

# Ecologic Studies

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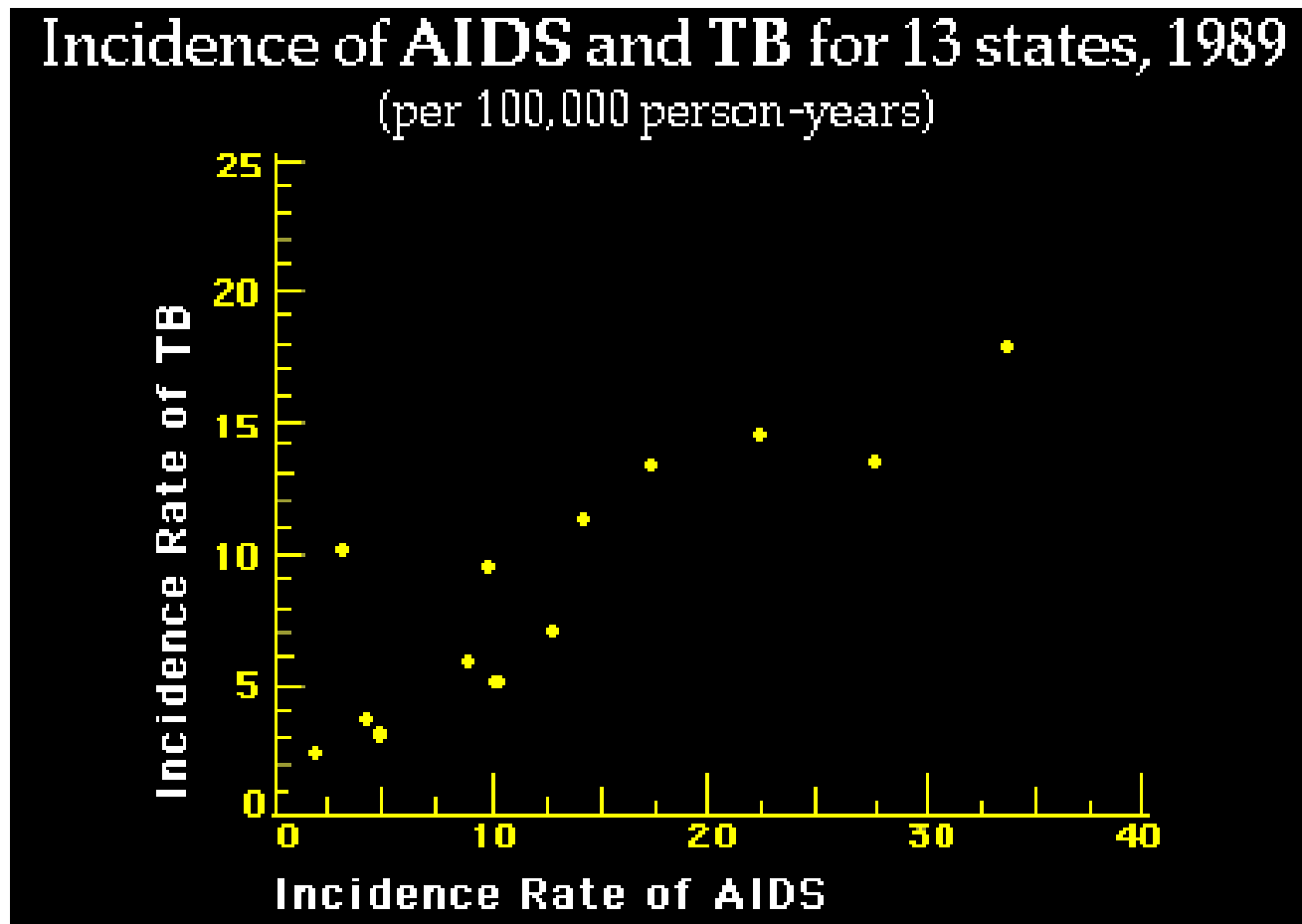
# Ecologic Studies

- “A study in which units of analysis are populations or groups of people than individuals.” — Dictionary [Porta 2008]
- “An ecologic or aggregate study focuses on the comparison of groups rather than individuals” — Morgenstern, Modern Epi, 2008

# Key issues with ecologic Studies

- Explores correlations between aggregate (group level) exposure and outcomes
- Unit of analysis: usually not individual, but clusters (e.g. countries, counties, schools)
- Useful for generating hypothesis
- Prone to “ecological fallacy”
- Cannot adjust well for confounding due to lack of comparability (due to lack of data on all potential covariates)
- Missing data is another concern

## Example: Correlation between TB and AIDS

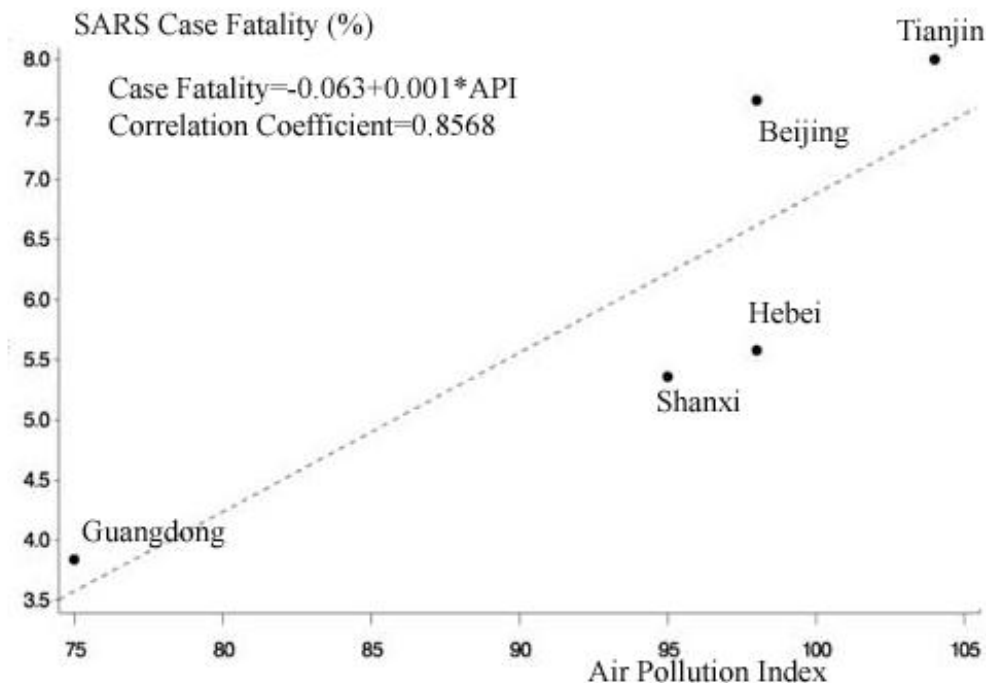


Research

**Open Access**

## **Air pollution and case fatality of SARS in the People's Republic of China: an ecologic study**

Yan Cui<sup>1</sup>, Zuo-Feng Zhang<sup>\*1</sup>, John Froines<sup>2</sup>, Jinkou Zhao<sup>3</sup>, Hua Wang<sup>3</sup>, Shun-Zhang Yu<sup>4</sup> and Roger Detels<sup>1</sup>



The Correlation and Association between Short-term Exposure to Ambient Air Pollution and Case Fatality of SARS in People's Republic of China.

## Kraft Officials: Mac & Cheese Sales Predict Recession

NewsNet5.com  
updated 2:49 p.m. ET, Tues., Dec. 2, 2008

Kraft officials said that they knew that a recession was on the horizon last year.

Company officials said the sales of Macaroni and Cheese began to spike last winter, reported consumer reporter John Matarese.

Officials said the sales of Kraft's Macaroni and Cheese is an accurate predictor of a recession.



[More local links from WEWS](#)

Monday's declaration by the National Bureau of Economic Research (NBER) that the US has been in a recession for more than a year is no surprise to buyers of Kraft Macaroni & Cheese, whose purchases jumped last winter.

Sales of Kraft's boxed mac-and-cheese rose to \$193.1 million in the first quarter, 10 percent over the previous year, according to Information Resources Inc., a Chicago-based market-data company. They remained above 2007's level in the second and third quarters as shoppers turned to cheaper options in a sagging economy.

# Why do ecologic studies?

- Low cost and convenience
- Some measurements cannot be made on individuals
- Ecologic effects are the main interest (at the population level)
- Simplicity of analyses and presentation
- Often helpful for generating new hypotheses for further research

# Levels of measurement

- Aggregate measures:
  - Means or proportions in groups, derived from individuals in groups (e.g. % smokers in a country)
- Environmental measures:
  - E.g. air pollution level in a country
  - Environmental measure has an analog at the individual level, but not easy to measure
- Global measures:
  - Attributes for groups or places for which there is no individual analog
  - E.g. population density, type of healthcare system, political system in the country



# Units of analysis

- Individual-level analysis:
  - Measurements are available for each individual in the study
- Completely ecologic analysis:
  - All variables (exposure, outcome, covariates) are ecologic, so unit of analysis is the group
- Partially ecologic analysis
- Multi-level analysis
  - Combines data collected at two or more levels

# Levels of inference

- Biologic inferences about effects on individual risks
  - E.g. if individual motorcyclists wear helmets, will it lower their risk of mortality?
- Ecologic inferences about effects on group rates
  - E.g. Do rates of motorcycle-related mortality of riders vary across different states that have different helmet laws in place?

Cross-level inferences are often made – ecological effects are interpreted as individual effects and this is vulnerable to bias

# Example: individual effect

Traffic Injury Prevention, 7:49–54, 2006  
Copyright © 2006 Taylor & Francis Group, LLC  
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DOI: 10.1080/15389580500338652



## Motorcycle Helmet Effect on a Per-Crash Basis in Thailand and the United States

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Institute of Safety Helmet, Silpakorn University, Nakhon-Pathom, Thailand

***Objective.** To compare the effectiveness of motorcycle helmets seen in prospective on-the-street motorcycle accident investigations. The data are drawn from two detailed, in-depth studies of motorcycle accidents, in which trained investigators collected extensive accident evidence on-scene immediately after the crash. This article compares helmeted and unhelmeted motorcycle riders on a per-accident basis for fatality rates, the rate of serious (AIS > 2) brain injuries among survivors, or an outcome that involved either of the two.*

***Methods.** Nine hundred motorcycle crashes in Los Angeles and 969 crashes in Thailand were investigated in detail at the accident scenes, including photos of vehicles, skids, damage, and sometimes the rider. Helmets were collected and injury information was obtained from riders and care providers. This evidence was then used to reconstruct collision events to identify speeds, precrash motions, collision contacts, injury causation, and helmet performance.*

***Results.** In both studies, approximately 6% of riders were killed and 20–25% were hospitalized. Overall, unhelmeted riders were two to three times as likely to be killed, and three times as likely to suffer either death or survival with AIS > 2 brain injury. Unhelmeted survivors had three to four times as many AIS > 2 brain injuries as helmeted riders on a per-crash basis. Nearly 100% of riders with AIS > 4 somatic injuries died. Such injuries were 30% of Thailand fatalities and 57% of L.A. fatalities, but only about 2–3% of the overall accident population. Among the 97–98% of riders with AIS < 5 somatic injuries, helmet use could prevent about three-fourths of fatalities and brain injuries.*

***Conclusions.** Helmets were extremely effective in preventing brain injury and death in 97% of the accident population in less-than-extreme crashes. Helmet use cannot prevent all fatalities because many of those killed succumb to below-the-neck injuries that a helmet cannot prevent.*

# Example: ecologic effect

*The Journal of TRAUMA® Injury, Infection, and Critical Care*

## The Effect of State Motorcycle Licensing Laws on Motorcycle Driver Mortality Rates

*Gerald McGwin, Jr., MS, PhD, James Whatley, BS, Jesse Metzger, MPH, Francesca Valent, MD, MSPH, Fabio Barbone, MD, PhD, and Loring W. Rue, III, MD*

**Objective:** The purpose of this study was to evaluate the association between motorcycle licensing and operation regulations and motorcycle mortality rates in the United States during 1997 through 1999.

**Methods:** A population-based ecologic study was used.

**Results:** Lower mortality rates were

observed in states with the following motorcycling requirements: skill test for a motorcycle permit (rate ratio [RR], 0.76; 95% confidence interval [CI], 0.69–0.84), driver training (RR, 0.80; 95% CI, 0.74–0.86), longer duration of learner's permits (95–190 days [RR, 0.86; 95% CI, 0.79–0.95] and >190 days [RR, 0.87; 95% CI, 0.81–0.93],

three or more learner's permit restrictions (RR, 0.78; 95% CI, 0.73–0.84), and a full helmet law (RR, 0.76; 95% CI, 0.71–0.81).

**Conclusion:** Specific motorcycle licensure policies appear to be associated with lower mortality rates.

**Key Words:** Crashes, Motorcycles, Epidemiology.

*J Trauma.* 2004;56:415–419.

# Types of ecologic designs

- Multiple group study
  - Compares disease rates among many regions during the same period
- Time-trend studies
  - Comparison of disease rates over time in one population
- Mixed designs
  - Multiple groups + multiple time periods

## Note:

- Meta-analyses can also be considered a type of ecological study (unit = publication)

# Example: Multiple group studies

An ecological study of obesity and income inequality

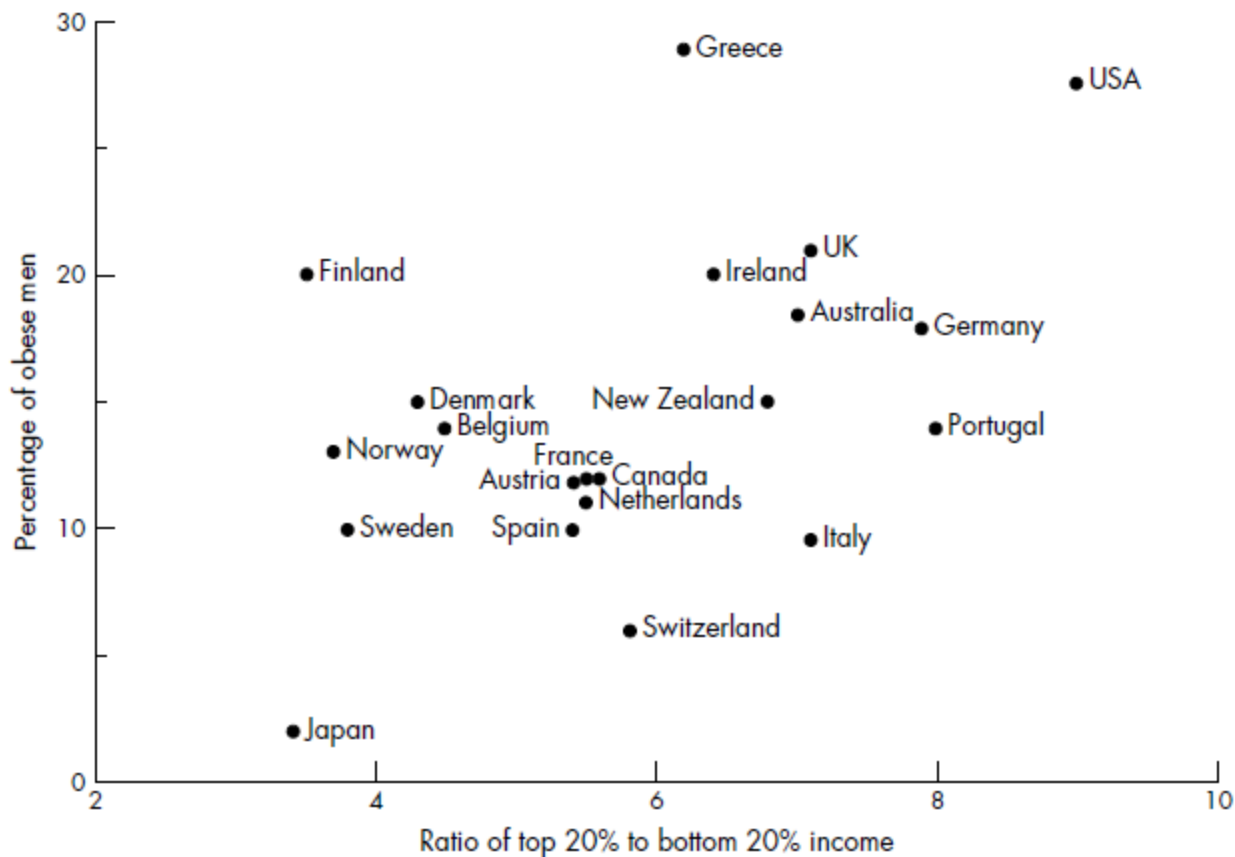
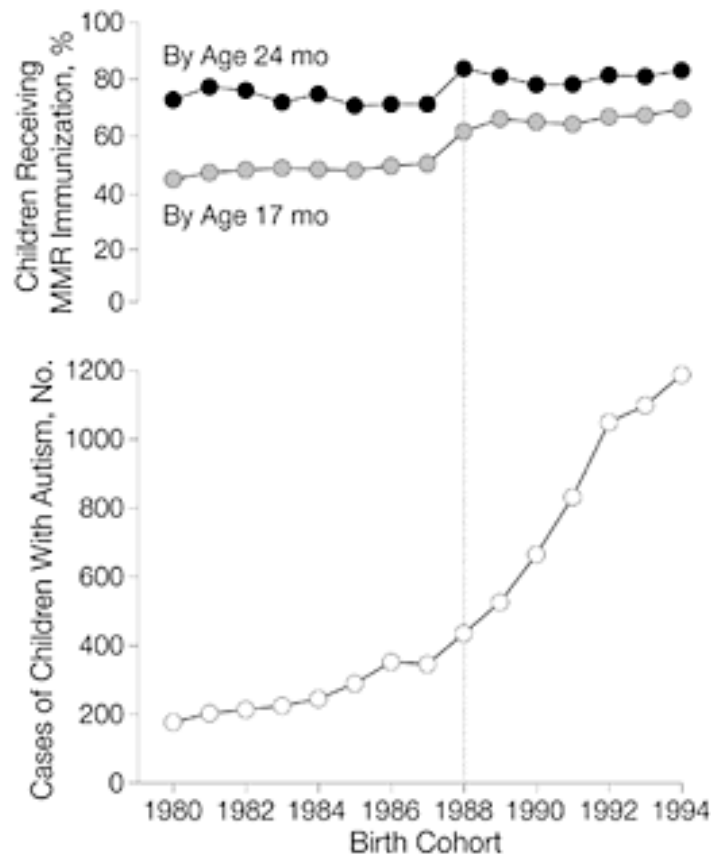


Figure 1 The relation between male obesity and income inequality in 21 rich countries.

# Example: Time-trend studies

## Time Trends in Autism and in MMR Immunization Coverage in California



Percentage of Children Receiving Measles-Mumps-Rubella (MMR) Immunization in Second Year of Life and Caseload of Children With Autism, by Year of Birth, California, 1980-1994

# Analytical Approach: linear regression and ecologic correlation coefficients

$$\hat{RR} = \frac{\hat{Y}|X=1}{\hat{Y}|X=0} = \underbrace{\frac{B_0 + B_1}{B_0}}_1 + \frac{B_1}{B_0}$$

From Linear Regression

Here, RR is interpreted as the risk of disease in a population with 100% exposure (i.e., X=1) relative to 0% exposure (i.e., X=0)

Assuming a linear model,  $B_1$  (the slope) is the estimated risk difference

$$\hat{EF} = \frac{\hat{p} (\hat{RR} - 1)}{\hat{p} (\hat{RR} - 1) + 1}$$



# Ecologic Correlation Coefficient

- The ecologic correlation coefficient (R) is given by:

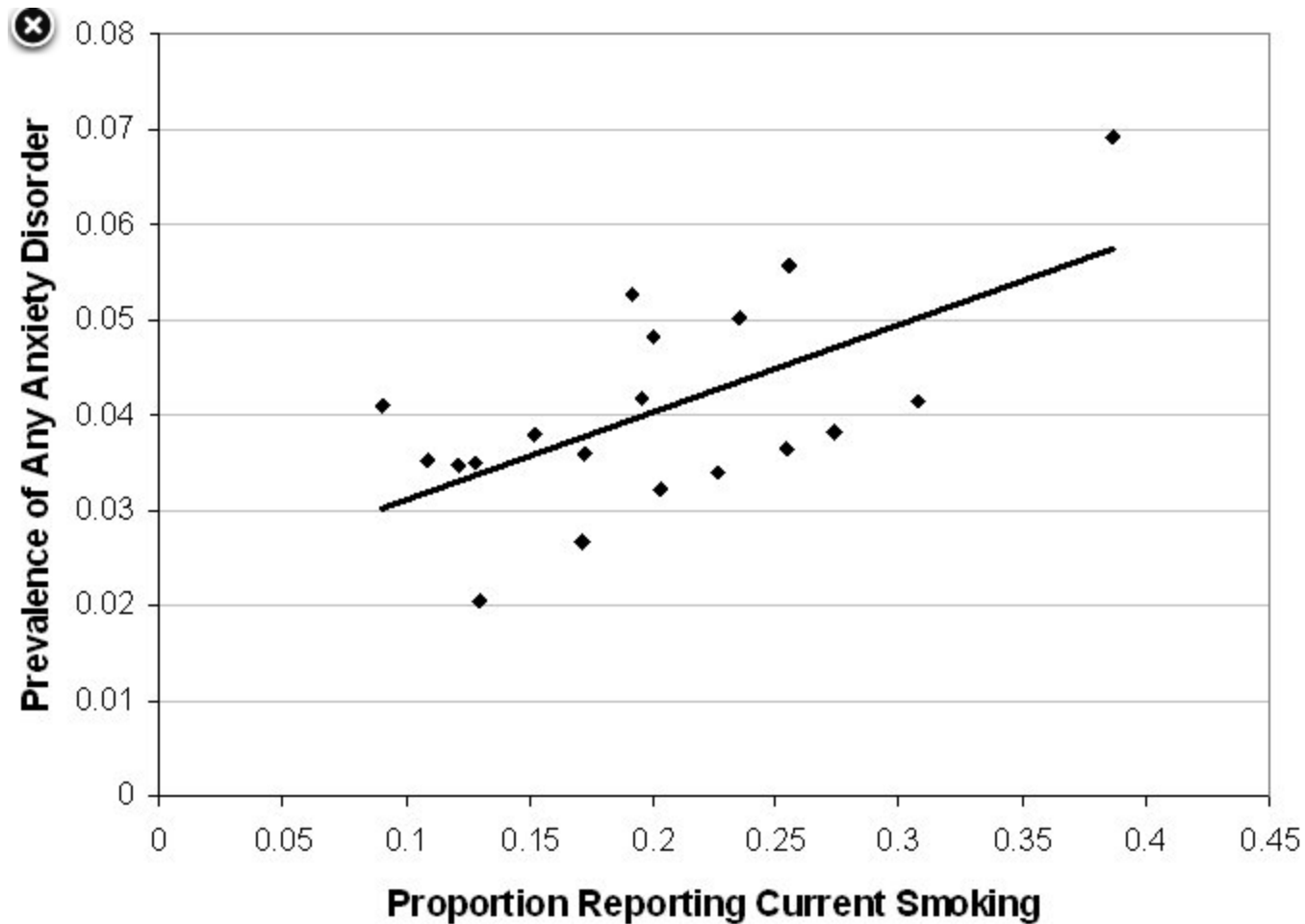
$$R = B_1 \{ \text{SQRT}(V_x / V_y) \}$$

- $V_x$  and  $V_y$  are the variances of X and Y.
- This value “R” is often calculated in ecologic analyses because  $R^2$  represents the proportion of the between group variance in the outcome variable (Y) that is explained by the predictor variable (X)

# Limitations of Ecological Studies

- Usually Hypothesis Generating
- Lack of adequate data and missing data
  - May not be recorded a group level
- Within-Group Misclassification
- Confounding
- Collinearity
- Temporal Ambiguity
- Ecological Fallacy

# Temporal sequence is not clear



**Figure 4: Ecological Analysis: Current Smoking and Anxiety Disorder Prevalence**

# Ecologic fallacy: Durkheim's study of suicide in Bavaria

## THE **B** FILES

**Case studies of bias in real life epidemiologic studies**

Bias File 3. Émile Durkheim and the ecological fallacy

# Émile Durkheim

- Émile Durkheim (1858 –1917) was a famous French sociologist and pioneer in the development of modern sociology and anthropology.
- In a groundbreaking book published in 1897, entitled *Le Suicide*, Durkheim explored the differing suicide rates among Protestants and Catholics.
- In 19th century Europe, suicide rates were higher in countries that were more heavily Protestant. Durkheim found that suicide rates were highest in provinces that were heavily Protestant.
- He concluded that stronger social control among Catholics resulted in lower suicide rates.
- However, Durkheim's study of suicide was criticized as an example of the logical error termed the "ecological fallacy."

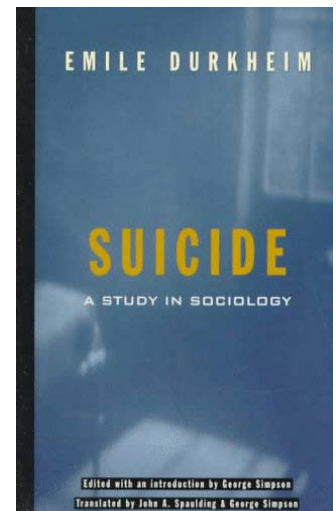
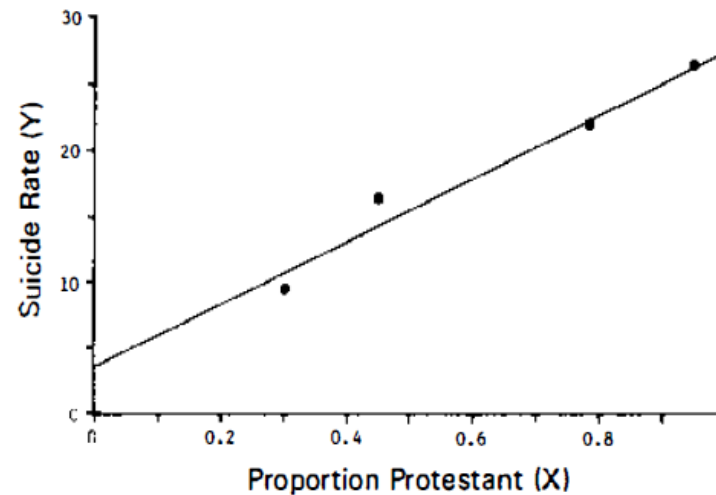


TABLE 4.14 Suicide rates per million population per proportion of Catholics, 15+ years, in Bavarian provinces, 1867-1875

Provinces with <50% Catholic		Provinces with 50-90% Catholic		Provinces with >90% Catholic	
Province	Rate	Province	Rate	Province	Rate
RP	167	LF	157	UP	64
CF	207	SA	118	UB	114
UF	<u>204</u>		—	LB	<u>19</u>
Average	192		135		75

SOURCE: From Durkheim E: *Suicide: A study in sociology*. Spaulding, JA and Simpson G (trans.) Glencoe, IL: The Free Press, 1951.

Using ordinary least-squares linear regression on Durkheim's data, Morgenstern (1995) found a strong positive correlation (Figure below) between proportion protestant and suicide rates. The estimated rate ratio, comparing Protestants with other religions, was 7.6 (i.e. suicide rates among protestants was about 8 fold higher than other religions).



**Figure 2** Suicide rate ( $Y$ , per  $10^5$ /year) by proportion Protestant ( $X$ ) for four groups of Prussian provinces, 1883–90. The four observed points ( $X$ ,  $Y$ ) are (0.30, 9.56), (0.45, 16.36), (0.785, 22.00), and (0.95, 26.46); the fitted line is based on unweighted least-squares regression [Source: Adapted from Durkheim (16)].

# The bias

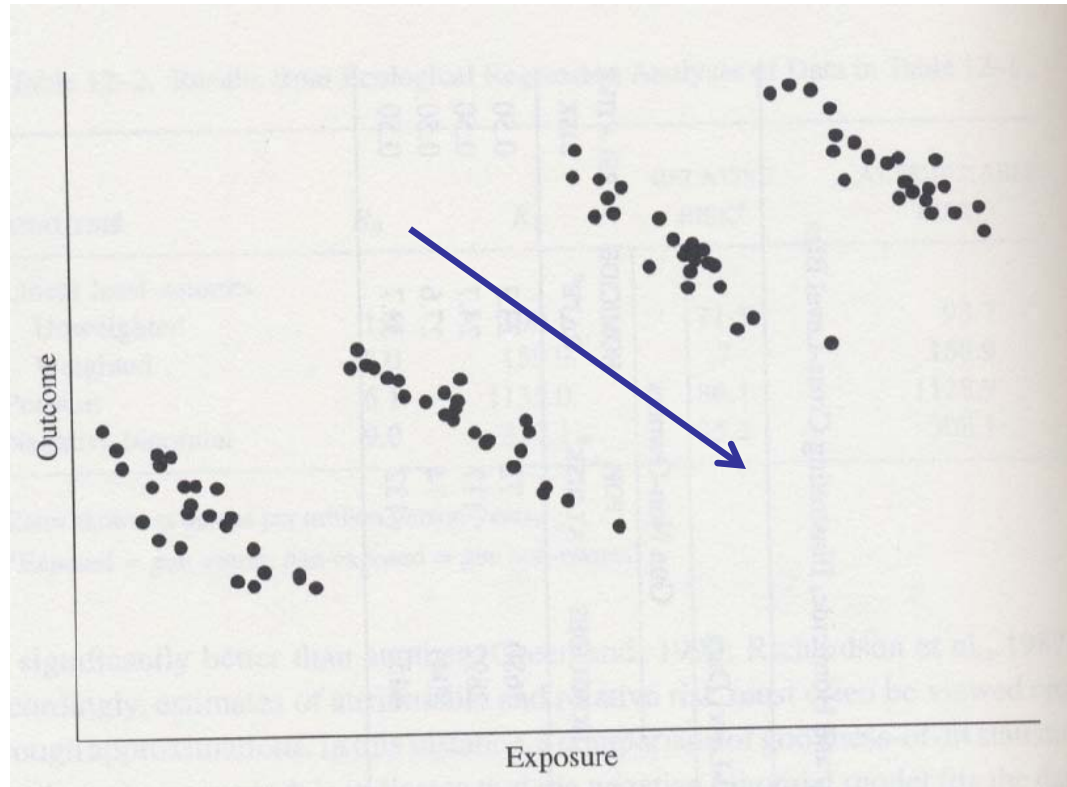
- According to Morgenstern, the estimated rate ratio of 7.6 was probably not because suicide rates were nearly 8 fold higher in Protestants than in non-Protestants.
- Rather, because none of the regions was entirely Protestant or non-Protestant, it may have been non-Protestants (primarily Catholics) who were committing suicide in predominantly Protestant provinces.
- It is plausible that members of a religious minority might have been more likely to commit suicide than were members of the majority.
- Living in a predominantly Protestant area had a contextual effect on suicide risk among Catholics.
- Interestingly, Morgenstern points out that Durkheim compared the suicide rates at the individual level for Protestants, Catholics and Jews living in Prussia, and from his data, the rate was about twice as great in Protestants as in other religious groups.
- Thus, when the rate ratios are compared (2 vs 8), there appears to be substantial ecological bias using the aggregate level data.



# Ecological fallacy

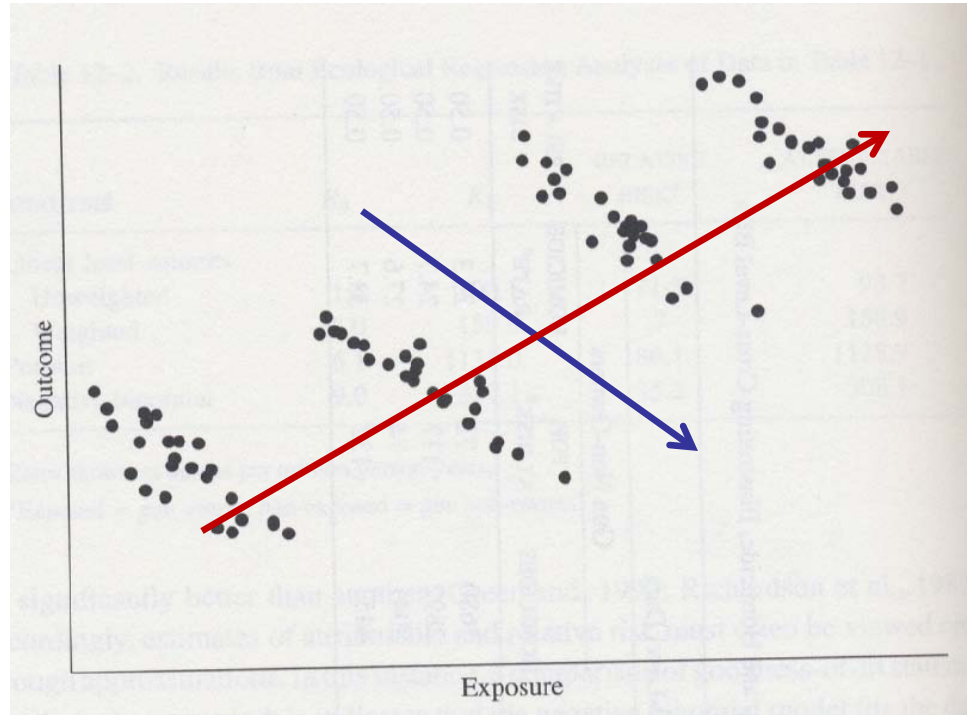
- Ecological fallacy arises from thinking that relationships observed for groups necessarily hold for individuals: if provinces with more Protestants tend to have higher suicide rates, then Protestants must be more likely to commit suicide; if countries with more fat in the diet have higher rates of breast cancer, then women who eat fatty foods must be more likely to get breast cancer.
- Such inferences made using group-level data may not always be correct at the individual level.
- Ecological bias can be interpreted as the failure of associations seen at one level of grouping to correspond to effect measures at the grouping level of interest.
- For example, associations seen using country-level data may not correlate with associations that exist at the individual or neighborhood-level.

# Aggregation Bias



Correlation **negative** at individual level

# Aggregation Bias



Correlation **negative** at individual level but **positive** at group level

Within each of the four populations, as exposure increases, outcome decreases. But across populations, as the mean exposure level increases, the mean rate of outcome increases.

# Example: individual effect does not match ecologic effect

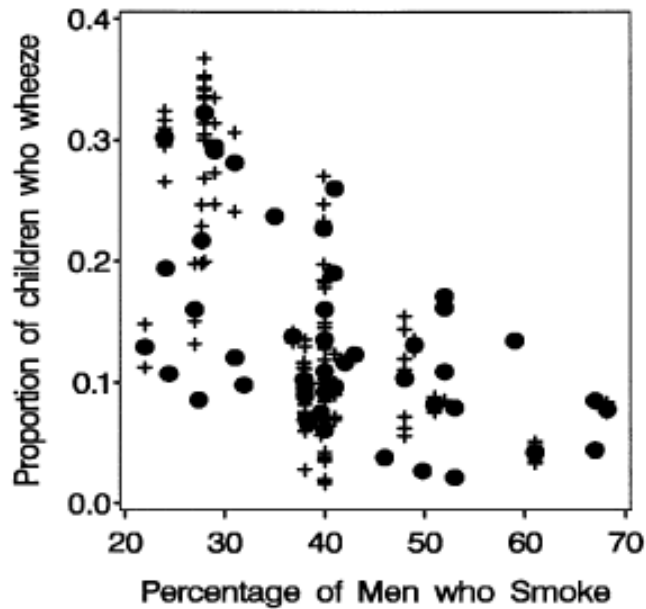
*European Journal of Epidemiology* 17: 667–673, 2001.  
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## **The ecological relationship of tobacco smoking to the prevalence of symptoms of asthma and other atopic diseases in children: The International Study of Asthma and Allergies in Childhood (ISAAC)**

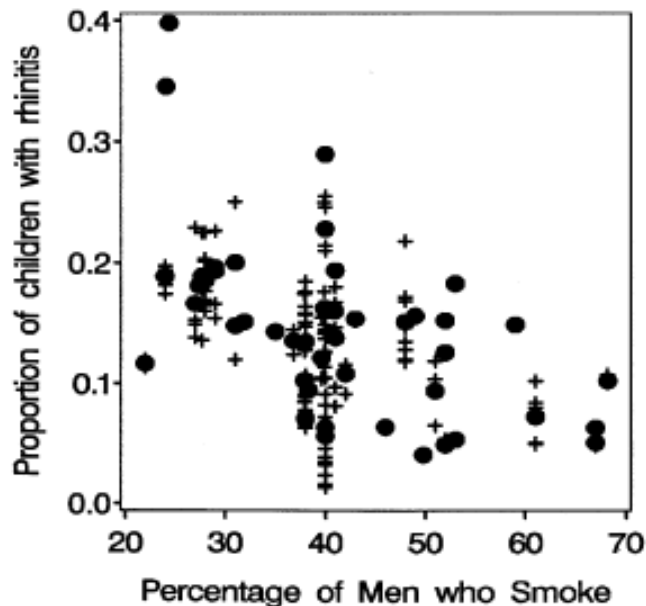
E.A. Mitchell<sup>1</sup>, A.W. Stewart<sup>2</sup>, on behalf of the ISAAC Phase One Study Group\*

<sup>1</sup>*Department of Paediatrics;* <sup>2</sup>*Department of Community Health, University of Auckland, Auckland, New Zealand*

This study examined the relationship between parental smoking and asthma and other atopic diseases at the ecological level. The prevalence of atopic symptoms in 6-7- and 13-14-year old children was assessed in 91 centres (from 38 countries) and 155 centres (from 56 countries) respectively in the International Study of Asthma and Allergy in Childhood (ISAAC). These symptoms were related to prevalence of tobacco smoking for each country by gender as reported by the WHO.



“For the countries included in this analysis, countries that have high adult male smoking rates have a lower risk of asthma and rhinitis symptoms in children...



It should be stressed that this analysis does not involve information on individual exposures and therefore does not contradict the well-established association of active and passive smoking in individuals with the occurrence of asthma symptoms in the same individuals. Rather, it indicates that this well-established individual-level association does not account for the international differences in asthma prevalence, and that other risk factors for asthma must be responsible for the observed international patterns.”

# Conclusions

- As emphasized by Morgenstern (1995 & 2008), several practical advantages make ecologic studies especially appealing for undertaking various types of epidemiologic research.
- Despite these advantages, ecologic analysis poses problems of interpretation when making inferences at the individual level.
- The correlation at the group level was valid in Durkheim's analysis. It was only invalid as a statement of individual causal effect.
- As pointed out by Greenland (2001), if we have predictors at the individual and the group level, and we want the causal effects at one or the other level, then our ecological level analysis could be confounded by omitted variables at the individual level.
- As pointed out by Morgenstern, we often require both ecological and individual-level data to make valid inferences. Multi-level models are powerful approaches to separate biologic, contextual and ecologic effects (Morgenstern 2009).

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