

Spatial Analysis of Pertussis Outbreaks and Herd Immunity in the USA

May 6, 2014

GEOG 596A

Ryan Warne

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Agenda

- Pertussis Overview
- Herd Immunity
- Objectives
- Data
- Other Health GIS Examples
- Methodology
- Limitations
- Timeline

Pertussis (Whooping Cough)

Respiratory disease caused by *Bordetella pertussis* bacteria

Transmitted via airborne droplets (coughing/sneezing)

Vaccine-preventable

Whooping cough is on the rise

~16 million cases & 195,000 deaths world-wide per year

~10k-40k cases & 10-20 deaths in USA per year

Approximately 50% of children <1 y are hospitalized

61° Mostly Cloudy



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San Diego County On Pace Toward Worst Year For 'Whooping Cough' Cases Since 2010

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Friday, April 25, 2014

By City News Service

Posted: 10:58 p.m. Tuesday, April 22, 2014

Doctors see increase in highly contagious Whooping Cough

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[KTVU.COM](#)

The Press Democrat

Whooping cough outbreaks reported in Sonoma County (w/video)

Why Are We Seeing Increases?

- Improved diagnostic testing and better reporting (CDC 2012)
- Waning effectiveness of the vaccine itself (CDC 2012)
- Cyclical Outbreaks (CDC 2012)
- Decreased perception of disease danger and severity (Kennedy 2011)
- Increase of parents delaying or fore-going vaccination due to personal beliefs or apathy about vaccinations (Lundquist 2010)

Exemptions due to religious, philosophical and medical reasons
1991-2004

- Nonmedical exemptions rose from 0.98% to 1.48 in USA
- Religious exemptions remained around 1%
- Philosophical or personal belief exemptions increased from 0.99% to 2.54% in states allowing personal belief exemptions

(Omer et al., 2009)

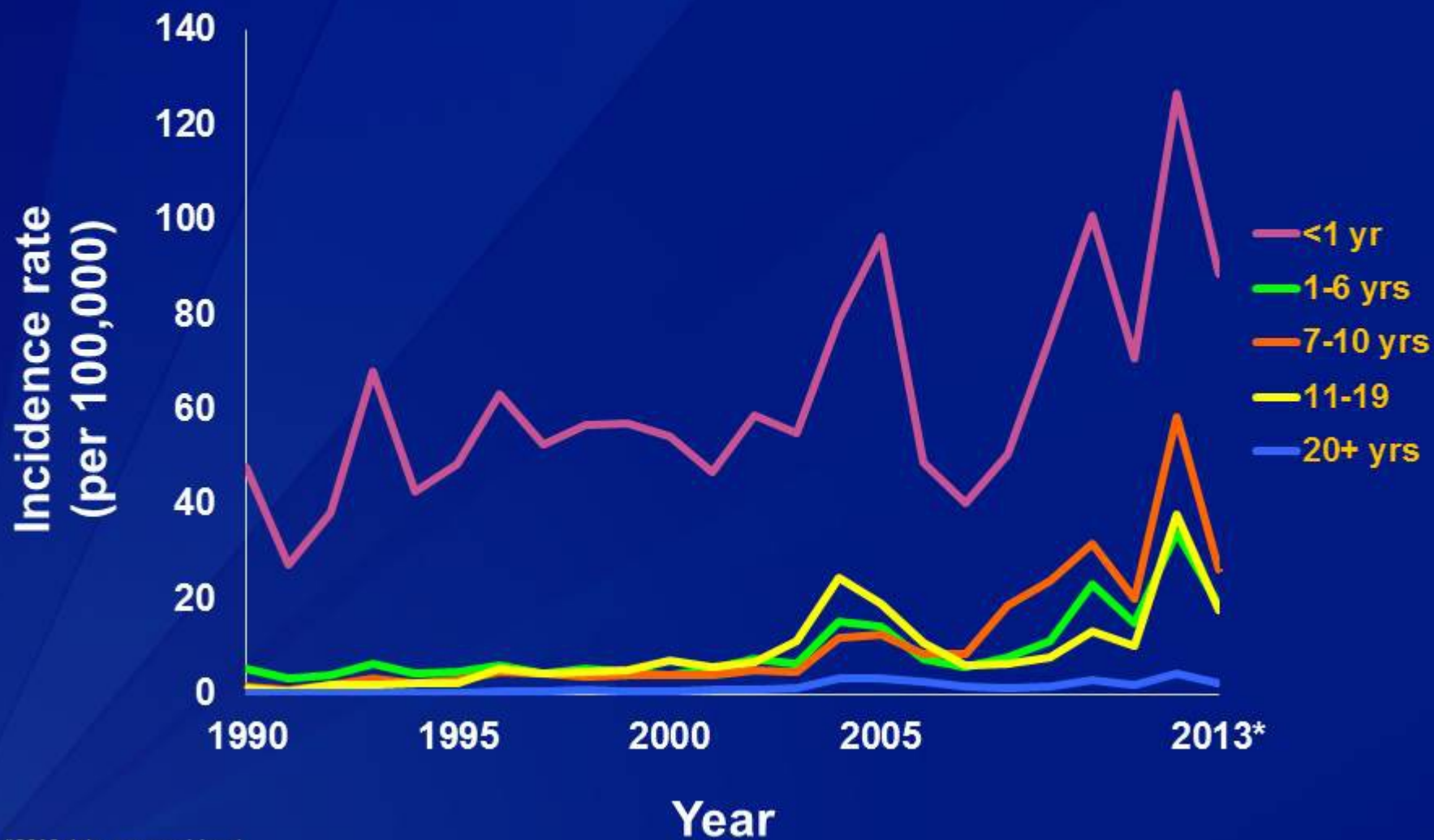
Reported NNDSS pertussis cases: 1922-2013*



*2013 data are provisional.




SOURCE: CDC, National Notifiable Diseases Surveillance System and Supplemental Pertussis Surveillance System and 1922-1949, passive reports to the Public Health Service

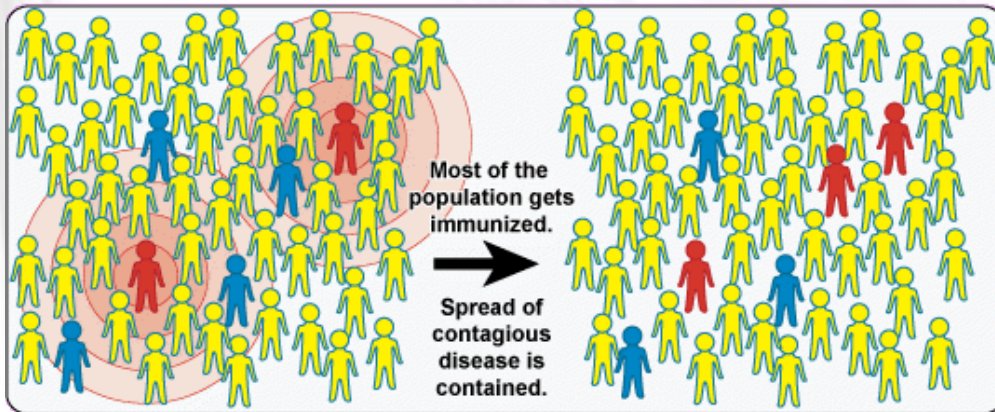
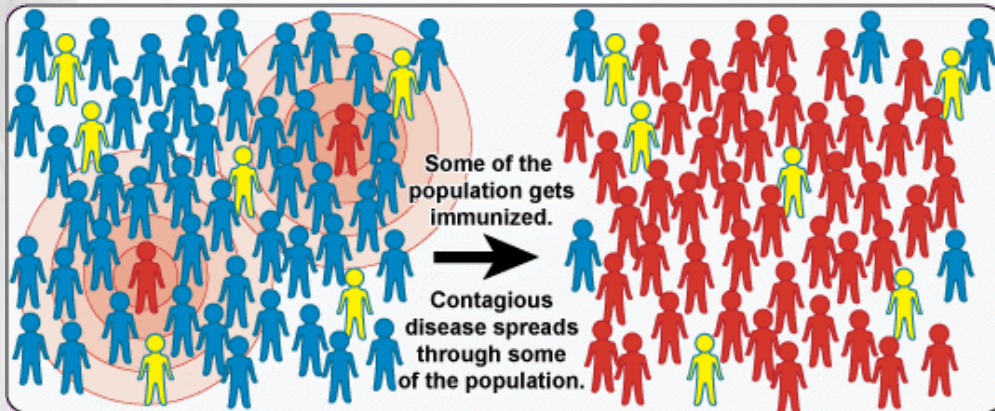
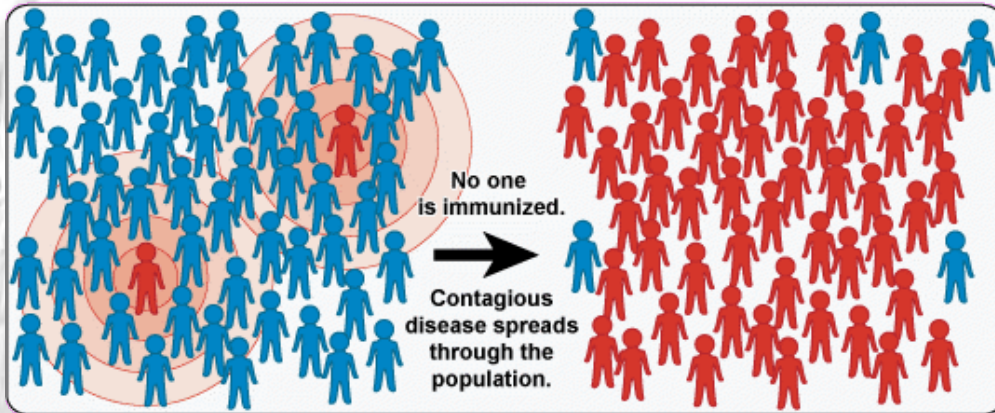
Reported pertussis incidence by age group: 1990-2013*



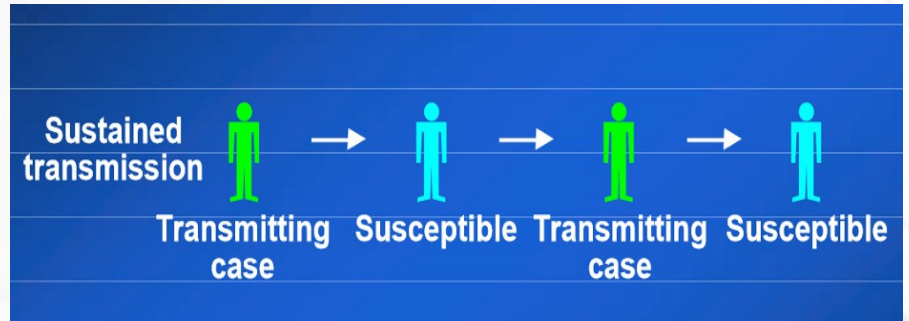
*2013 data are provisional.

SOURCE: CDC, National Notifiable Diseases Surveillance System and Supplemental Pertussis Surveillance System

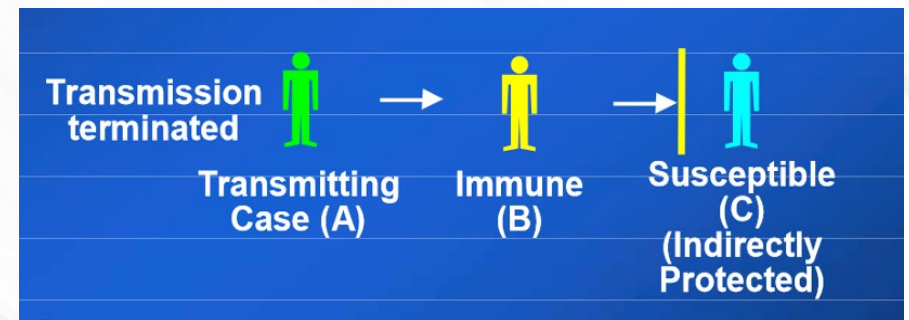
 = not immunized but still healthy
  = immunized and healthy
  = not immunized, sick, and contagious



Herd Immunity



- Protect the population from disease
- Minimize outbreaks through high levels of immunity
- Different diseases have varying thresholds of herd immunity



Herd Immunity Thresholds for Vaccine Preventable Diseases

R_0 is the basic reproduction number, or the average number of secondary infectious cases that are produced by a single index case in a completely susceptible population.

Disease	Transmission	R_0	Herd immunity threshold
Mumps	Airborne droplet	4–7	75–86%
Polio	Fecal-oral route	5–7	80–86%
Rubella	Airborne droplet	5–7	83–85%
Smallpox	Social contact	6–7	83–85%
Diphtheria	Saliva	6–7	85.00%
Measles	Airborne	12–18	83–94%
Pertussis	Airborne droplet	12–17	92–94%

Anti-Vaccination & Disease Rebound

Anti-vaccine movement is giving diseases a 2nd life

Apr. 8, 2014 | 0 Comments

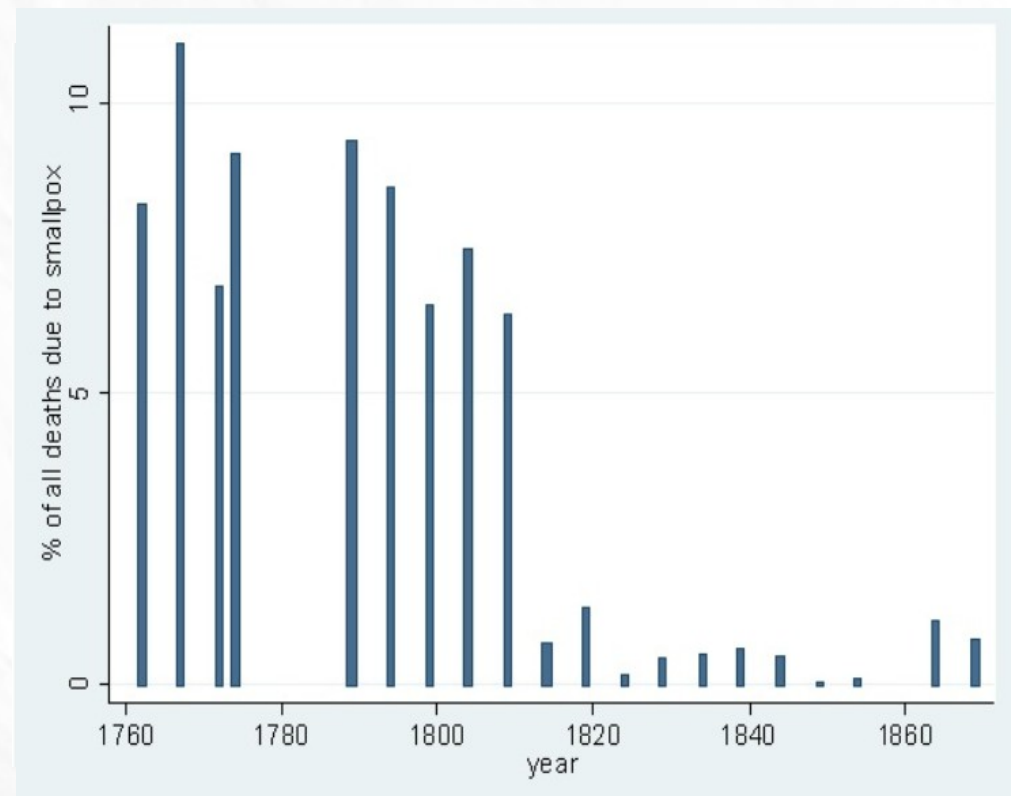
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Similar to smallpox (now eliminated) in the 19th century, reduction in vaccinations led to resurgence of smallpox

Smallpox fell between 1802 and 1840 through vaccination
Resurgence of smallpox in 1850's vaccination decreased leading to disease outbreaks throughout 1870's

1905 – *Jacobson v. Massachusetts*

(Omer et al 2009)



Smallpox % deaths in Berlin

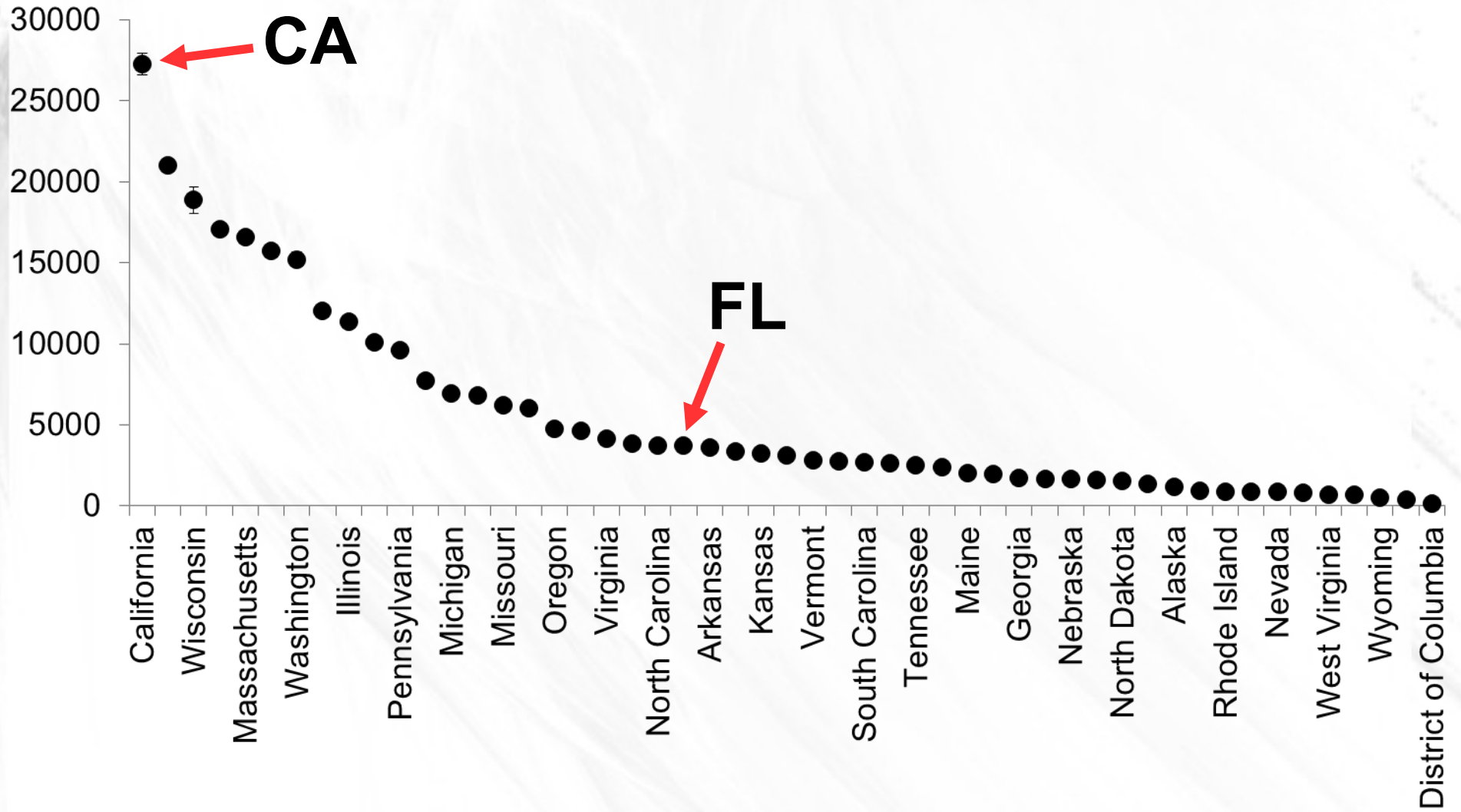
http://www.ewi-ssl.pitt.edu/econ/files/courses/110908_misc_smallpoxgraphs.pdf

Objectives

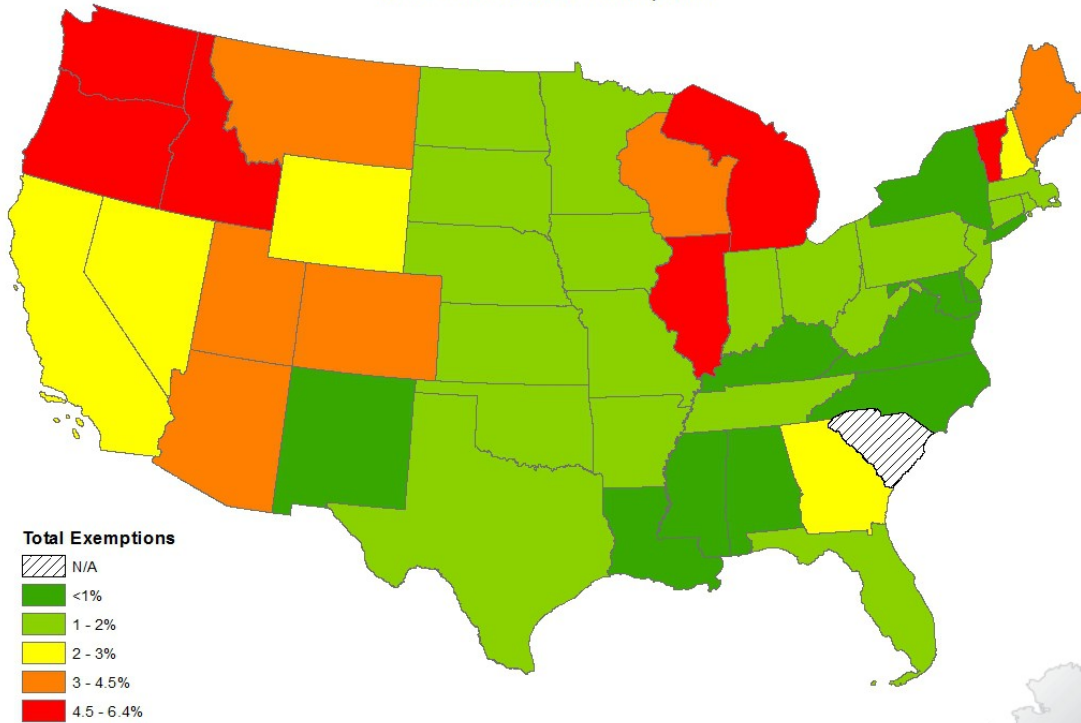
- (1) Explore the spatial distribution of pertussis cases and exemptions throughout the USA
 - Areas with positive or negative trends

- (2) Compare and contrast pertussis incidence over the past 5-10 years in 2 states.
 - Investigate the relationship between vaccination rates (i.e. herd immunity) and pertussis
 - Characterize demographic composition in these areas

Cases of Pertussis in the USA 1993-2012



2012-13 Vaccination Exemptions



Vaccination Exemptions

All states allow medical exemptions for schoolchildren

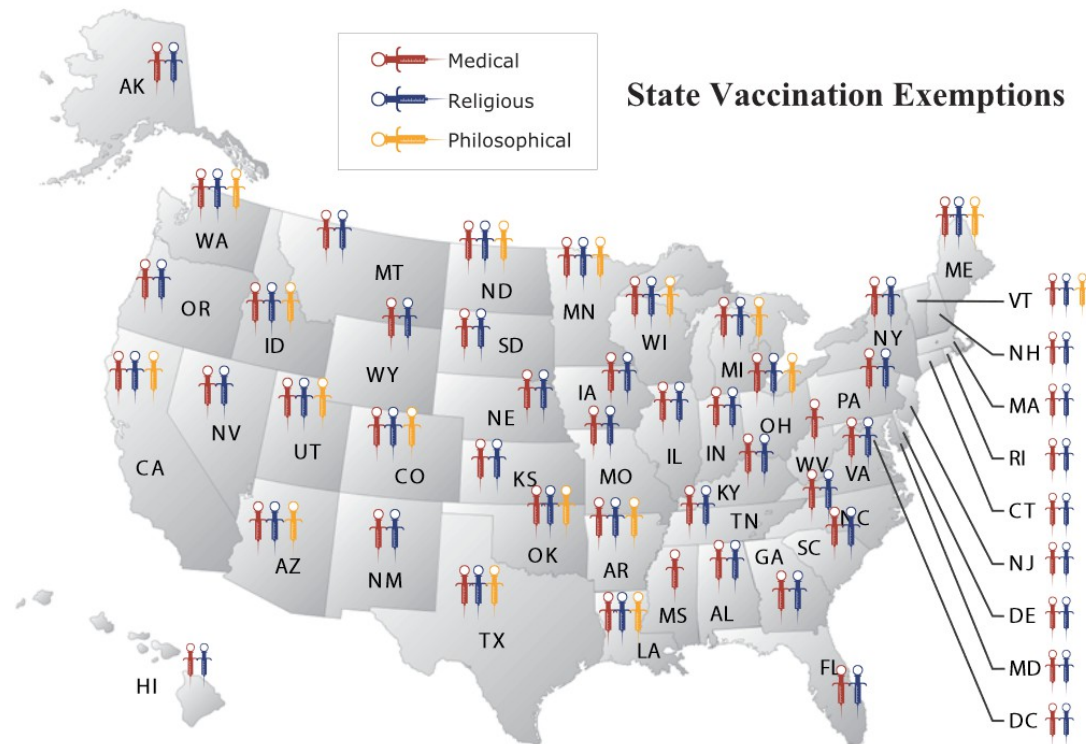
48 states allow religious exemptions

17 states allow philosophical or person belief exemptions (PBE)

Varying degrees of difficulty to receive PBEs

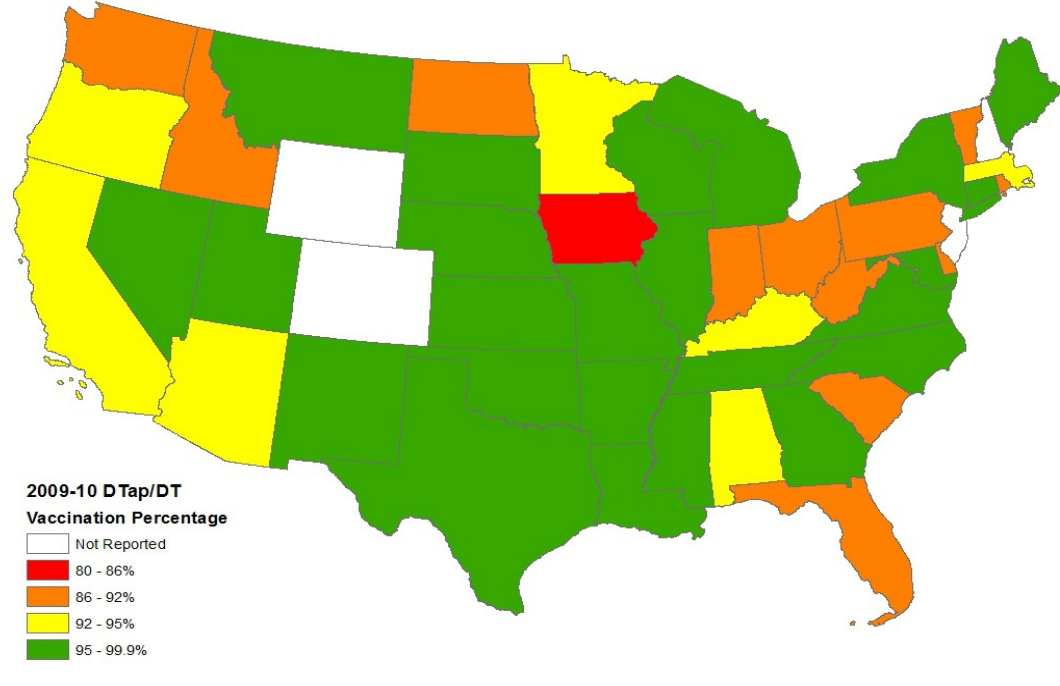
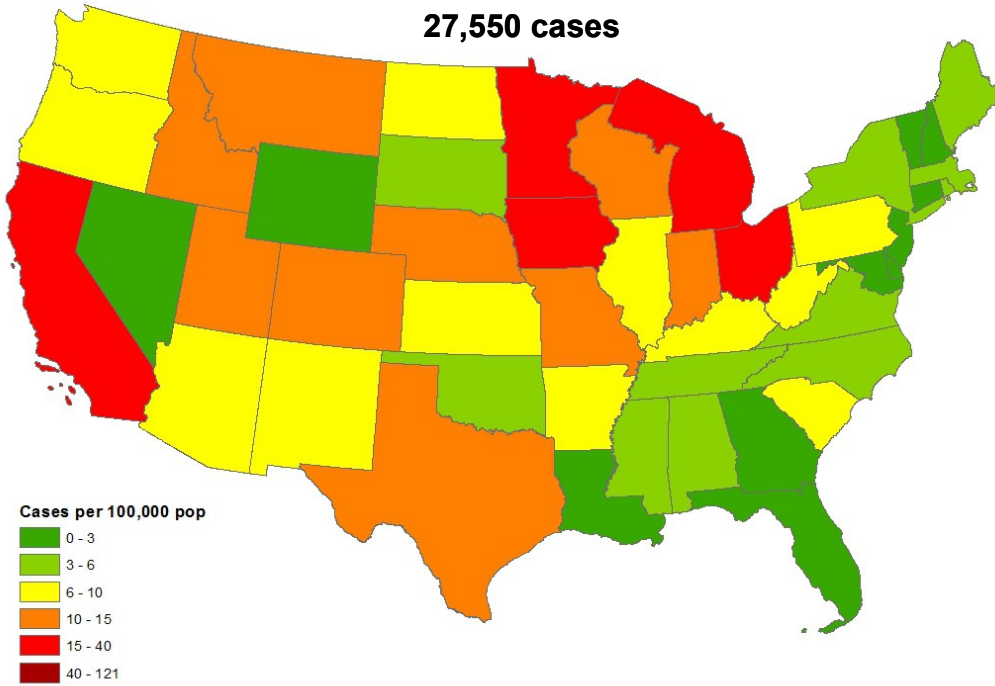
PBEs:

WA, CA, ID, UT, CO, AZ, ND, MN, WI, MI, OH, TX, OK, AR, LA, VT, ME



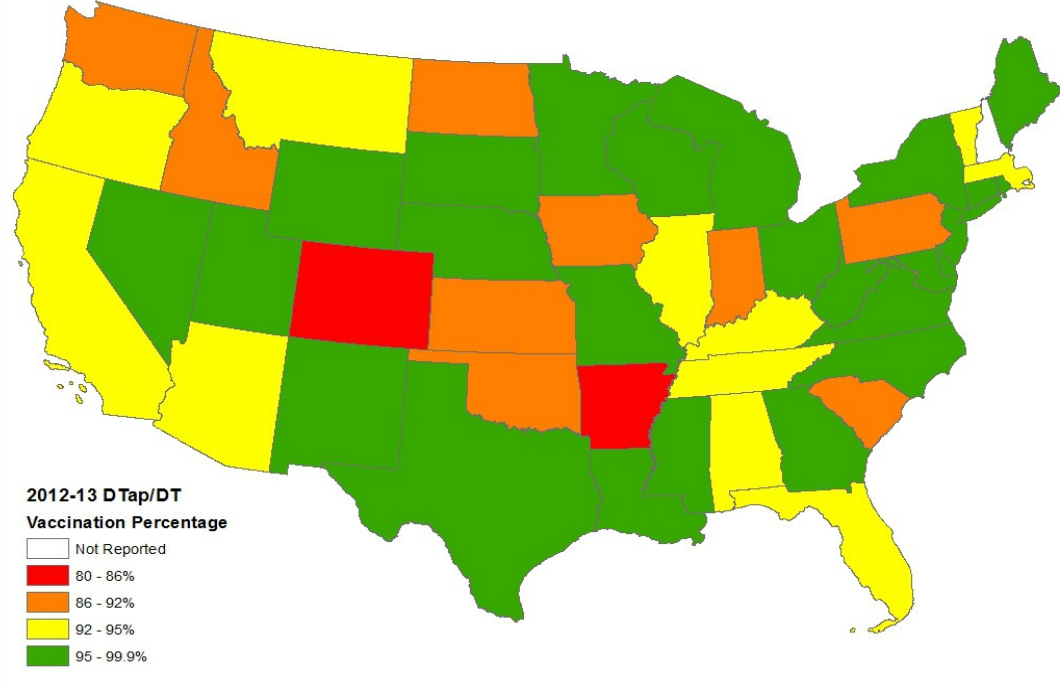
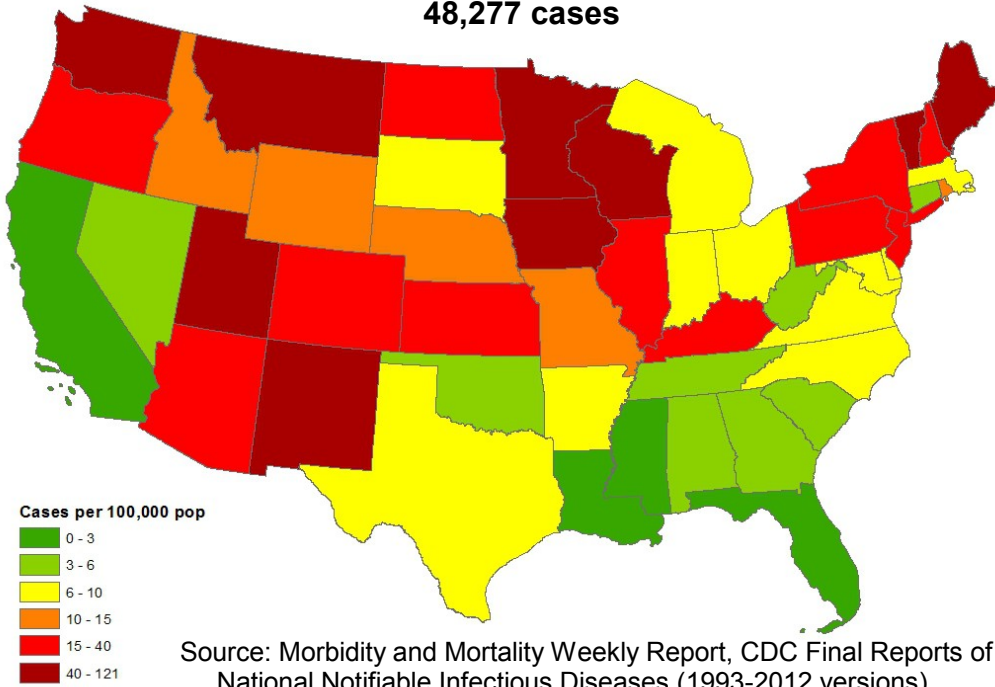
2010

27,550 cases



2012

48,277 cases



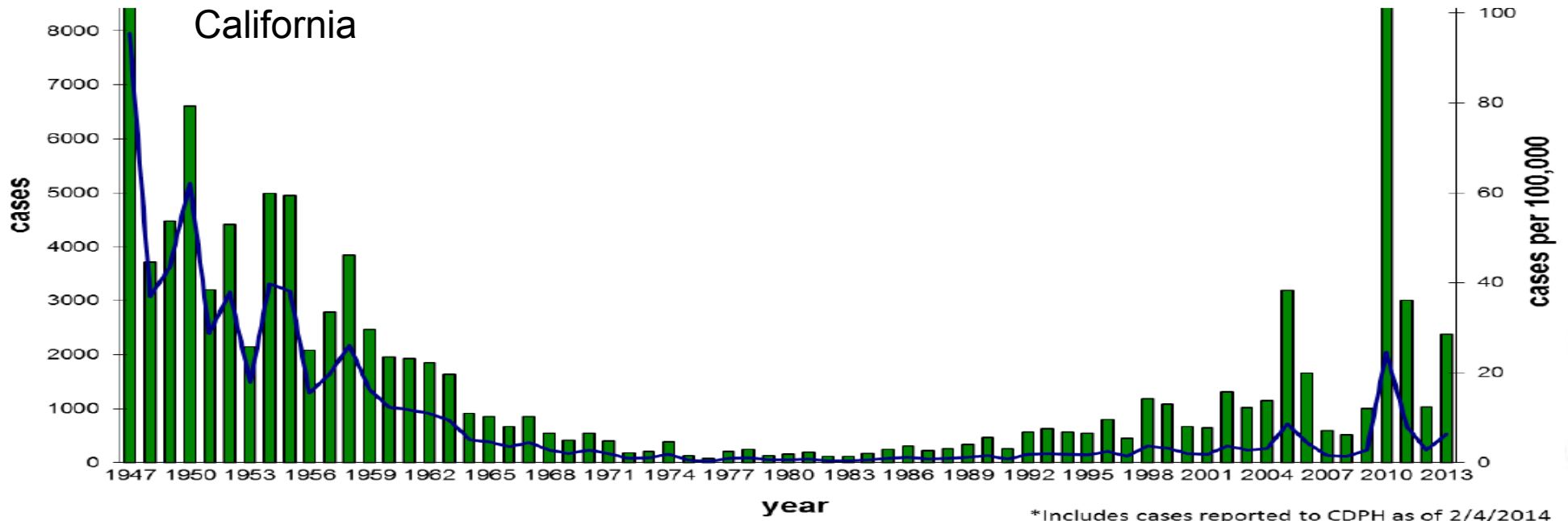
Source: Morbidity and Mortality Weekly Report, CDC Final Reports of National Notifiable Infectious Diseases (1993-2012 versions)

Pertussis Incidence Over the Past 20 Years California & Florida

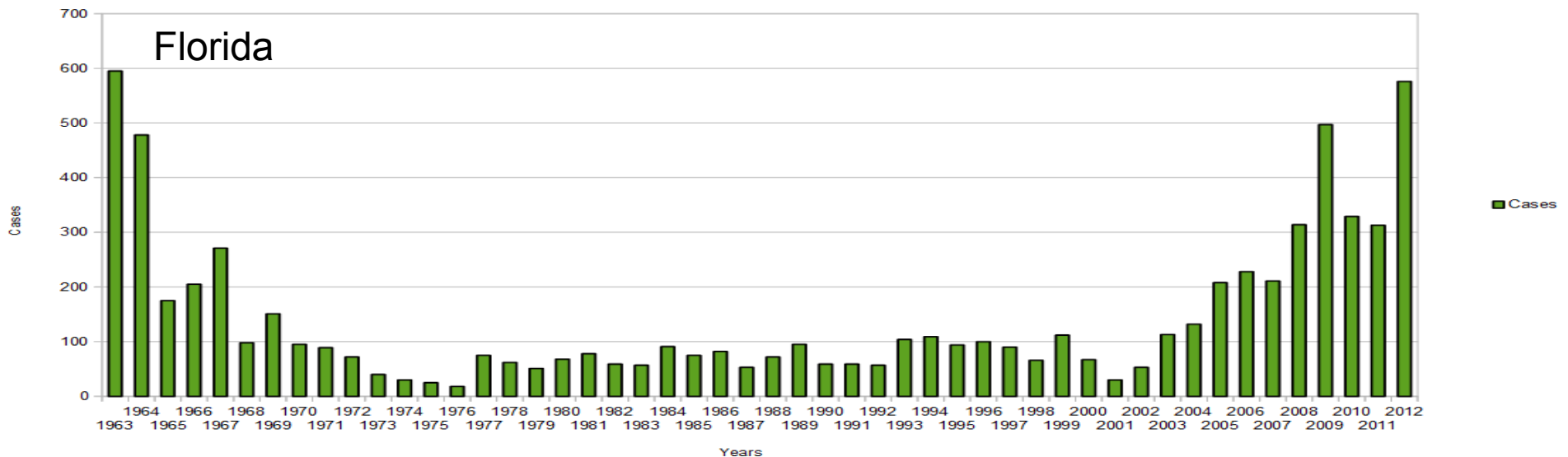
- California
- Averaged 1,960 cases / year
 - highest annual number of cases in the USA
 - Cyclical outbreaks in last 20 years with 1.5 – 19.3 cases/100,000 population
 - Current outbreaks in 2014

- Florida
- Averaged 290 cases / year
 - Average number of cases annually in the USA
 - Stable number of cases in last 20 years with < 3 cases/100,000 population

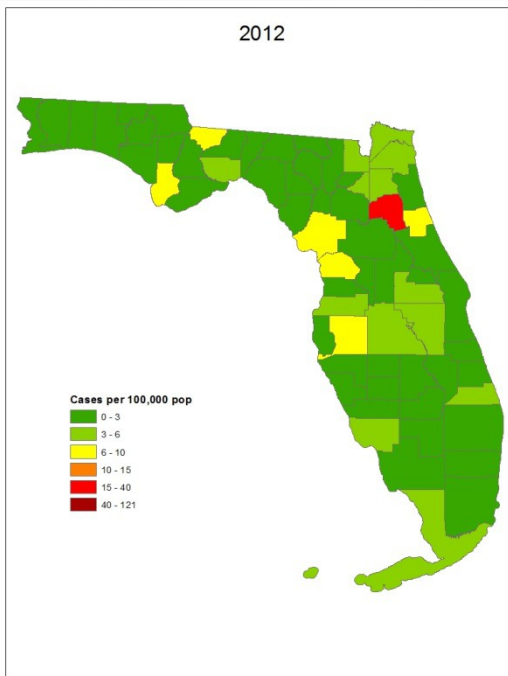
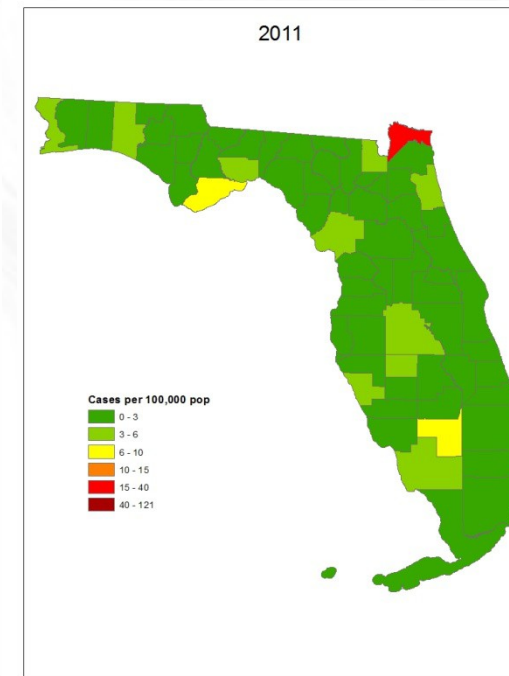
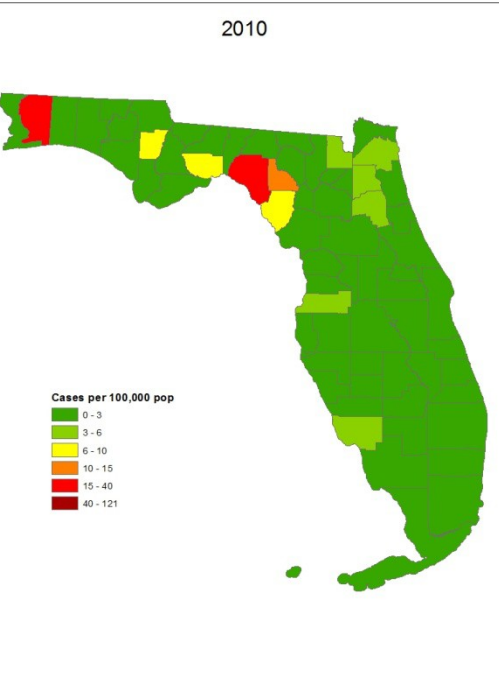
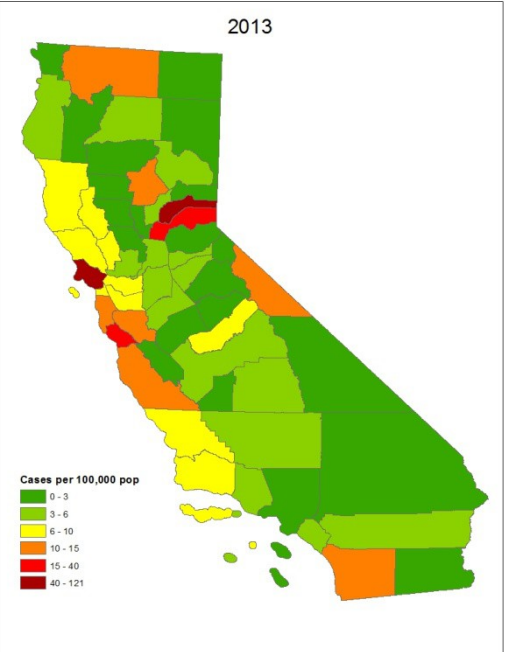
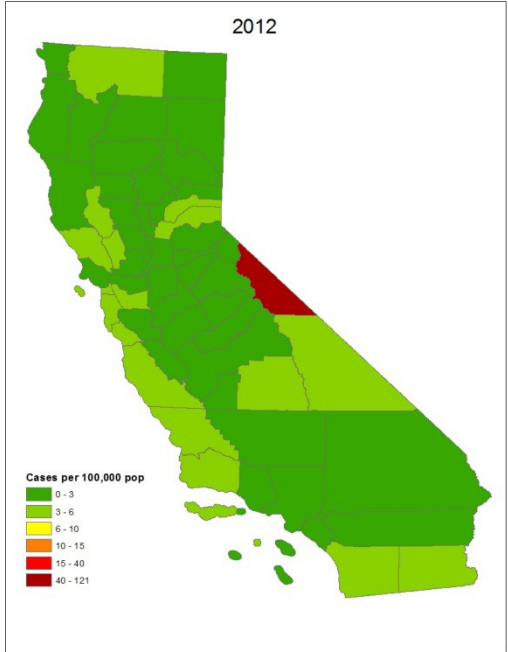
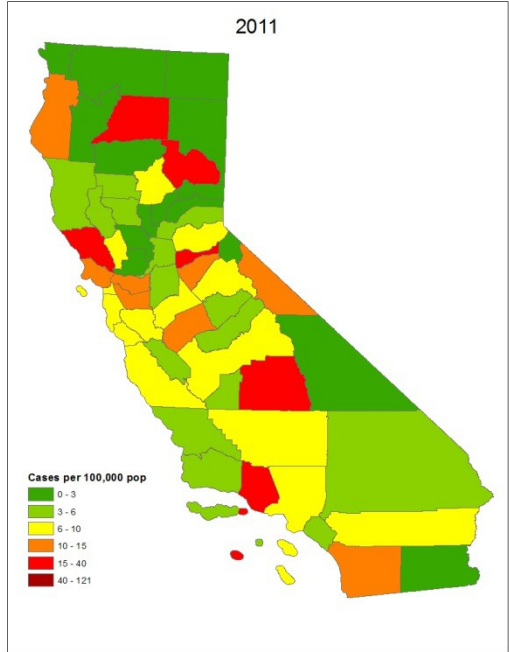
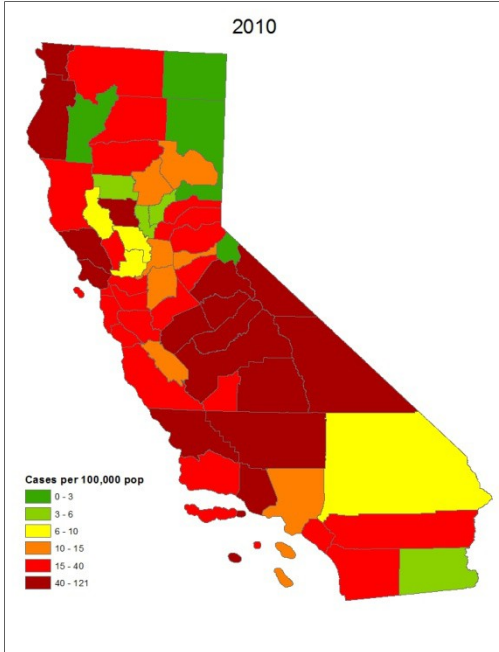
Pertussis Cases in California (1947 – 2013) and Florida (1963 – 2012)



Pertussis Cases in Florida 1963-2012

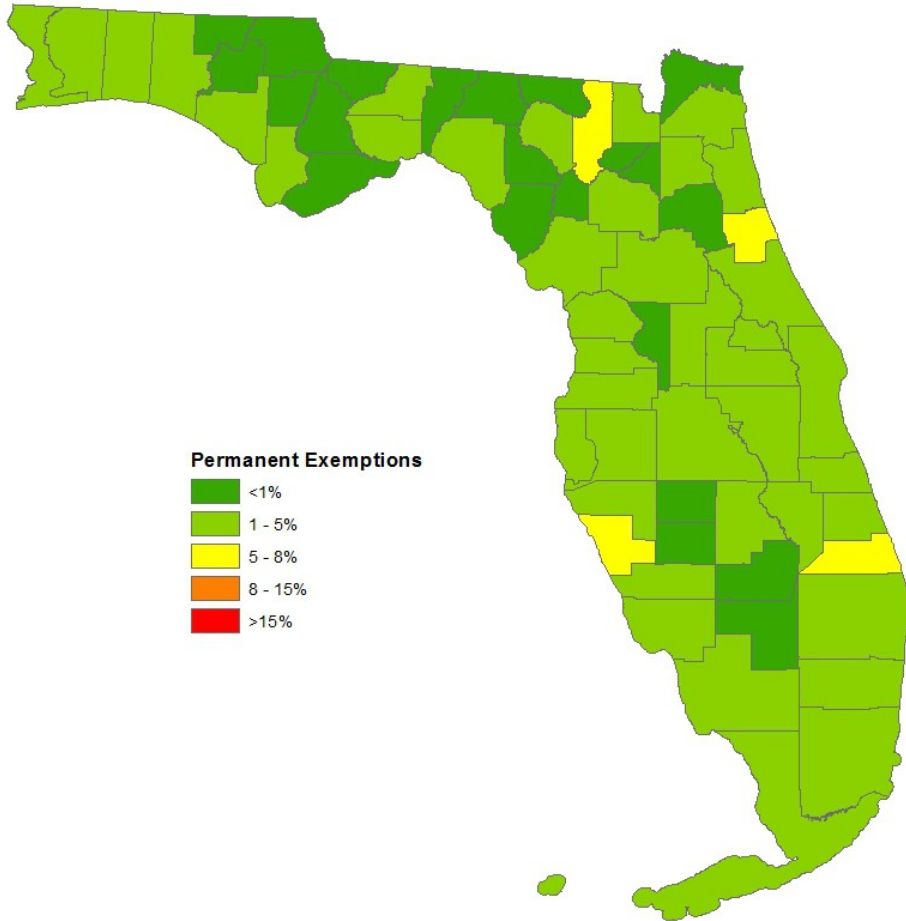


Pertussis Incidence by County – California & Florida

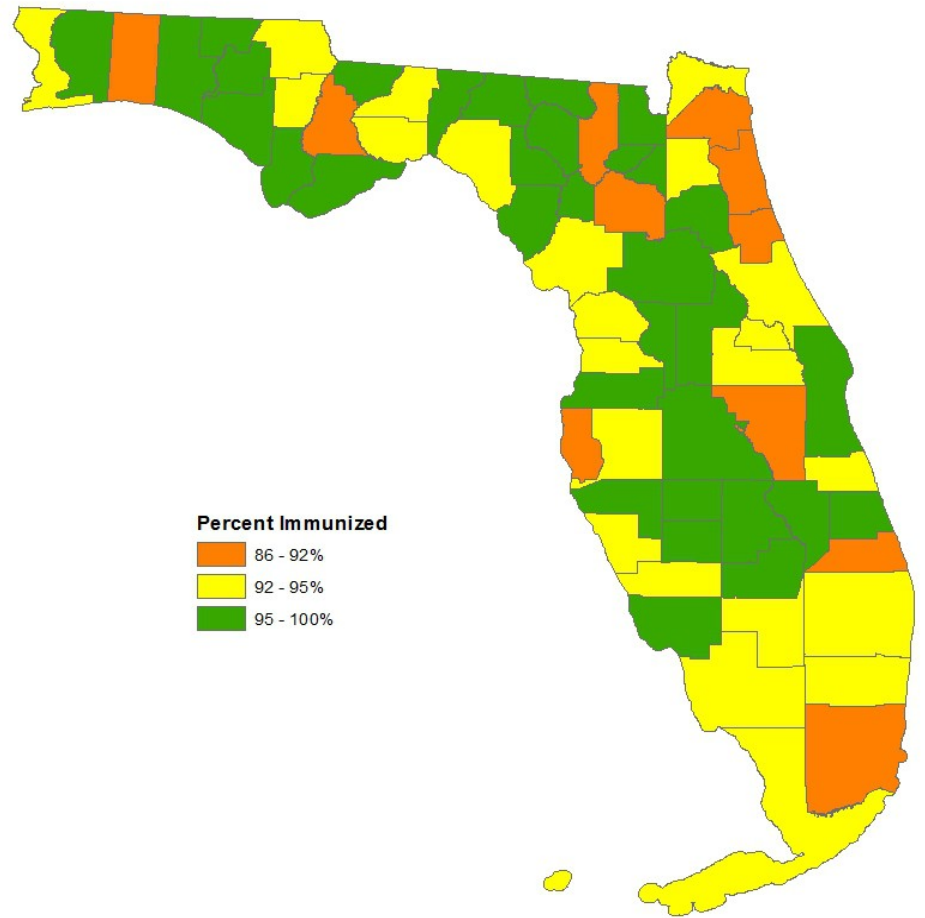


Florida
Pertussis
Incidence
Data
Published in
December

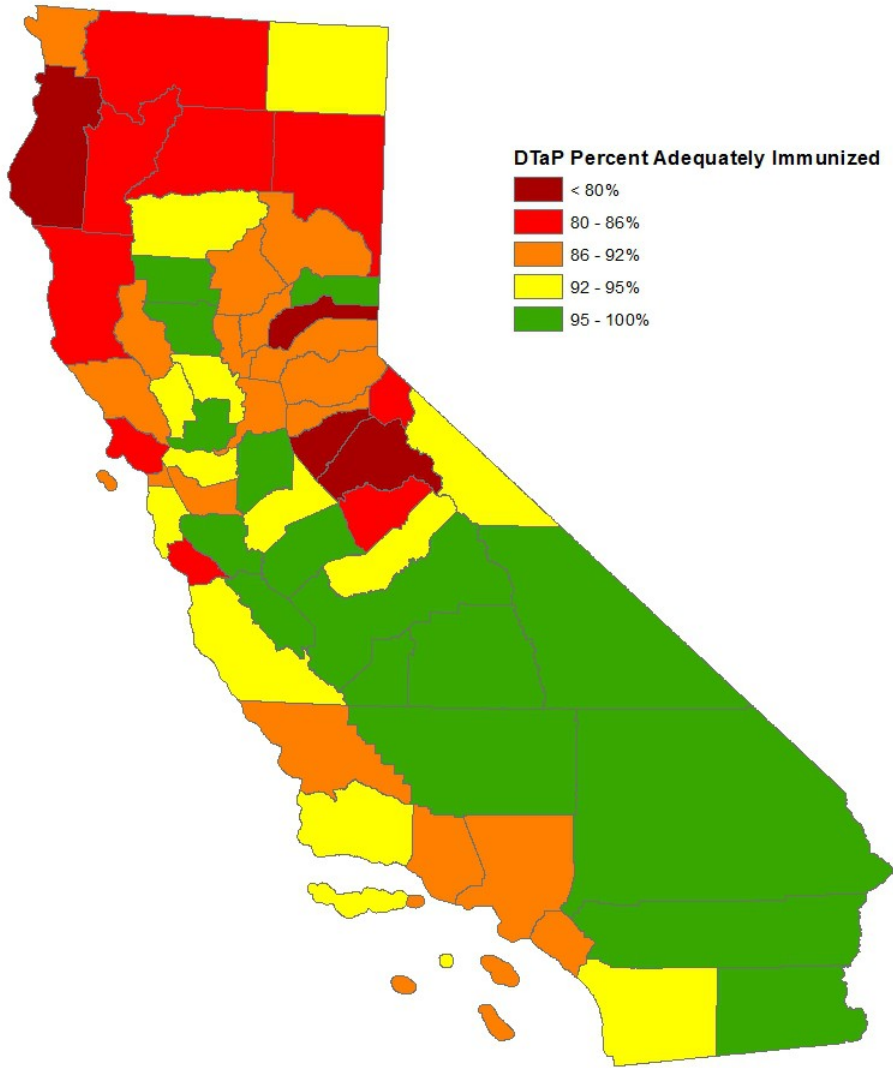
2013-14 School Year - Kindergarten



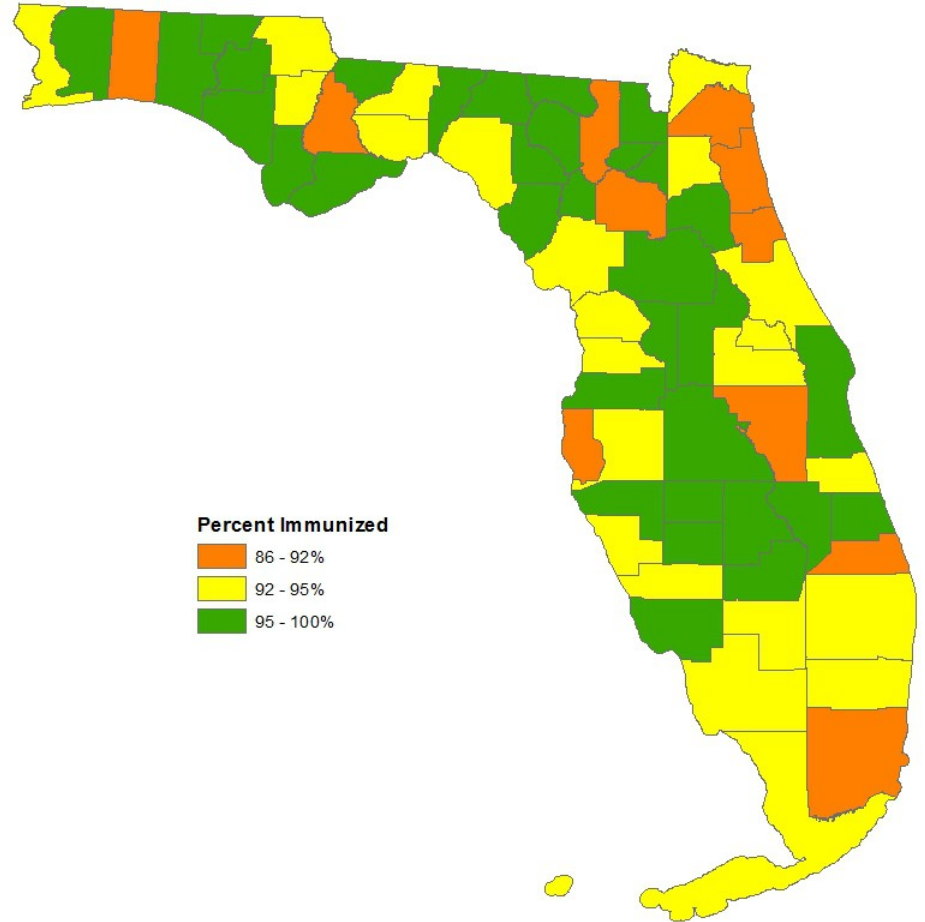
2013-14 School Year - Kindergarten



2012-13 School Year - Kindergarten

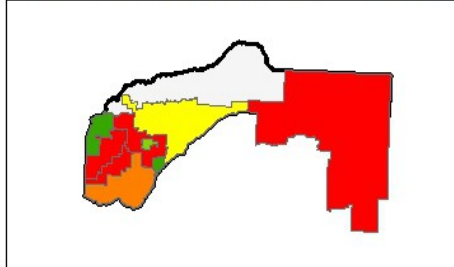


2013-14 School Year - Kindergarten

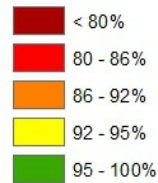


2012-13 School Year - Kindergarten

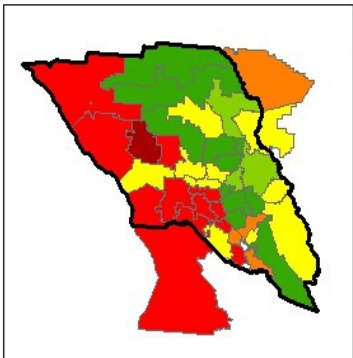
Nevada County by School District



DTaP % Immunized



Sonoma County by School District



Variation exist across the states, within counties, and within school districts and communities

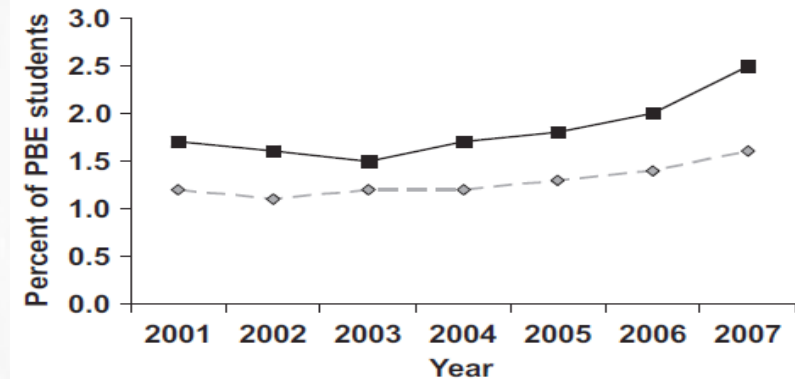
Nevada County

Sonoma County

The Press Democrat
Whooping cough outbreaks reported in Sonoma County (w/video)

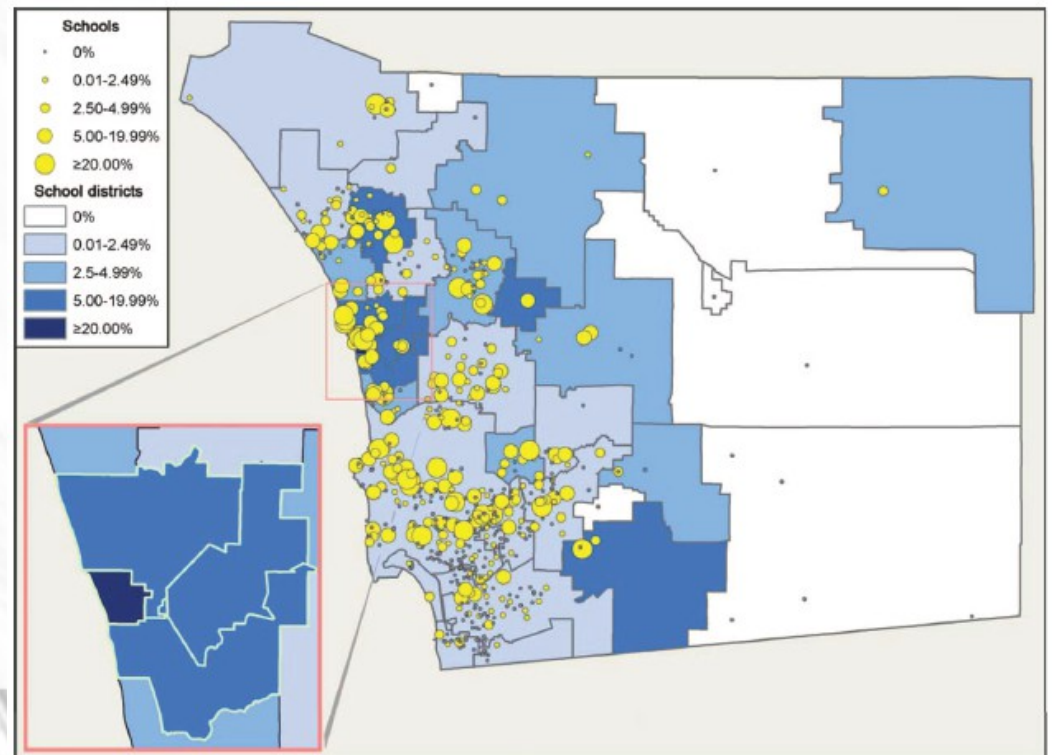
Measles Outbreak San Diego, 2008

1 infected child exposed 839 people to measles and caused 11 new cases (all in unvaccinated children)



Variables statistically evaluated using chi-square and regression testing

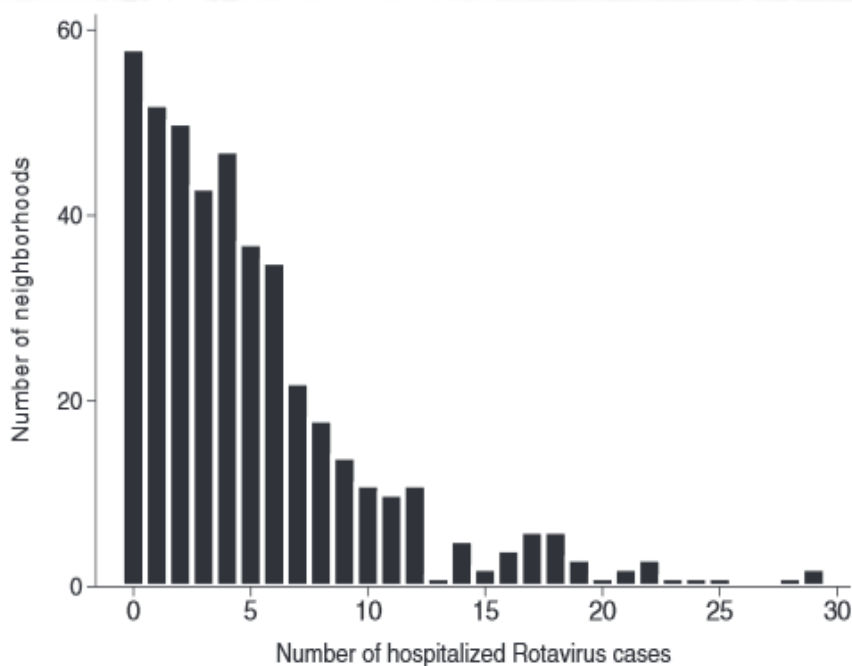
Higher exemption rates correlated to higher median income (\$88k vs. \$53k)



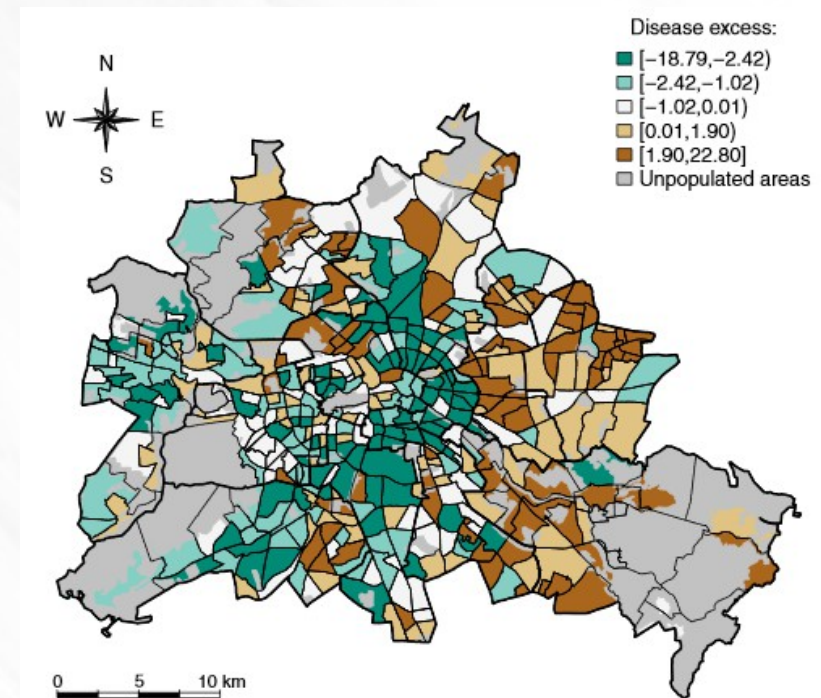
Rotavirus in Berlin, Germany 2007-09

Spatial Bayesian regression models for statistics

Link found between hospitalization rates from Rotavirus and 1) Percent unemployment in the neighborhood & 2) Percentage of children attending day care



Source: Wilking, 2012



Methodology

Data:

- Number pertussis cases available at county level in Florida (2009-2012) and California (2010-2013)
- Number kindergarteners immunized and exempted by school district/city/county
- Number of kindergarteners by school district/city/county
- US Census Bureau demographic information from 2010 census

Ideally like to perform analysis at address level but may be unlikely. Instead analyze data at smallest scale possible.

Analysis:

Examine the correlation between immunization coverage and pertussis incidence.

Explore relationship between socioeconomic factors: unemployment, income, median age, population density WITH pertussis cases AND PBEs (simple & multivariate regression analysis). Test for significance using Chi-Square.

Limitations

Data:

Range of years available for data between FL and CA

Level of geographic detail for ideal analysis

Exemption and immunization data is for kindergarteners but pertussis cases by county/state is for the entire population

Analysis:

Cyclical nature of disease may cause statistically significant results one year but not another

Expected Outcomes

Identify critical areas with high pertussis numbers both by volume and cases per 100k population

Identify critical areas with little to no herd immunity

Find a correlation between exemption areas and pertussis outbreaks

Find a correlations between socioeconomic factors (education/income/ethnicity, etc.) and pertussis outbreaks

Suspect the rates are too low in Florida to drawn statistically significant results, but not the case in California

Timeline

May – July : Data collection and analysis

Aug – Oct : Analysis of data

Oct – Dec : Writing of capstone project

Presentation Venue: ESRI Health GIS Conference, Nov. 3-5 Colorado Springs, CO
Deadline to submit abstract is August 1, 2014

Paper outlet: International Journal of Health Geographics

Acknowledgments

Dr. Justine Blanford - PSU

Laura Rutledge, RN, BSN – Fl. Dept. of Health

Valerie Warne, MD

Sources

California Department of Public Health

Centers for Disease Control and Prevention

U.S. Census Bureau

Florida Department of Health

Kennedy, A., LaVail, K., Nowak, G., Basket, M., Landry, S., (2011). *Confidence About Vaccines In The United States: Understanding Parents' Perceptions*. Health Affairs 30(6):1151-1159.

Lundquist, L. (2010). Whooping cough rising in vaccine-averse Idaho. *McClatchy - Tribune Business News*. Retrieved from <http://search.proquest.com/docview/731783684?accountid=13158>

The National Institute of Allergy and Infectious Diseases

National Vaccine Information Center

Omer, S., Salmon, D., Orenstein, W., deHart, P., Halsey, N. (2009). *Vaccine Refusal, Mandatory Immunizations, and the Risks of Vaccine-Preventable Diseases*. The New England Journal of Medicine. 360:1981-8

Sugerman, D., Barskey, A., Delea, M., Ortega-Sanchez, I., Bi, D., Ralston, K., Rota, P., Waters-Montijo, K., LeBaron, C. (2010). *Measles Outbreak in a Highly Vaccinated Population, San Diego, 2008: Role of the Intentionally Undervaccinated*. Pediatrics. 125(4):747-755.

The University of Pittsburgh, http://www.ewi-ssl.pitt.edu/econ/files/courses/110908_misc_smallpoxgraphs.pdf

Wiling, H., Hhle, M., Velasco, E., Suckau, M., Eckmanns, T., (2012). *Ecological analysis of social risk factors for Rotavirus infection in Berlin, German, 2007-2009*. International Journal of Health Geographics 11(1):37-48.

Thank You!

Question?

