TITLE PAGE

Original Article

Increasing Insect Reactions in Alaska: Is this Related to Changing Climate?

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Key Messages: The incidence of medical visits due to insect stings and bites has increased during the past decade in Alaska. Over the past fifty years, Alaska's average temperature has risen 2.2 degrees Celsius (3.4 degrees Fahrenheit); four times higher than the average for the planet, which may be a contributing factor in these medical visits. To the best of our knowledge, this is the first report linking climate change to an increase in medical visits due to sting and bite reactions.

Capsule Summary: The incidence of medical visits due to insect reactions has increased significantly over the past decade in Alaska, during which Alaska has experienced increasing temperatures associated with climate change.

Abbreviations used:

ICD-9: International Classification of Diseases, Ninth Revision

EMS: Emergency Medical Services

CPR: Cardiopulmonary Resuscitation

FMH ED: Fairbanks Memorial Hospital Emergency Department

AAIC: Allergy, Asthma and Immunology Center of Alaska

Key Words: Climate Change, Hymenoptera, Yellowjacket, Yellow Jacket, Global Warming, Anaphylaxis, Alaska, Wasp, Stinging Insect

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Abstract:

Background: During the summer of 2006, Fairbanks Alaska experienced its first two known cases of fatal anaphylaxis as a result of Hymenoptera stings, presumably from yellowjackets (*Vespidae*). An increase in insect bites and stings has been observed throughout the state.

Objectives: To determine if there has been an increased incidence of medical visits due to insect bites and stings in Alaska in recent years.

Methods: We conducted a retrospective review of three independent patient databases in Alaska to identify trends of patients seeking medical care for adverse reactions following insect bites and stings. For each database, an insect bite or sting episode warranting medical care was defined as a claim for the Clinical Modification of the International Classification of Diseases, Ninth Revision (ICD-9-CM), codes E905.3 (venomous insect; Hymenoptera); E906.4 (bite; non-venomous arthropod), and 989.5 (toxic effect; venom). Increases in bite and sting events in each region were compared to temperature changes in the same region.

Results: Each database revealed a statistically significant trend in patients seeking care for reactions to insect bites and stings. Fairbanks Memorial Hospital Emergency Department reported a four-fold increase in patients in 2006 compared to previous years (1992-2005). The Allergy Asthma and Immunology Center of Alaska reported a three -fold increase in patients from 1999 - 2002 to 2003- 2007. A retrospective review of the Alaska Medicaid database between 1999 and 2006 showed increases in billings for insect bites and stings among all regions, with the largest percentage increases occurring in the most northern areas.

Conclusion: Alaska has experienced an increase in insect bites and stings, most dramatically indicated by two anaphylaxis deaths due to Hymenoptera stings. Statistically significant increases in patients seeking medical care for insect bite and sting related events are observed throughout the state, with 5 of the 6 regions experiencing at least a 6 degree Fahrenheit increase in winter temperature since 1950.

INTRODUCTION:

During the summer of 2006, two cases of fatal anaphylaxis due to yellowjacket stings in Alaska were reported.[1,2] These are the first reported fatalities due to Hymenoptera anaphylaxis in Fairbanks. The deaths occurred during what is colloquially called an "outbreak summer" when the yellowjacket populations around Fairbanks were estimated to be more than ten times the average number. "Outbreak year" is a colloquialism used by entomologists to describe a general, localized increase in insect population. Jack Whitman, a wildlife biologist with the Alaska Department of Fish and Game in Fairbanks, set up three homemade traps around his house. Within four days he had trapped 3,461 yellowjackets. Over the next few weeks he identified and destroyed nine ground nests and estimated killing 12,000 yellowjackets.[3] Annual numbers of yellowjackets are not officially monitored or recorded in Alaska. However, in 2003 and 2004, Landolt, et al, reported capturing over 642 yellowjackets during the second week of July in Fairbanks in 2003 and approximately 2000 in traps maintained in Fairbanks, Delta Junction, and in Palmer from early May through September 2004.[4] There are several potential explanations for increased incidence of insect related events including "wasp or outbreak years". Such outbreak years are well documented in the entomological literature with accounts dating from the 19th century in Europe[5], though their causes remain poorly understood. The 2006 spike in Fairbanks notwithstanding, trends throughout Alaska during the study period have illuminated increasing bite and sting-related events resulting in medical care. Those two sting-related deaths in Fairbanks were the sentinel events that stimulated the query.

Cases: Two fatalities due to stings occurred in Fairbanks, during the data analysis period.

Case 1: A 29 year old male with asthma was working in his yard with a weed trimmer. He was stung by a winged Hymenoptera (presumed a yellowjacket). He attempted to drive himself to the Emergency Department; however, he lost consciousness before arrival and rolled his vehicle off the road into a fence at a low rate of speed. Emergency Medical Services (EMS) responded to the scene where they found him unconscious with an albuterol inhaler in his lap. He was in respiratory distress with gasping respirations. After intubation at the scene, he was noted to have very high airway pressures. Epinephrine was administered resulting in reduced airway resistance and improved ventilation. Prior to arrival at the Emergency Department, he received three boluses of epinephrine and three boluses of atropine. Advanced cardiac life support continued in the Emergency Department, but was unsuccessful. He had no previous history of insect sting hypersensitivity.

Case 2: A 50 year old male with hypertension, for which he was taking lisinopril and hydrochlorothiazide, was cutting trees with a chainsaw and was stung in the back of the neck by a yellowjacket. The event was witnessed by his wife. He shut off his chainsaw, took off his shirt and showed his wife the sting. Two minutes later, he fell to the ground. His wife went into their home and retrieved an EpiPen®, which she carried because of her own sensitivity to Hymenoptera. When she returned he was face down and non-responsive. She called 911, then after three unsuccessful attempts, she administered the epinephrine. She then began cardiopulmonary resuscitation (CPR). EMS arrived within five minutes and continued CPR. He was transported to Fairbanks Memorial Hospital. Field intubation was difficult because of laryngeal edema, although EMS was able to insert a Combitube® airway. In the Emergency

Department, resuscitation was unsuccessful. He had been stung two weeks earlier, by winged Hymenoptera, without adverse reaction.

METHODS:

To determine the trends in patients seeking care for insect bites and stings, we conducted a retrospective review of three databases. For each database, a case was defined as a billing claim for International Classification of Diseases, Ninth Revision (ICD-9) codes E905.3 (venomous insect specific to Hymenoptera); E906.4 (bite from non-venomous arthropod); and 989.5 (toxic effect from venom). The ICD-9 was published in 1977, and has been in use as the standard for morbidity documentation since before 1983; this predates all data used in our analysis. 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 city). Data were available from 1992 through 2006. The second database is from a site providing clinical services, the Allergy Asthma & Immunology Center of Alaska (AAIC), located in Anchorage. Alaska's most populous city, Anchorage contains almost half of the state's population. The AAIC is the only allergy and immunology centre in the state. Data were available from 1999 through 2007. The only known reasons for increases in cases during the study period were those expected from population increases.

We also evaluated a state-wide 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; lengths of Medicaid enrolment did not change appreciably over time. Data were presented for each of the six epidemiologic regions of Alaska (based on residence at enrolment 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 (US Centers for Disease Control and Prevention, Atlanta GA.).

We utilize 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, 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 US Census Bureau).[6] Fairbanks Memorial Hospital serves the city as well as patients throughout the North Star Borough with an estimated total population of 82,840.[6] Emergency Department data were obtained from 1990 through 2006. Between 1990 and 1992 there were no reported visits for insect related events. Data from 1993 revealed 28 patients seeking care in the Emergency Department for bite and sting related events. From 1993 through 2005 there were between 20 and 40 patients seen in the Emergency Department per year. In 2006 there was a fourfold rise to 178 patients seeking care for bite and sting related events, an estimated annual incidence of 208 per 100,000 (Figure 1). Fairbanks North Star Borough's population increased from 81,383 to 86,754 (6.5% increase) between 1992 and 2006.[6]

We reviewed the AAIC database for referrals of patients with insect related events. From a low of 4 referrals for Hymenoptera sting reaction in 1999, there has been an upward trend of referrals to a high of 17 in 2006 and 23 in 2007. AAIC reported an increase of 2.5 cases per year (chi-square for linear trend $p<0.001$) with no known increase in patient referral sources outside of those associated with population increases (Figure 2). From 1999 to 2006, Anchorage population increased from 260,283 to 278,700 (7% increase).

During 1999, there were 106,312 persons enrolled in Medicaid, compared to 132,515 during 2006. The number of identified cases by year during 1999-2006 were 250, 294, 334, 376, 300, 493, 583, and 383 respectively; while incidences per 100,000 enrolled persons per year were 235, 254, 274, 296, 371, 432, and 289 (chi-square for trend, 54.3; $p<0.0001$). These values reflect cases with insect bite and sting as the primary diagnosis. Interestingly, if we include insect bite and sting as any diagnosis, the values increase by approximately 50% with little variation by year (Figure 3).

The Alaska Division of Public Health divides Alaska into six regions (Figure 4). Five of Alaska's six regions recorded statistically significant increases (at the 95% confidence level, based on individual year data) in billing for insect bites and stings among Medicaid enrolees (Figure 5). The lone exception was the Gulf Coast. The Northern Region experienced an increase of 626% from the average incidence of 16 per 100,000 per year during 1999-2001 to 119 per 100,000 per year during 2004-2006. Increases in average incidence over the same time period for other regions were: Southwest, 114% (62 to 133); Interior, 53% (333 to 509); Anchorage, 47% (276 to 405); and Southeast, 26% (221 to 279). For all of Alaska, the average insect bite and sting incidence increased 43% from 254 per 100,000 per year during 1999-2001 to 364 per 100,000 per year during 2004-2006 (Table I).

A review of the data reported by the Alaska Climate Research Center reveals an increase in the average annual temperature of 3.4 degrees Fahrenheit in Alaska since 1950, an increase of 6.3 degrees Fahrenheit when we consider only the winter months. Each region of Alaska experienced comparable increases with the exception of the Gulf Coast which only experienced a 1.5 degree Fahrenheit rise during that period (Table II). Each of the other five regions experienced at least a 6 degree increase in average winter temperatures. This suggests that one contributing factor for the increase in bite and sting events may be associated with a rise in temperature and more specifically winter temperature (Table II). This is not a test of hypothesis but rather is the generation of the hypothesis, warranting further study.

DISCUSSION:

We report two accounts of fatal anaphylaxis due to Hymenoptera sting in Fairbanks during the summer of 2006; these represent the first reported venom-associated deaths in Fairbanks. Data from the AAIC illustrates an increase in referrals for evaluation of bite and 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 per year (chi-square for linear trend $p<0.001$). AAIC serves Alaska as the only group of board certified allergists providing consultation 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 the Alaska Medicaid further support these findings, and show an increasing trend in almost all regions of Alaska, going back to at least 1999. While the increase from 2005 to 2006 was dramatic in Interior Alaska (including the Fairbanks area), the greatest increase in bite and sting incidence occurred in the Northern regions of Alaska, which experienced an increase of over 600%. This trend does not appear to be unique to Alaska, and has been observed in other circumpolar regions. In 2004, a Canadian entomologist and associate curator of the Natural History Museum in Los Angeles confirmed yellowjackets (*Vespula rufa*) in the village of Arctic Bay, Nunavut, at 73 degrees latitude. [7]

The summer of 2006 was notable for anecdotal reports of an extremely high number of yellowjackets in interior Alaska. The level of Hymenoptera sightings and incidence of stings led to the cancelling of cross-country running events and several school district field trips. Similar Hymenoptera outbreak years have been reported from the Fairbanks region, suggesting the 2006 outbreak is not abnormal over the long term historic record. Our study shows an increase in clinical visits for bites and stings but does not provide information on aetiology for this increase. However, our data combined with other studies suggests that increases in temperature and changes in other climactic variables could make such outbreak years more common and/or increase their severity. Unfortunately, data are limited in correlation between current climate changes and the impacts on arthropods. Indeed many observations are limited to reports in newspapers and websites.

Yellowjacket 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, demonstrated that while freezing causes death in the common yellowjacket, *Vespula vulgaris*; this species is able to 'supercool' to temperatures below minus 16 degrees Celsius without freezing. In their study, snow depths of as little as 60cm provided enough insulation to allow the overwintering queens to survive in hibernacula, maintaining an average of minus 6.5 degrees Celsius, while average above-snow air temperatures were minus 19.4 degrees Celsius (with minima often below minus 30 degrees Celsius). These findings illustrate that snow depth could be an important factor in the annual population growth of yellowjackets. Their work also demonstrated that once the queens emerge, their ability to 'supercool' declines. A cold snap occurring after emergence could kill many queens. If cold snaps become less frequent and less intense due to climate change, queen survival should increase. It seems likely to expect larger populations from warmer temperature minima; winters with deep snow; warm, dry spring weather; and a lack of cold snaps; given what limited information we have on the influence of weather on yellowjacket populations in Alaska. [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 favourable spring weather was further strengthened by the findings of Barlow et al. [12] who monitored *Vespula vulgaris* at six sites in New Zealand for thirteen years. In Alaska, where winter temperatures are often sub-zero, warmer temperatures frequently result in more snowfall, increasing the insulation for overwintering of the queens. This, in combination with warmer spring temperatures, creates an ideal scenario for increased Hymenoptera survival. Our findings demonstrate that in each of five regions that had a statistically significant increase in bite and sting related events, there was at least a 6 degree Fahrenheit increase in average winter temperature. The Gulf Coast, whose bite and sting event increase of only 11% failed to reach statistical significance, had only a 1.5 degree Fahrenheit increase in winter temperature. Interestingly, this region has the highest average winter temperature in the state (30.1 deg F)[13], and correspondingly had the highest incidence of bite and sting events at the beginning of the study period. It had the smallest rise in temperature over the study period, as well as the smallest increase in bite and sting events (only 11% compared with the state-wide increase of 43%).

Over the past 50 years Alaska's climate has warmed 2.2 degrees Celsius, at a rate of 0.4 degrees Celsius per decade.[13,14] A 2.2 degree C temperature rise may not seem very large; however, global temperatures during the "Ice Age" averaged only 3 to 6 degrees C lower than today. The United Nations UNCCC Executive Secretary stated that in the past 100 years the planet has warmed 0.7 degrees C (1.44 degrees F) with the majority of the warming occurring over the past

50 years. In fact, eleven of the past twelve 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]

According to Dominique Bachelet[16], Oregon State University, the Polar Regions will continue to be the first to experience the impacts of climate change. Further, over the next 100 years, Alaska is projected to lose up to 90% of its historic tundra, allowing forestation and growth of other vegetation, and resulting in dramatic ecological change. Bachelet predicts an increase in insects and pathogens, causing epidemics of plant disease and insect attacks, all as a consequence of climate change.[17] Outbreaks of destructive insects in unprecedented numbers such as the spruce bark beetle have infested Alaskan forests and killed 4.4 million acres of mature white spruce trees in the Kenai Peninsula. This has been attributed to longer, warmer summers and warmer winters which produce heavy, wet snow loads in Southcentral Alaska.[18] In the summer of 2003; Alaska experienced another upswing of unexpected visitors. Southcentral Alaska witnessed an 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]

Butterflies may be one of the most sensitive indicators of climate change. In North America and Europe they have shifted their northern range by up to 200 kilometers.[20] There are also compelling projections that warmer temperature will promote survivability of arthropods such as tick and mosquito species that are vectors of disease like malaria and dengue fever.[21,22] Mosquitoes and other small arthropods are very temperature sensitive. Warmer temperature can enhance reproductive rates, extend breeding seasons and shorten maturation periods. As glaciers retreat and permafrost thaws, arthropods, as well as 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.[23,24,25]

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 demonstrated 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 the Alaskan four-fold increases in temperature as compared to global changes in the same period, supporting the findings of increased human encounters with Hymenoptera as demonstrated by the Medicaid database.

Our observations suggest that adaptation to warming temperature along with other related factors such as adequate snow pack and the absence of cold snaps inevitably alters the population dynamics. There are opportunities for future research in Hymenoptera and climate data correlations. Most importantly, we propose that further studies should be done to bring us closer to understanding the mechanism 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 there is correlation with changes in Hymenoptera encounters. It is also important to keep an open mind and test for non-climate change variables.

Erica Feulner[28] stresses that “the epidemiologic study designs appropriate for global change and health are observational rather than experimental.” Just so, our finding of increased insect bites and stings in Alaska – where the effects of climate change are most profoundly observed – warrant further studies to determine if the observed correlation between temperature and insect related events is due to causation. If so, Hymenoptera and other arthropods may become indicator species or bellwethers, helping us to measure and predict the effects of climate change.

Table I. Incidence (per 100,000 population per year) of billing claims for insect stings as a primary diagnosis among Medicaid enrolled persons, by year and region; Alaska 1999-2006.

Year	Anchorage/Mat-Su	Interior	Northern	Southwest	Gulf Coast	Southeast	Total
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	46.7%	53.0%	625.5%	114.3%	11.4%	26.5%	43.2%

Table II. Annual and winter temperature increases and changes in insect sting incidence among Medicaid-enrolled persons; Alaska.

Region	**Largest Community**	**Annual temperature increase***	**Winter temperature increase***	**1999-2001 insect sting incidence**[†]	**2004-2006 insect sting incidence**[†]	**Percent change in insect sting incidence (X^2 for trend, p-value)**[‡]
Northern	Barrow	3.8	6.1	16	119	626% (13, p<0.001)
Southwest	Bethel	3.7	6.9	62	133	114% (8, p=0.005)
Interior	Fairbanks	3.6	8.1	333	509	53% (28, p<0.001)
Anchorage	Anchorage	3.4	7.2	276	405	47% (22, p<0.001)
Southeast	Juneau	3.6	6.8	221	279	27% (22, p<0.001)
Gulf	Kodiak	1.5	1.5	437	487	11% (0.1, p=0.75)
Statewide		3.4	6.3	254	364	43% (54, p<0.001)

* Annual and winter average temperature increase (°F) from 1950 to 2006 based on data for largest community

† Incidence per 100,000 Medicaid-enrolled persons per year for entire region

‡X^2 for trend and p-value calculation based on individual years from 1999 to 2006

Figures

Figure 1. Increase in ED visits for Stings at Fairbanks Memorial

[figure_1_fairbanks_graph.tif]

Figure 2. Patients referred to AAIC for evaluation of sting reactions between 1999 and 2007.

[figure_2_aaic_graph.tif]

Figure 3. Increase in Medical Visits for Stings Among Alaska Medicaid Recipients (Approximately 132,000 enrolees)

[figure_3_medicaid_graph.tif]

Figure 4. Map of Alaska, divided into epidemiologic regions

[figure_4_alaska_regions.tif]

Figure 5. 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.

[figure_5_regional_graph.tif]

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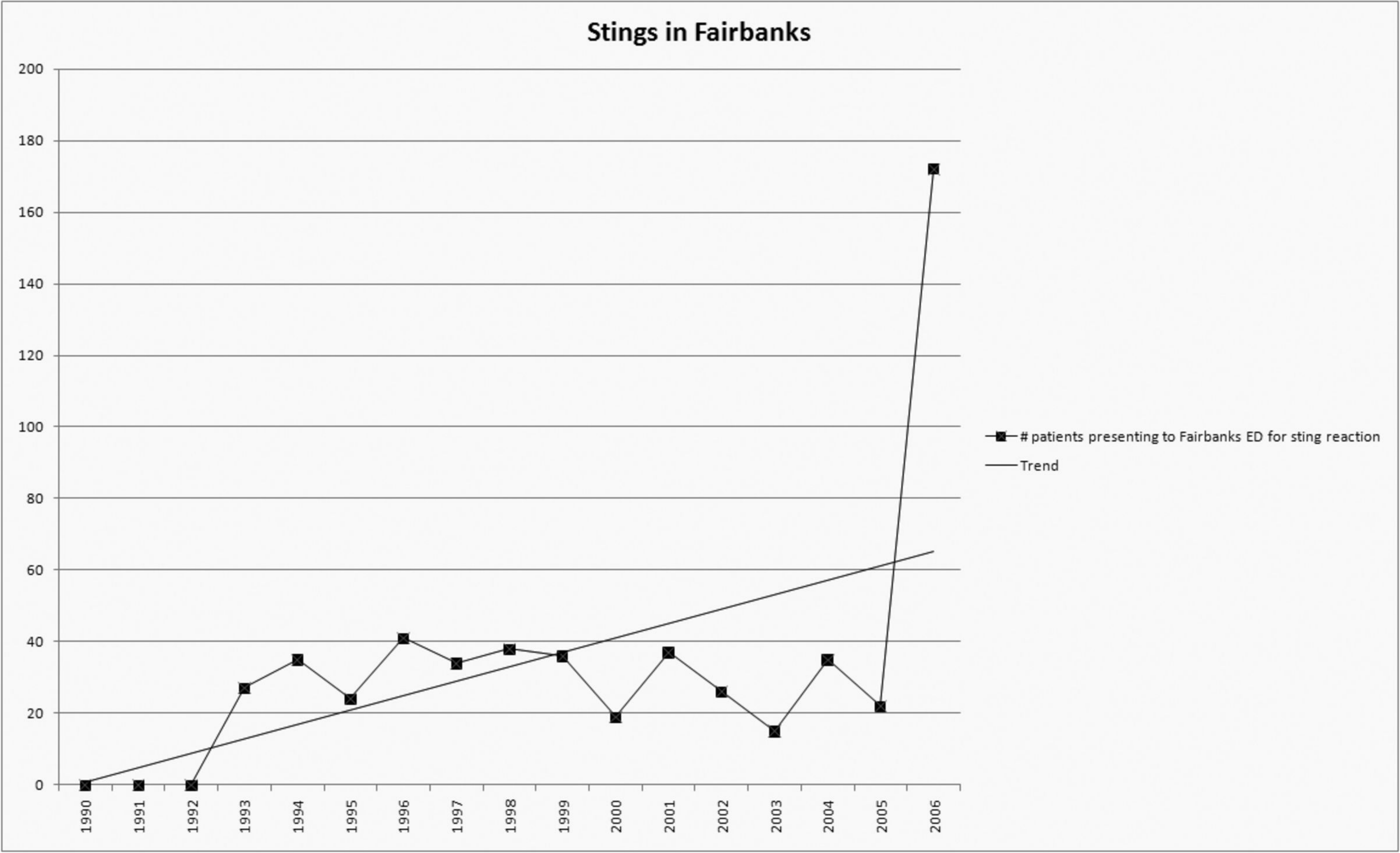
Stings in Fairbanks
200
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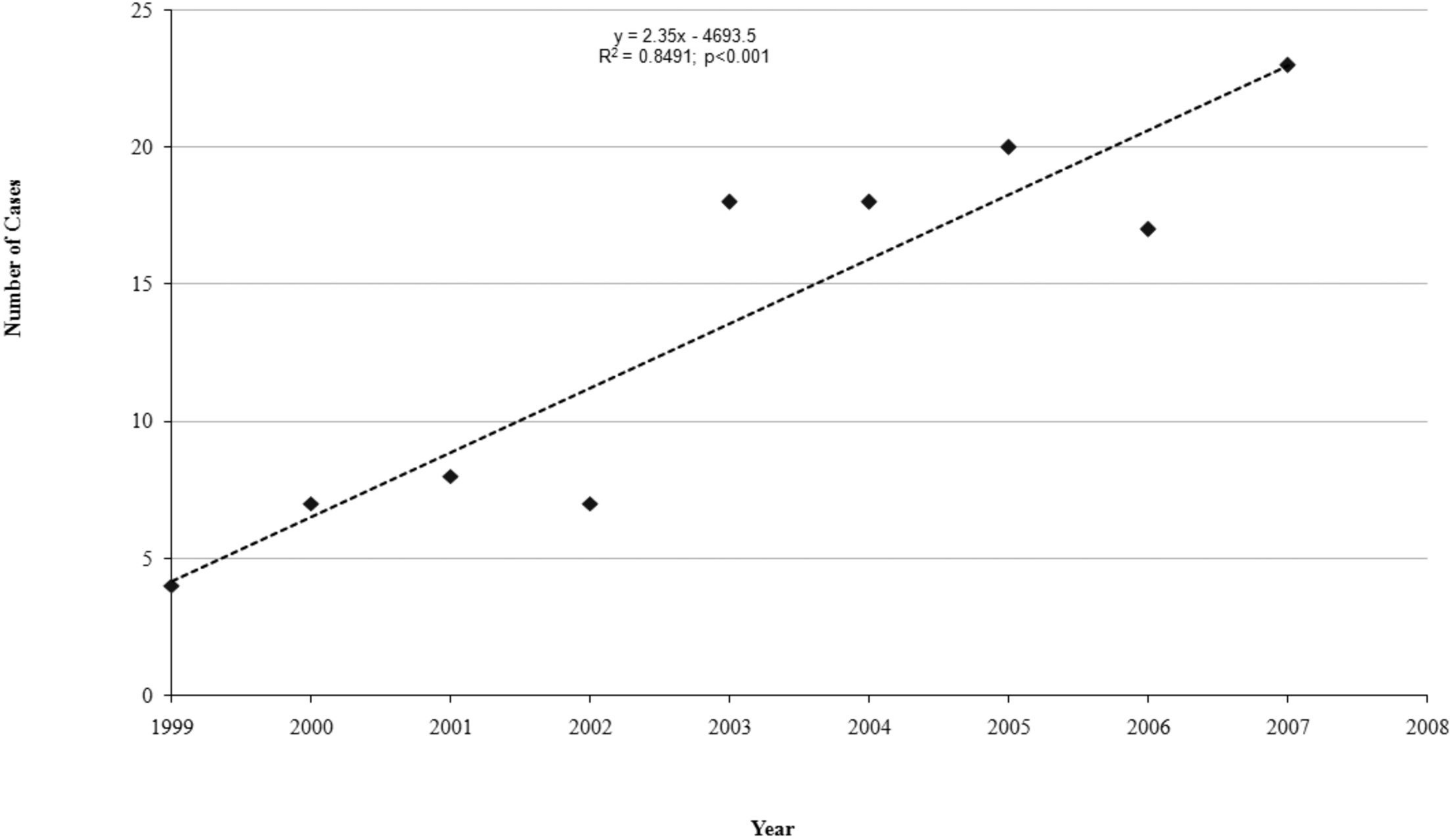
patients presenting to Fairbanks ED for sting reaction
Trend



y = 2.35x - 4693.5
R2 = 0.8491; p<0.001
Number of Cases
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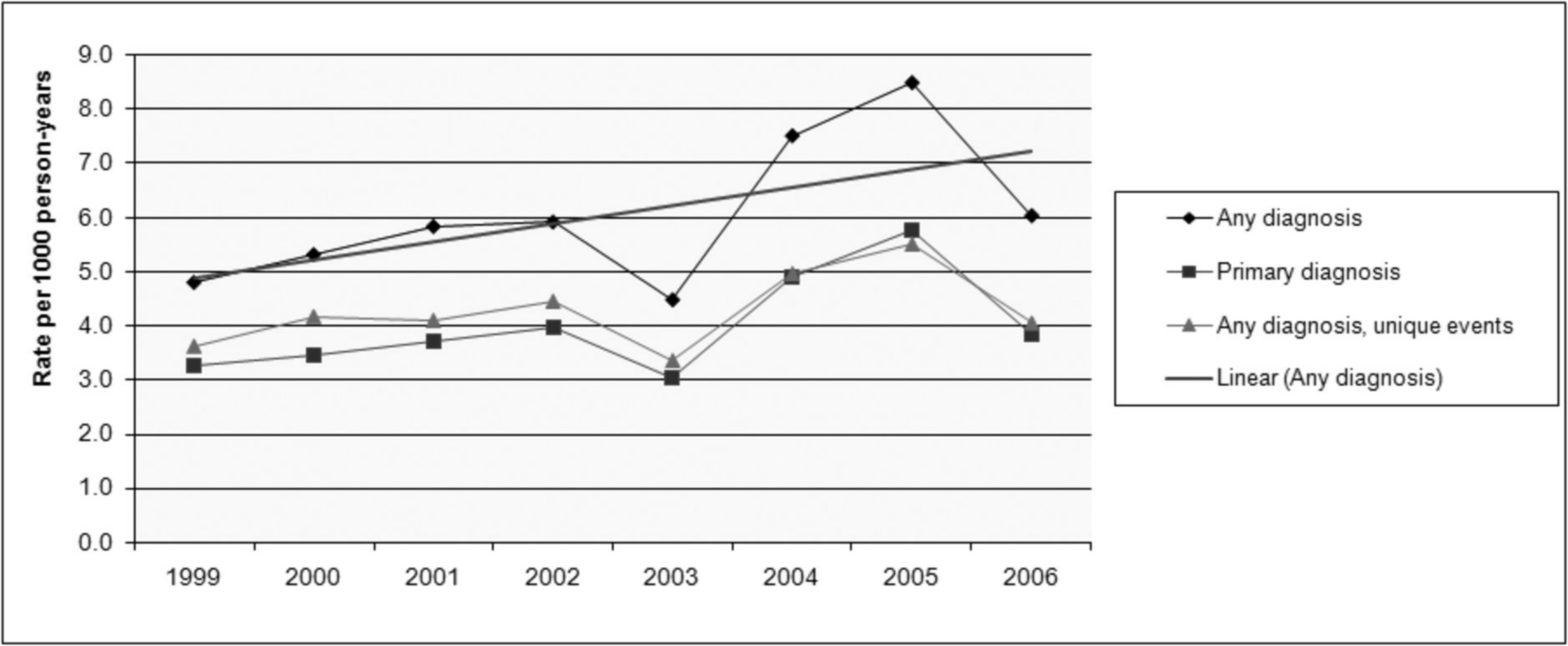
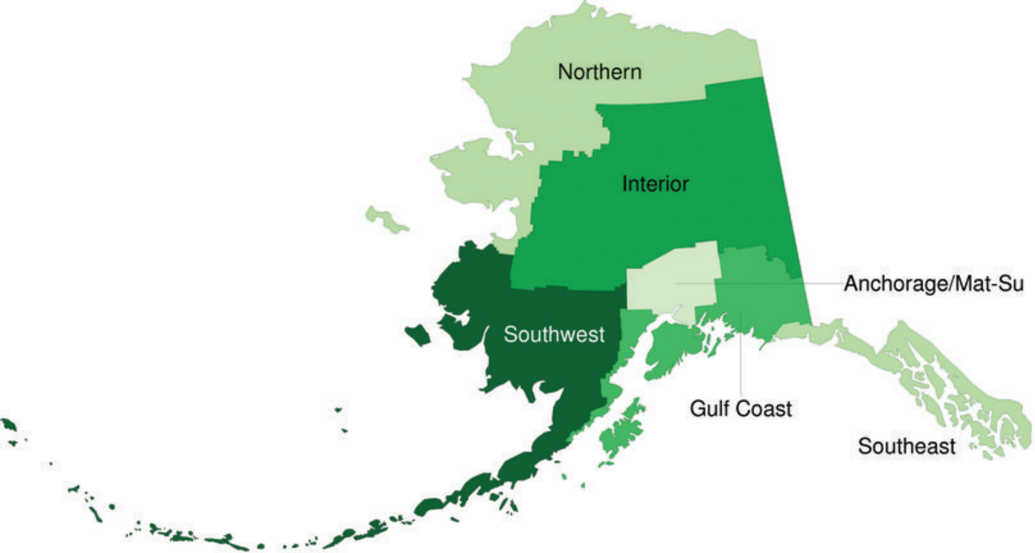
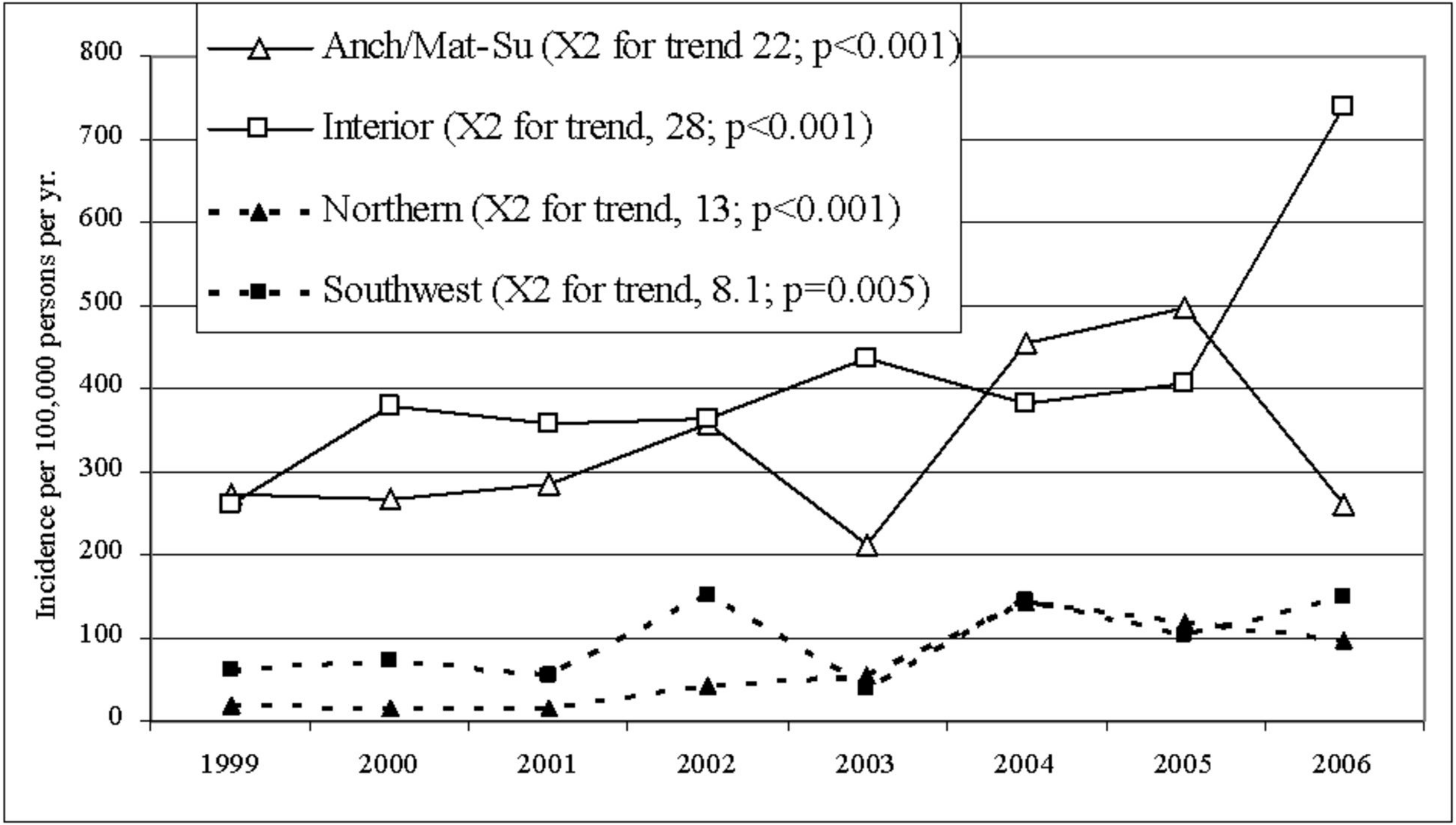
2008
Year


Rate per 1000 person-years
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1999
2000
2001
2002
2003
2004
2005
2006
Any diagnosis
Primary diagnosis
Any diagnosis, unique events
Linear (Any diagnosis)


Northern
Interior
Anchorage/Mat-Su
Southwest
Gulf Coast
Southeast



Anch/Mat-Su (X2 for trend 22; p<0.001)
Interior (X2 for trend, 28; p<0.001)
Northern (X2 for trend, 13; p<0.001)
Southwest (X2 for trend, 8.1; p=0.005)
Incidence per 100,000 persons per yr.
800
700
600
500
400
300
200
100
0
1999
2000
2001
2002
2003
2004
2005
2006