Increasing insect reactions in Alaska: is this related to changing climate?

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ABSTRACT

In 2006, Fairbanks, AK, reported its first cases of fatal anaphylaxis as a result of Hymenoptera stings concurrent with an increase in insect reactions observed throughout the state. This study was designed to determine whether Alaska medical visits for insect reactions have increased. We conducted a retrospective review of three independent patient databases in Alaska to identify trends of patients seeking medical care for adverse reactions after insect-related events. For each database, an insect reaction was defined as a claim for the International Classification of Diseases, Ninth Edition (ICD-9), codes E9053, E906.4, and 989.5. Increases in insect reactions in each region were compared with temperature changes in the same region. Each database revealed a statistically significant trend in patients seeking care for insect reactions. Fairbanks Memorial Hospital Emergency Department reported a fourfold increase in patients in 2006 compared with previous years (1992–2005). The Allergy, Asthma, and Immunology Center of Alaska reported a threefold increase in patients from 1999 to 2002 to 2003 to 2007. A retrospective review of the Alaska Medicaid database from 1999 to 2006 showed increases in medical claims for insect reactions among all regions, with the largest percentage of increases occurring in the most northern areas. Increases in insect reactions in Alaska have occurred after increases in annual and winter temperatures, and these findings may be causally related.

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During the summer of 2006, two cases of fatal anaphylaxis due to yellow jacket stings in Alaska were reported as an abstract[1] and in the *Alaska State Epidemiologic Bulletin*.[2] These are the first documented fatalities due to Hymenoptera anaphylaxis in Fairbanks. The deaths occurred during a period when the yellow jacket populations around Fairbanks were estimated to be >10 times the average number. Annual numbers of yellow jackets are not officially monitored in Alaska. Jack Whitman, a wildlife biologist with the Alaska Department of Fish and Game in Fairbanks, trapped 3461 yellow jackets using three homemade traps around his house. Over the next few weeks he identified and destroyed nine ground nests and estimated killing 12,000 yellow jackets.[3] Landolt *et al.* reported capturing over 642 yellow jackets during the 2nd week of July in Fairbanks in 2003 and ~2000 in traps maintained in Fairbanks, Delta Junction, and in Palmer from early May through September 2004.[4] Outbreak years such as Fairbanks experienced in 2006 are well documented in the entomological literature with accounts dating from the 19th century in Europe,[5] although their causes remain poorly understood. The 2006 spike in Fairbanks notwithstanding, trends throughout Alaska during the study period have illuminated increasing bite or sting-related events resulting in medical care. The two sting-related deaths in Fairbanks were the sentinel events that stimulated the query.

METHODS

To determine the trends in patients seeking care for insect bites or stings, we conducted a retrospective review of three databases. For each database, a case was defined as a billing claim for the International Classification of Diseases, Ninth Revision (ICD-9), codes E905.3 (venomous insect specific to Hymenoptera), E906.4 (bite from nonvenomous arthropod), and 989.5 (toxic effect from venom). It is noteworthy that Alaska has no venomous reptiles.

The Fairbanks Memorial Hospital Emergency Department (FMH ED) is the only ED serving the civilian sector of Fairbanks (Alaska's second most populous

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city). Data were available from 1992 through 2006. The second database contained data from 1999 through 2007 from the Allergy Asthma and Immunology Center (AAIC) of Alaska, a clinical site located in Anchorage. Alaska's most populous city, Anchorage comprises almost one-half of the state's population. The AAIC is the only allergy and immunology center in the state. The only known reasons for increases in the total number of clinic visits during the study period were those expected from population growth.

We also evaluated a statewide Medicaid database that included approved billing claims for all age groups from 1999 through 2006. Because this database included all persons enrolled in Medicaid, it allowed the determination of incidence. Only cases with the appropriate ICD-9 code identified as the primary billing code were included. Not all persons were continuously enrolled in Medicaid during the study period; thus, some instances of insect-related events may have been missed. The main goal of the review of the Medicaid database was to evaluate changes in incidence rather than precisely determine incidence for a particular year. Data were presented for each of the six epidemiologic regions of Alaska (based on residence at enrollment during a given study year). For the Medicaid database, changes in incidence over time were analyzed with EpiInfo Version 3.3.2, February 9, 2005 (U.S. Centers for Disease Control and Prevention, Atlanta, GA.).

We used the temperatures published by the Alaska Climate Research Center from 1950 through 2006, recorded in the largest communities of each of the six regions. Temperature variance was reported for spring, summer, fall, and winter as well as annual average. These reports were originally published using non-SI units (degrees Fahrenheit); we cite those data here in their original units to preserve their accuracy.

RESULTS

The city of Fairbanks has a population of 30,224 (2000 U.S. Census Bureau).[6] FMH serves the city as well as patients throughout the North Star Borough with an estimated total population of 82,840.[6] Between 1990 and 1992, the ED reported no visits for insect-related events, with an increase to 28 during 1993, and a subsequent occurrence of 20–40 patients/year through 2005. In 2006 there was a fourfold rise to 178 patients seeking care for bite or sting-related events, providing an estimated annual incidence of 208/100,000. Fairbanks North Star Borough's population increased 6.5% from 81,383 to 86,754 (estimated) between 1992 and 2006.[6]

The database for the AAIC clinic in Anchorage revealed a low of 4 referrals for Hymenoptera sting reaction in 1999 followed by an upward trend of referrals to a high of 17 in 2006 and 23 in 2007. On average, the AAIC reported an annual increase of 2.5 cases (chi-square for linear trend $p < 0.001$) with no known increase in patient referral sources outside of those associated with population increases. From 1999 to 2006, the Anchorage population increased 7% from 260,283 to 278,700 (estimated).

During 1999, there were 106,312 persons enrolled in Medicaid, compared with 132,515 during 2006. For all of Alaska, the number of identified cases with insect bites or stings as the primary diagnosis by year during 1999–2006 were 250, 294, 334, 376, 300, 493, 583, and 383 respectively; while annual incidences per 100,000 enrolled persons were 235, 254, 274, 296, 371, 432, and 289 (chi-square for trend, 54.3; $p < 0.0001$; Table 1). Interestingly, if we include insect bites or stings as any diagnosis, the values increase by ~50% with little variation by year.

The Alaska Division of Public Health divides Alaska into six regions (Fig. 1). Five of Alaska's six regions recorded statistically significant increases (at the 95% confidence level, based on individual year data) in claims for insect bites or stings among Medicaid enrollees (Fig. 2). The northern region experienced an increase of 626% from the average incidence of 16/100,000 per year during 1999–2001 to 119/100,000 per year during 2004–2006 (Table 1).

A review of the data reported by the Alaska Climate Research Center revealed increases in the average annual and winter temperatures of 3.4 and 6.3°F in Alaska since 1950. Each region of Alaska experienced comparable increases with the exception of the Gulf Coast, which only experienced a 1.5°F rise during that period (Table 1). Each of the other five regions experienced at least a 6°F increase in average winter temperatures. This suggests that one contributing factor for the increase in bite or sting events may be associated with a rise in temperature and more specifically winter temperature (Table 1).

DISCUSSION

During the summer of 2006, two cases of fatal anaphylaxis due to yellow jacket stings in Alaska were reported.[1,2] These are the first documented venom-associated deaths in Fairbanks. In interior Alaska, the summer of 2006 was notable for anecdotal reports of an extremely high number of yellow jackets, resulting in the cancellation of cross-country running events and several school field trips. Data from the AAIC illustrates an increase in referrals for evaluation of bite or sting reactions over the past 8 years. The trend from 1999 of 4 referrals increased to a high of 17 in 2006 and 23 in 2007, an increase of 2.5 cases/year (chi-square for linear trend, $p < 0.001$). The AAIC serves Alaska as the only group of board certified allergists providing con-

Table 1 Incidence (per 100,000 population/yr) of billing claims for insect stings as a primary diagnosis among Medicaid enrolled persons, by year and region, Alaska 1999–2006, compared with temperature increases in the largest communities of the same regions from 1950 to 2006

	Anchorage Mat-Su	Interior	Northern	Southwest	Gulf Coast	Southeast	Total
Insect stings							
Year							
1999	274	260	18	60	442	146	235
2000	267	379	16	72	453	168	254
2001	286	358	15	55	417	348	274
2002	357	363	43	150	316	192	296
2003	211	438	55	40	311	270	229
2004	455	381	141	145	521	171	371
2005	497	407	119	104	701	431	432
2006	262	739	97	150	239	235	289
1999–2001	275.7	332.5	16.4	62.0	437.1	220.6	254.3
2004–2006	404.5	508.7	119.0	132.9	487.0	279.1	364.1
Percent increase (χ^2 for trend, p value)*	47% (22, $p < 0.001$)	53% (28, $p < 0.001$)	626% (13, $p < 0.001$)	114% (8, $p = 0.005$)	11.4% (0.1, $p = 0.75$)	27% (22, $p < 0.001$)	43% (54, $p < 0.001$)
Temperature change							
Measurement site (largest community)	Anchorage	Fairbanks	Barrow	Bethel	Kodiak	Juneau	Average
Annual temperature increase (°F)#	3.4	3.6	3.8	3.7	1.5	3.6	3.4
Winter temperature increase (°F)#	7.2	8.1	6.1	6.9	1.5	6.8	6.3

*χ^2 *for trend and p value calculation based on individual years from 1999 to 2006.*
#2006 Annual and winter average temperature increase (°F) from 1950 to 2006.

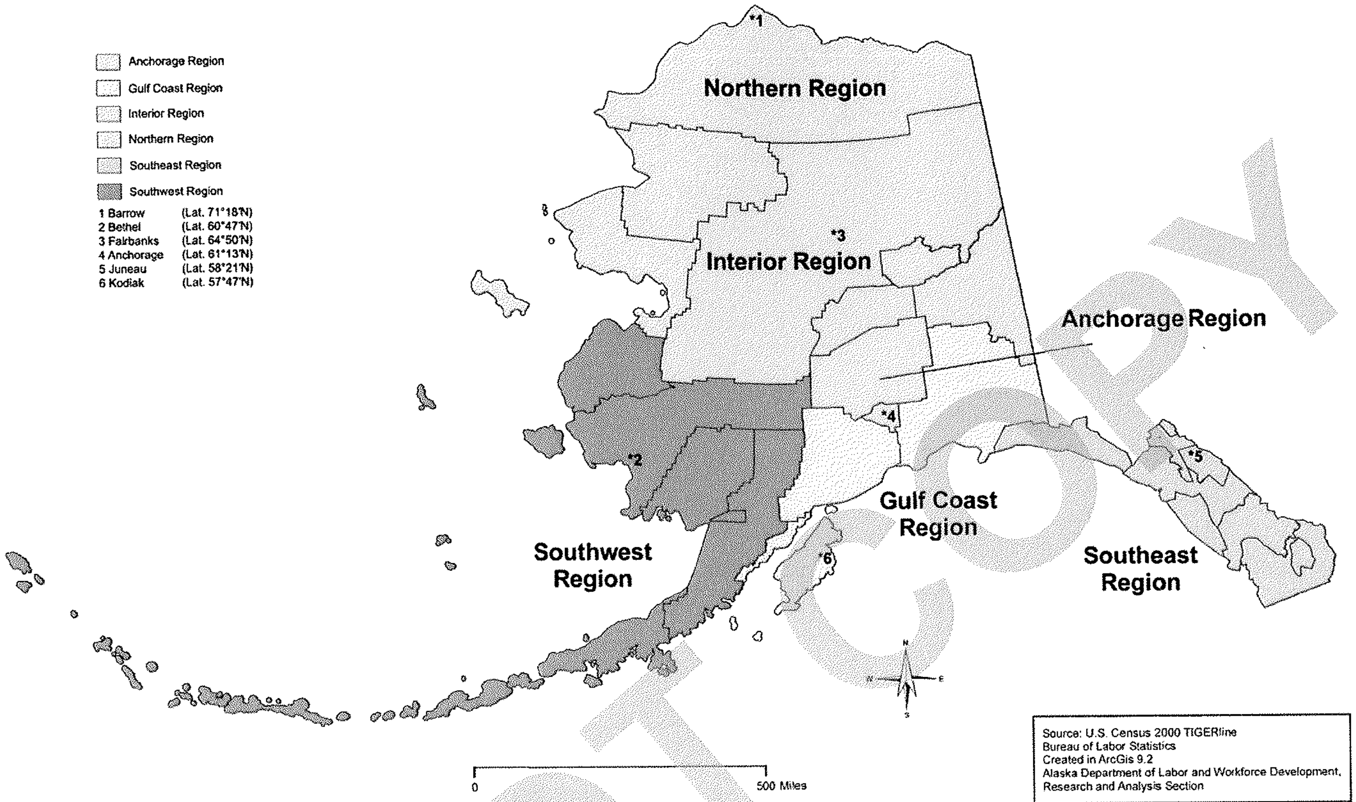

Figure 1. Map of Alaska, divided into epidemiologic regions. The largest city of each region is identified along with corresponding latitude.

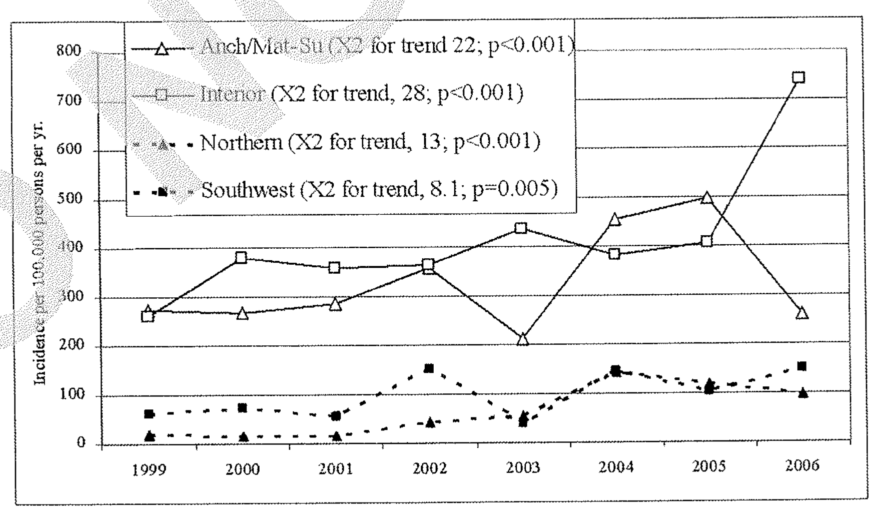

Figure 2. The annual incidences of approved claims for envenomation as the primary diagnosis among Medicaid-enrolled persons, by Alaska Region; Alaska, 1999–2006. For ease of visual interpretation, the Gulf Coast and southeast regions of Alaska are not included.

sultation service to the civilian sector in Alaska and has had no known increase in patient referral sources outside of those associated with population increases. Although the number of physicians increased, the referral base remained essentially unchanged. Data from Alaska Medicaid further support these findings and show an increasing trend in almost all regions of Alaska, going back to at least 1999. Although the increase from 2005 to 2006 was dramatic in interior Alaska (including the Fairbanks area), the greatest increase in bite or sting incidence occurred in the northern regions of Alaska, which experienced an increase of over 600%. In 2004, Roy Snelling, at the time an entomologist at the Natural History Museum of Los

Angeles, confirmed the first report of yellow jackets (*Vespula rufa*) in the village of Arctic Bay, Nunavut, Canada, at 73°N.[7]

Our study shows an increase in clinical visits for bites or stings but does not provide information on an etiology for this increase. Our data combined with other studies suggest that increases in temperature and changes in other climactic variables could make such outbreak years more common and/or increase their severity. Unfortunately, data showing a correlation between current climate changes and impacts on arthropods remain limited. Indeed, many observations are limited to reports in newspapers and websites.

Yellow jacket populations are limited by factors influencing survival of the overwintering queens and nesting success of queens in the spring.[5] Failure rates of queens are well over 90%. It is unknown what percentage of these queens fails to survive the winter, but studies have shown high failure rates of emerging queens in the spring. No relationship has been found between the number of emerging queens and the number of established nests later in the season.[5] Barnes *et al.*,[8] working in Fairbanks, showed that while freezing causes death in the common yellow jacket, *Vespula vulgaris*; this species is able to "supercool" to temperatures below −16°C without freezing. Snow depths of 60 cm provided enough insulation to allow the overwintering queens to survive in hibernacula, maintaining an average temperature of minus 6.5°C, while average air temperatures were −19.4°C (with minima often below −30°C). These findings illustrate that snow depth could be an important factor in the annual population growth of yellow jackets.[8] In Alaska, where winter temperatures are often subzero, warmer temperatures frequently result in more snowfall, increasing the insulation for overwintering of the queens. Barnes *et al.*[8] also showed that once the queens emerge, their ability to supercool declines. If the frequency and intensity of cold snaps decreases due to climate change, queen survival should increase. It is reasonable to expect larger populations from warmer temperature minima, winters with deep snow, warm dry spring weather, and a lack of cold snaps.[9,10] Arke and Reed[11] proposed hot, dry spring weather to be one of the strongest predictors of outbreak years for two *Vespula* species in the Pacific Northwest. The importance of favorable spring weather was further strengthened by the findings of Barlow *et al.*[12] who monitored *V. vulgaris* in New Zealand for 13 years. Our findings indicate that in each of five regions that had a statistically significant increase in bite or sting-related events, there was at least a 6°F increase in average winter temperature. The Gulf Coast, where bite or sting event increase of only 11% (compared with 43% statewide) failed to reach statistical significance, had only a 1.5°F increase in winter temperature. Interestingly, this region has the highest average winter temperature in the state (30.1°F),[13] and, correspondingly, had the highest incidence of bite or sting events at the beginning of the study period.

Over the past 50 years, Alaska's climate has warmed 2.2°C, at a rate of 0.4°C/decade.[13,14] This may not seem very large; however, global temperatures during the last "Ice Age" averaged only 3–6°C lower than today. The United Nations Conference on Climate Change Executive Secretary stated that in the past 100 years the planet has warmed 0.7°C (1.44°F) with the majority of the warming occurring over the past 50 years. In fact, 11 of the past 12 years (1995–2006) are the warmest recorded.[15] During the past 50 years, Alaska's average temperature has increased at four times the average rate of the planet.[13]

Hymenoptera are not the only insects potentially affected by a warming climate. According to Bachelet,[16] Oregon State University, climate change will lead to an increase in insects and pathogens, particularly in polar regions, causing epidemics of plant disease and insect attacks.[17] Outbreaks of destructive insects in unprecedented numbers such as the spruce bark beetle have killed 4.4 million acres of mature white spruce trees on the Kenai Peninsula in Alaska. This has been attributed to longer, warmer summers and warmer winters that produce heavy, wet snow loads in south central Alaska.[18] In the summer of 2003, south central Alaska also experienced infestation of stinging tussock moth caterpillars. The *Anchorage Daily News* published reports of berry pickers developing pruritic dermatitis resulting from encounters with this caterpillar.[19]

Documented changes in insect populations already exist for other areas. For example, butterflies, one of the most sensitive indicators of climate change, have shifted their northern range by up to 200 km in Europe and North America.[20] There are also compelling projections that warmer temperature will promote survivability of arthropods such as tick and mosquito species that are vectors of diseases such as malaria and dengue fever.[21,22] Mosquitoes and other small arthropods are temperature sensitive. Warmer temperature can enhance reproductive rates, extend breeding seasons, and shorten maturation periods. As glaciers retreat and permafrost thaws, arthropods, along with lowland plant species, will advance to higher elevations and latitudes, dramatically altering the current ecological communities. Similarly, studies looking at other insect species have reported a northern migration pattern in response to temperature; particularly winter temperatures.[23–25]

Frazier *et al.*[26] reported on the relationship between increasing temperatures and population growth of 65 insect species. Insects that adapt well to warmer environments experienced an increase in population growth rates. Deutsch *et al.*,[27] in turn, showed that with a warming climate, the fitness of ectothermal organisms is expected to generally increase with their latitude. They predict faster population growth for insects at mid- to high latitudes, and negative consequences and increased extinction rates for ectothermal species near the equator. This corresponds to findings from this study.

Our observations suggest that insect response to warming temperature, along with other related factors such as adequate snow pack and the absence of cold snaps, inevitably alters population dynamics. We propose that further studies should be done to better understand the mechanisms of the pattern we report. It is our intent to gather climate variable data from each of the six regions of Alaska and determine whether those data correlate with changes in insect reactions. It is also important to keep an open mind and test for nonclimate change variables.

Feulner[28] stresses that "the epidemiologic study designs appropriate for global change and health are observational rather than experimental." Our finding of increased insect bites or stings in Alaska—where the effects of climate change are most profoundly observed—warrant further studies to determine if temperature increases are a cause. If so, Hymenoptera and other arthropods may become indicator species or bellwethers, helping us to measure and predict the effects of climate change.

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