2003. These numbers demonstrate the variation in apprehensions.

Assuming that USBP apprehensions in the Tucson sector are proportional to the number of border crossers in Pima County, the rate of heat-related deaths in Pima County per 10,000 crossers can be estimated **(Table 2)**. The rate of heat-related death has increased from 0.31 death per 10,000 apprehensions in 1998 to 2.73 deaths per 10,000 apprehensions in 2003.

Table 2. Number and Rate of Heat-Related Deaths Compared to Annual USBP Apprehensions

Year	Number of heat-related deaths	Number of apprehensions by USBP	Rate per 10,000 apprehensions
1998	12	387,000	0.31
1999	10	470,000	0.21
2000	32	617,000	0.52
2001	50	449,000	1.11
2002	99	352,832	2.81
2003	100	366,046	2.73

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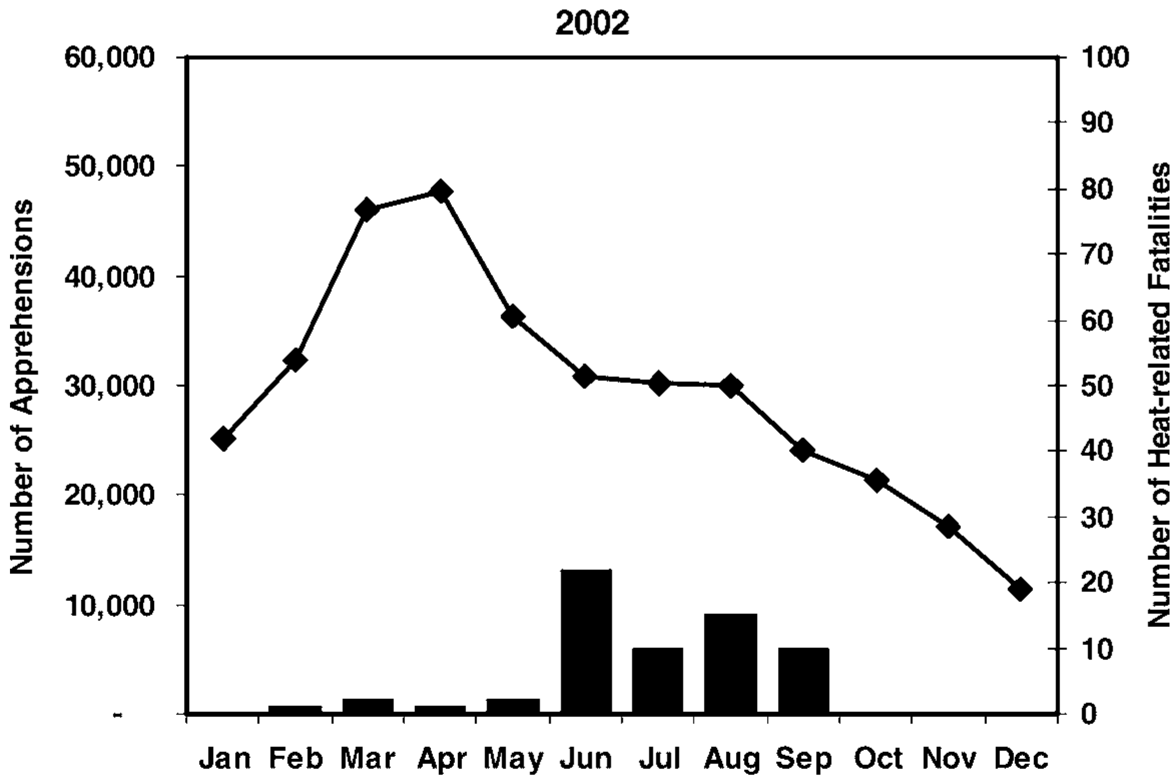
Association of Daily Ambient High Temperature

Figure 4 illustrates the seasonal variation in apprehensions and heat-related fatalities for 2002 and 2003 and provides further evidence that numbers of fatalities are related to days and months of the year with extended periods of high temperatures, but unrelated to numbers of apprehensions.



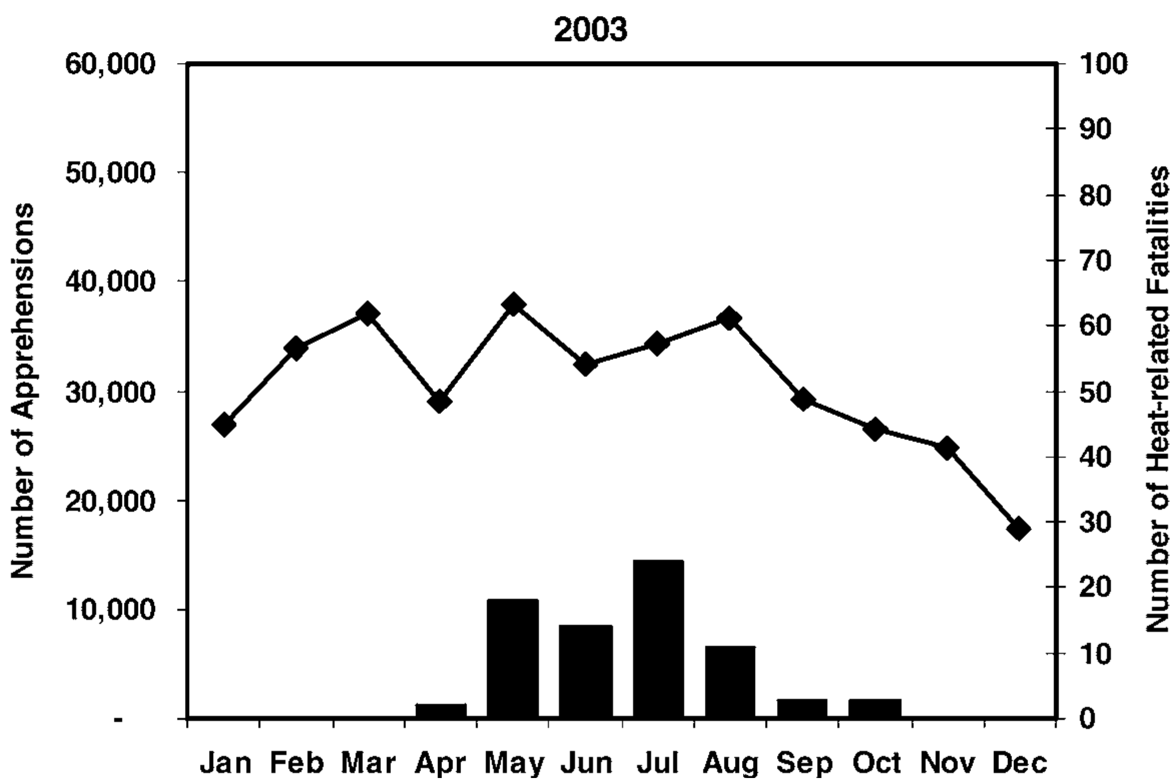


Figure 4. Relationship of number of apprehensions to number of heat-related fatalities
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Because the actual border crosser population at risk is unknown with regard to most characteristics, this project focused on determining the degree of association between high temperatures and heat deaths. **Figure 5** is a simple descriptive graph that shows the number of days at specific high temperatures for 2002 – 2005 (1461 consecutive days) along with the number of days that Pima County witnessed one or more heat related deaths. It is important to note that the neither temperatures nor deaths are cumulative but individual values. **Figure 6** shows the simple proportion of days at any given temperature with one or more deaths occurring at the same individual high temperatures from 2002 – 2005 (1461 consecutive days). **Figure 7** shows is a histogram of the proportion of days with one or more deaths that occurred at different daily ambient high temperatures between 2002 and 2005.

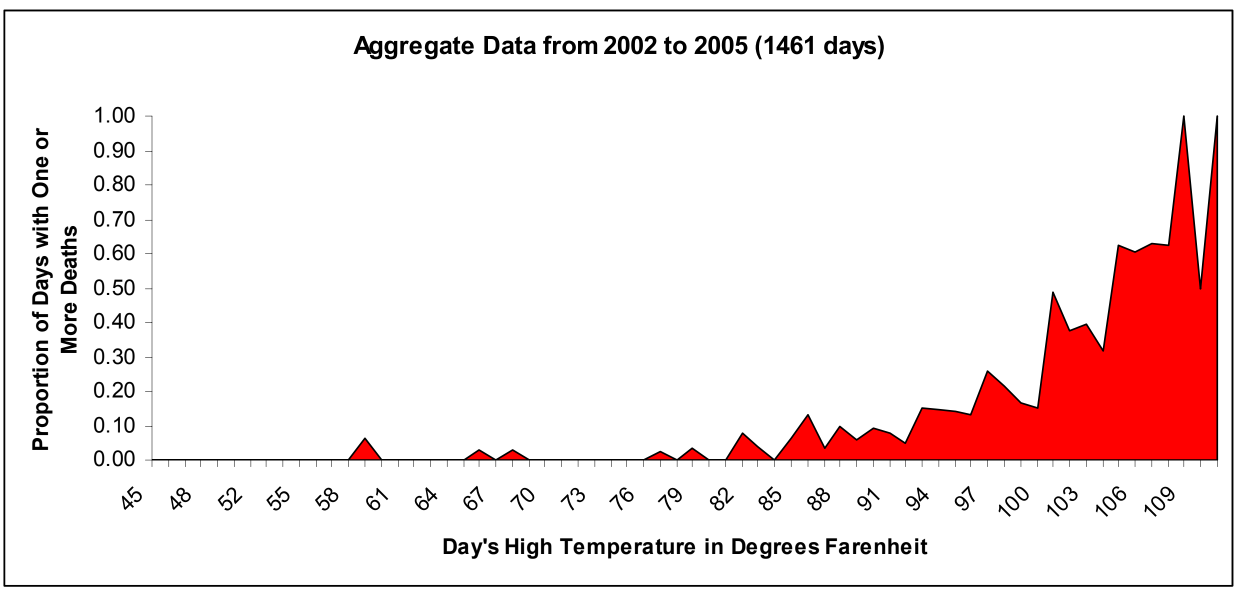

Figure 5. Number of days at each high temperature with days of one or more deaths

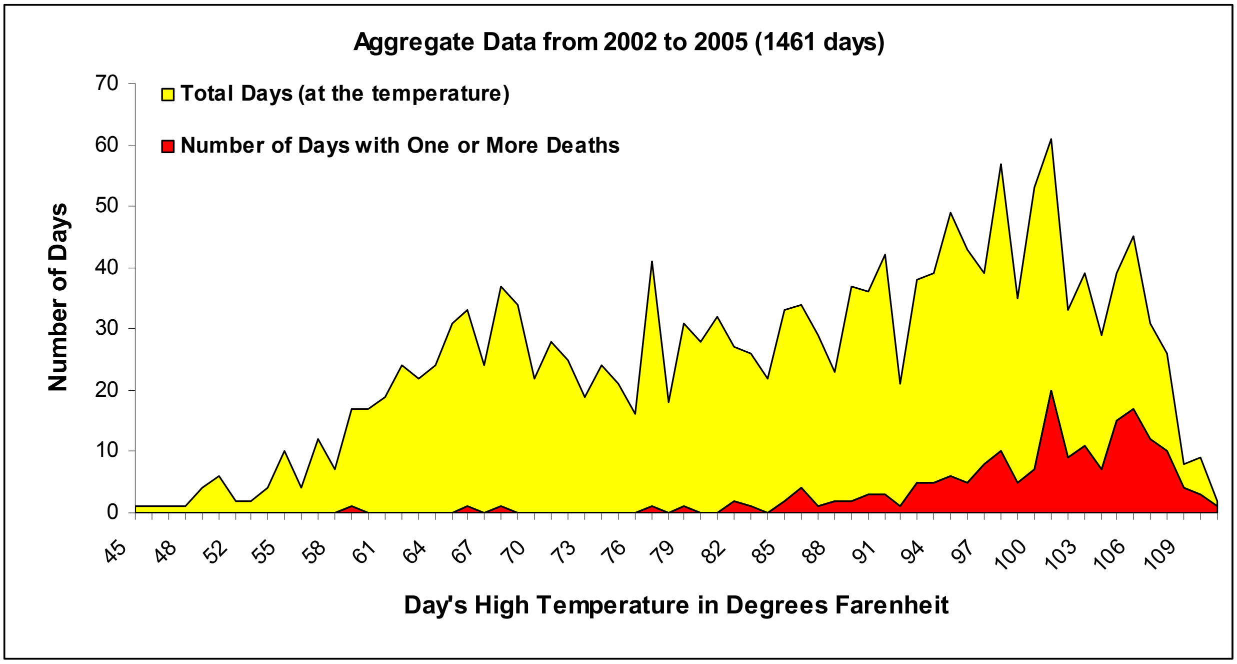

Figure 6. Simple proportion of days with one or more deaths occurring at each daily high temperature

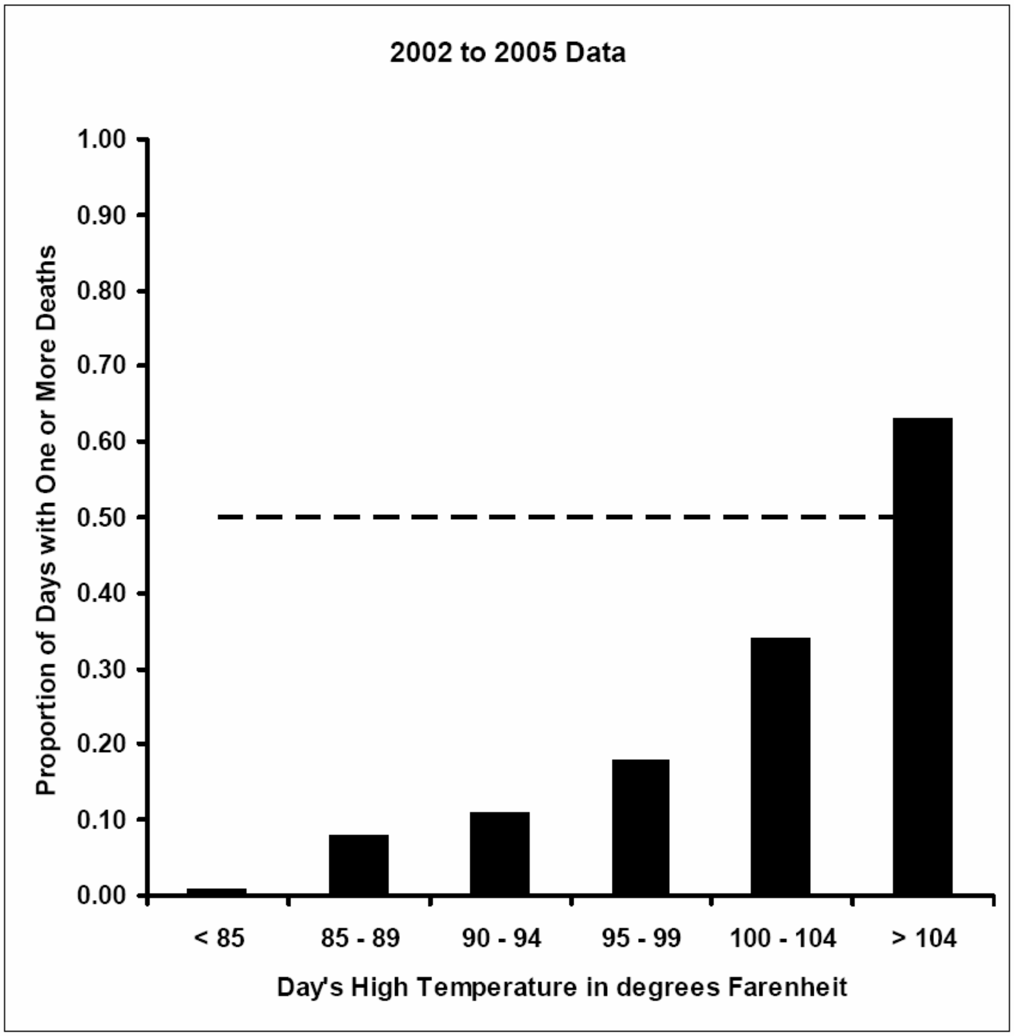

Figure 7. Proportion of days with one or more deaths at various daily ambient high temperatures

Table 3 shows the relationship of temperatures above 32° C (~90° F) and the proportion of days with heat deaths reported. This cross-tabulation used days in 2002 and 2003 on which the temperature exceed 32° C, with the days on which one or more heat deaths were reported.

Table 3. Relationship of ambient high temperature > 32° C and deaths

Relationship of ambient high temperatures > 32 °C and the occurrence of one or more heat fatalities in 2002 and 2003

		At least one heat fatality occurred on this day?	
		No	Yes
Ambient high temperature > 32 °C on this day?	No	430	9
	Yes	202	89

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The odds ratio for this relationship is 21.05 (95% CI: 10.39 – 42.63). Logistic regression was used to analyze the relationship of DAHT for the same years (each day of 2002 – 2003) to the presence or absence of one or more reported heat death. For each degree of increase in temperature (° C), there was a 35% increase in the odds of one or more reported heat death (ß= 0.30, Wald (1) = 83.23, $p < 0.001$). A curvilinear polynomial regression was used to fit the relationship between the days experiencing a death and the high temperatures in Tucson that suggests a cubic equation without a constant represents the best fit accounting for over 90% of the variance ($R^2 = 0.91$). The final polynomial model is:

$$\text{Predicted } Y = (0.01926 * X) + (- 0.000577 * (X^2)) + (0.000004194 * (X^3))$$

Using this model, when X high temperature = 104.6, the predicted Y odds that the day will have one or more deaths = 0.50 or a 50-50 odds.

These odds are stated in terms of a day in Pima County with a stated high temperature as measured at Tucson International Airport having one or more deaths among border crossers.

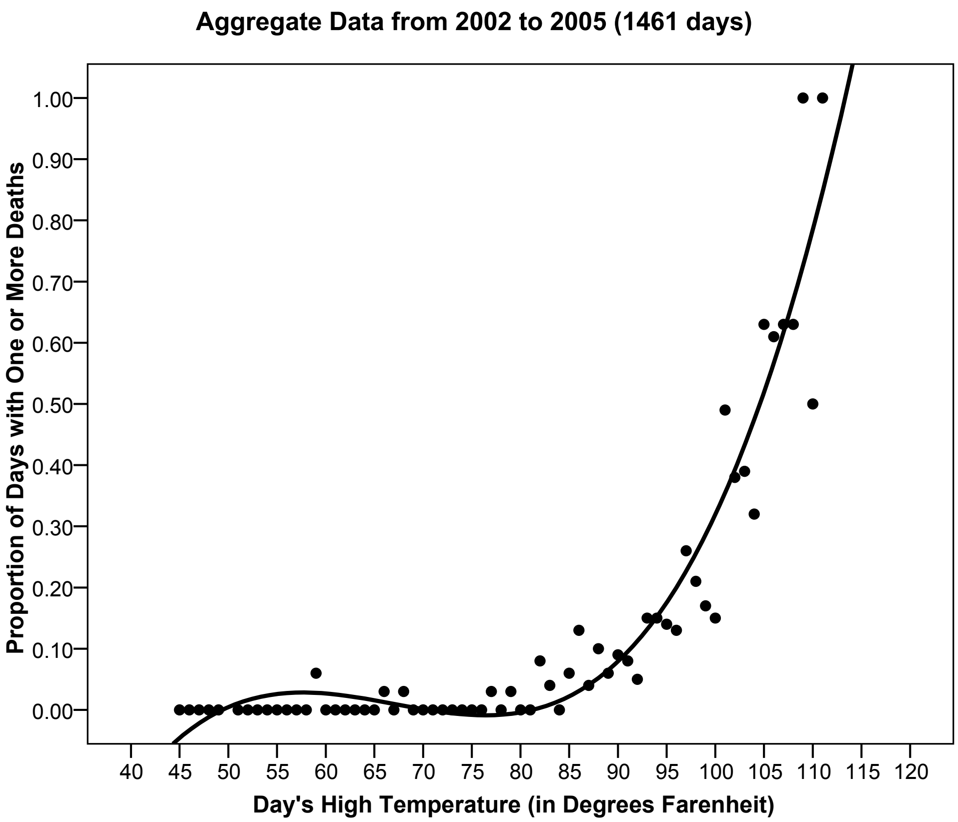

Figure 8. Polynomial regression estimate of proportion of days with given high temperatures having one or more deaths

DISCUSSION

Increase in Heat-Related Deaths

A major increase in the number and rate of heat-related deaths has occurred in recent years among undocumented immigrant border crossers in Pima County, Arizona. This conclusion, based upon a descriptive medical examiner consecutive case series, is justified as the Pima County OME is responsible for all such deaths in this stated area. The duty of the Pima County Medical Examiner is to determine and certify the cause of all unattended deaths within the jurisdiction of Pima County.(93) All individuals dying of acute heat stroke, either prior to hospitalization or after, in Pima County are also referred to the OME. It is, however, possible that some cases are not referred and it is probable that border crossers died in remote areas that have not yet been found. Both issues suggest probable under-counting of cases. Case series are traditionally felt to be useful primarily for hypothesis generation, unless the findings are strikingly different than expected. They are believed by some, in fact, to be the weakest form of study design, but may be the only available or practical information regarding a rare or recently emerging disease.(94) The data provided by the Pima County Forensic Science Center and Medical Examiner are likely to be the most reliable and practical data available regarding these deaths. Pima County is used as the geographical reference for cases because 1) it appears to have the largest number of cases per the State of Arizona Health Services and media reports, 2) all cases are reported to a single medical examiner and 3) the area is sufficiently large to find a meaningful number of cases. Pima County, Arizona is in reality a large jurisdiction, comprising over 9,000 square miles. Compared to some States, Pima County is larger than New Jersey, Connecticut, Rhode Island and Delaware.

It is composed of mostly desert wilderness and likely hides many skeletons of border crossers.

Despite a decrease in the number of apprehensions of border crossers by the United States Border Patrol (which suggests that the number of border crossers has decreased), the number of heat deaths in this population increased dramatically between 1999 and 2002. This increase continues with the exception of an unusual, and difficult to explain, apparent decrease in 2004. The increase in the number of heat-related fatalities is, therefore, not a simple result of an increase in the volume of border crossers. This rate increase suggests an increase in risk to the population or a segment of the population. A limitation of the apprehension data is that it reflects a different geographical area than Pima County. The Tucson Sector of the USBP covers nearly the entire State of Arizona. Despite this, it is appropriate to use for 1) the vast majority of Tucson Sector apprehensions occurred within Pima County, and 2) the vast majority of heat deaths in the Tucson Sector occurred within Pima County.(10, 89) Another clear limitation of this inference is that apprehensions may not reflect or be associated with the actual border crosser volume. That data are likely impossible to accurately measure and as a result, apprehension data has been recognized and used by many as a surrogate.(86, 89, 90)

Undocumented immigrant border crosser cases are defined by OME as individuals who appeared based on case investigation to be individuals who crossed the US Mexico border without legal authorization. This case definition clearly has imprecision and lack of clarity as the intentions of the immigrants are rarely known, but is practically useful. The OME staff is diligent about these designations as the notification of next of kin and international consulates are at stake. Some of the crossers may not intend to stay permanently in the US, might have been crossing covertly to smuggle illicit cargo or may be crossing guides themselves. The precise nature, therefore, of the reasons for their decision to cross are largely unknown(95). Case identification is provided by board-certified and licensed OME forensic pathologists and a dedicated forensic anthropologist.

This report is consistent with others. The increase in deaths has been noted previously by media and also described in a newsletter report by the Arizona Department of Health Services in 2002(10). Data on heat death throughout the United States are, however, imperfect secondary to a less than precise case definition, probable underreporting, and the fact that the National Center for Health Statistics data do not include OME data unless the patients died in a hospital.(19, 47, 48, 50) This increase has just recently been reported by another study.(96) In that 2006 CDC study of deaths among unauthorized migrants along the border from Tijuana to El Paso from 2002-2003, environmental heat death was listed as the leading cause of death.

Ambient daily high temperatures appear to be strongly associated to the probability of heat death in this population. Summertime temperatures in Pima County easily meet the classic definition of “heat wave” (three consecutive days > 90◦F) for nearly the entire summer without interruption. Heat deaths have, however, been extremely rare in Pima County until these recent border crosser death increases. Prolonged exposure is uncommon in individuals living in the area secondary to the nearly ubiquitous presence of household cooling and risk avoidant behaviors. The environmental exposure and consequent thermal stress incurred by border crosser immigrants is probably quite different. Many border crossers utilize the services of illicit crossing guides, or smugglers, also known by the vernacular term: *coyotes*.(90) News reports of ruthless practices by these individuals, including the purposeful abandonment of their human cargo "clients" in remote areas without adequate drinking water, are common.(8, 9, 24) Those that cross without guides are perhaps at no less risk as they may be unfamiliar with the wilderness area and the demand for food and water when hiking in these conditions. Additionally, as stated earlier, the final stages of heat illness include marked disorientation that make thermal stress avoidance or successful desert trekking improbable.(97, 98)

The United States Government has been concerned about the volume of undocumented border crossings from Mexico for many years. Major new efforts to stem undocumented border immigration were implemented in the Southwest US in 1995. Operations "Gatekeeper" (El Paso, TX), "Hold the Line" (San Diego, CA) and "Safeguard" (Nogales, AZ) directed large amounts of new resources to the USBP in 1995.(8, 9) The US Customs and Border Protection agency, news media and some advocacy groups have suggested that many border crossers avoid capture by crossing in more remote areas. The 123-mile Pima County–Mexico border represents only 6% of the 1,952-mile international border and 44% of the 281 mile USBP Tucson Sector border (see Fig. 1). Any generalization of these results to the larger US-Mexico border crosser population magnitude of both undocumented immigrant volume and deaths during attempted crossings is speculative. Well publicized clusters of heat-related deaths associated with heat waves internationally and in the United States, however, suggest a need for better predictive models and excessive heat warnings.(11, 12, 14, 18, 99) Surveillance systems with greater sensitivity and less reaction time may allow public health workers the ability to direct attention to those at greatest risk.(15, 100, 101) It is unclear how a prediction model may be effectively created or implemented for this at risk population or other social immigrants around the world who might cross environmentally dangerous borders covertly.

Predicting Risk Based upon Daily Ambient High Temperature

These results show that heat deaths in Pima County were strongly associated with increasing daytime ambient high temperature at Tucson International Airport (the NWS reporting station for Tucson). The association begins at what local Tucsonans would consider to be a relatively mild temperature. The relationship between high temperatures and occurrence of "death days" in Pima County can be seen easily on **Figures 5 – 8**. These results support earlier studies which suggested that daytime ambient high temperatures (DAHTs) above 32° C pose a high risk of fatal heatstroke for individuals who cannot engage in risk avoidance behaviors.(102) The odds ratio for this relationship is 21.05 (95% CI: 10.39–42.63). In other words, the odds of a heat fatality occurring on a day in Pima County when the DAHT exceeded 32° C was 21 times higher than the odds of a heat fatality occurring on a day when the DAHT did not exceed 32° C. This model suggests that on a day at or above 40° C, the risk that Pima County will have a border crosser heat death event reaches 50%. The dose–response nature of the relationship can be described as the proportion of days at a specified DAHT on which one or more heat fatalities occurred. For each degree of increase in temperature (° C), there was a 35% increase in the odds of one or more heat fatalities occurring (see **Figure 7**). These results also expand upon the earlier studies by demonstrating the dose–response nature of the relationship between DAHT and the odds of a heat fatality occurring.(102) The results should, however, not be interpreted in terms of the relative risk of death due to heat exposure. Because the majority of fatalities occurred among undocumented immigrants, whose border crossing behaviors run the gamut from desperately ill-conceived to completely secure, and whose numbers cannot be credibly determined, it is impossible to know the number of persons at risk on any given day. Our data are derived from deaths reported to the Pima County Medical Examiner alone. This is obviously an underestimate of the total number of deaths. Nor should these results be interpreted as indicating that high ambient temperatures are the primary factor in determining heat fatalities. Rather, these results indicate that high ambient temperatures systematically contribute to the risk of fatal heat stroke. They illustrate the danger of extended exposure to high ambient temperatures and provide information that could be used in weather and pubic health advisories.(45) These results could constitute the basis for an extreme weather warning for this population. The major challenges are 1) how to disseminate such a warning to a covert population and 2) would they read or adhere to such a warning. Both are valid future research areas.

CONCLUSIONS

Heat-related fatalities in Pima County, Arizona have increased in recent years and occur predominantly among border crossers. Daily high temperature exposure appears to be a major associated factor. Variables contributing to risk of exposure of these border crossers are likely complex. It is also probable that many undocumented border crossers died in remote areas and are not included in this study.

Implications of this work include improved future research, informed public health policy and better planning of prevention strategies. Future research can be aimed at the forensic investigations, identification of unknown victims, case definitions of heat-related deaths, pathological changes related to heat stroke, qualitative analysis of risk perception of border crossers, identification of high-risk behaviors of both border crossers and USBP, and public perception in both countries. An extreme weather prediction model can be used in prevention strategies. Those strategies can include public service announcements aimed at future border crossers, USBP and Emergency Services training. Significant challenges will likely persist in finding effective tools of risk communication to this population.

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31 August 2006

Samuel Keim, M.D.
Department of Emergency Medicine
1842 E. Elm
PO Box 245057

RE: HEAT-ILLNESS DEATHS IN PIMA COUNTY, ARIZONA IN 2002

Dear Dr. Keim:

We received your 28 August 2006 letter concerning your above cited project. Change is to extend the currently approved exempt project to includes publicly available deaths recorded in the year 2005 by the Pima County Medical Examiner. (use of publicly available US Border Patrol Apprehension data and National Weather Service temperature for the years 1998-present acknowledged). Approval for this change to your **exempt** project granted effective 31 August 2006

Continued exempt status is granted with the understanding that no further changes or additions will be made to the procedures followed (copies of which we have on file) without the review and approval of the Human Subjects Committee and your College or Departmental Review Committee. Any research related physical or psychological harm to any subject must also be reported to each committee.

Thank you for informing us of your work. If you have any questions concerning the above, please contact this office.

Sincerely,

Rebecca Dahl

Rebecca Dahl, R.N., Ph.D.
Director
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cc: Departmental/College Review Committee

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