Epidemiologic Studies Related to Climate Change and Health

Kristina W. Kintziger, PhD, MPH

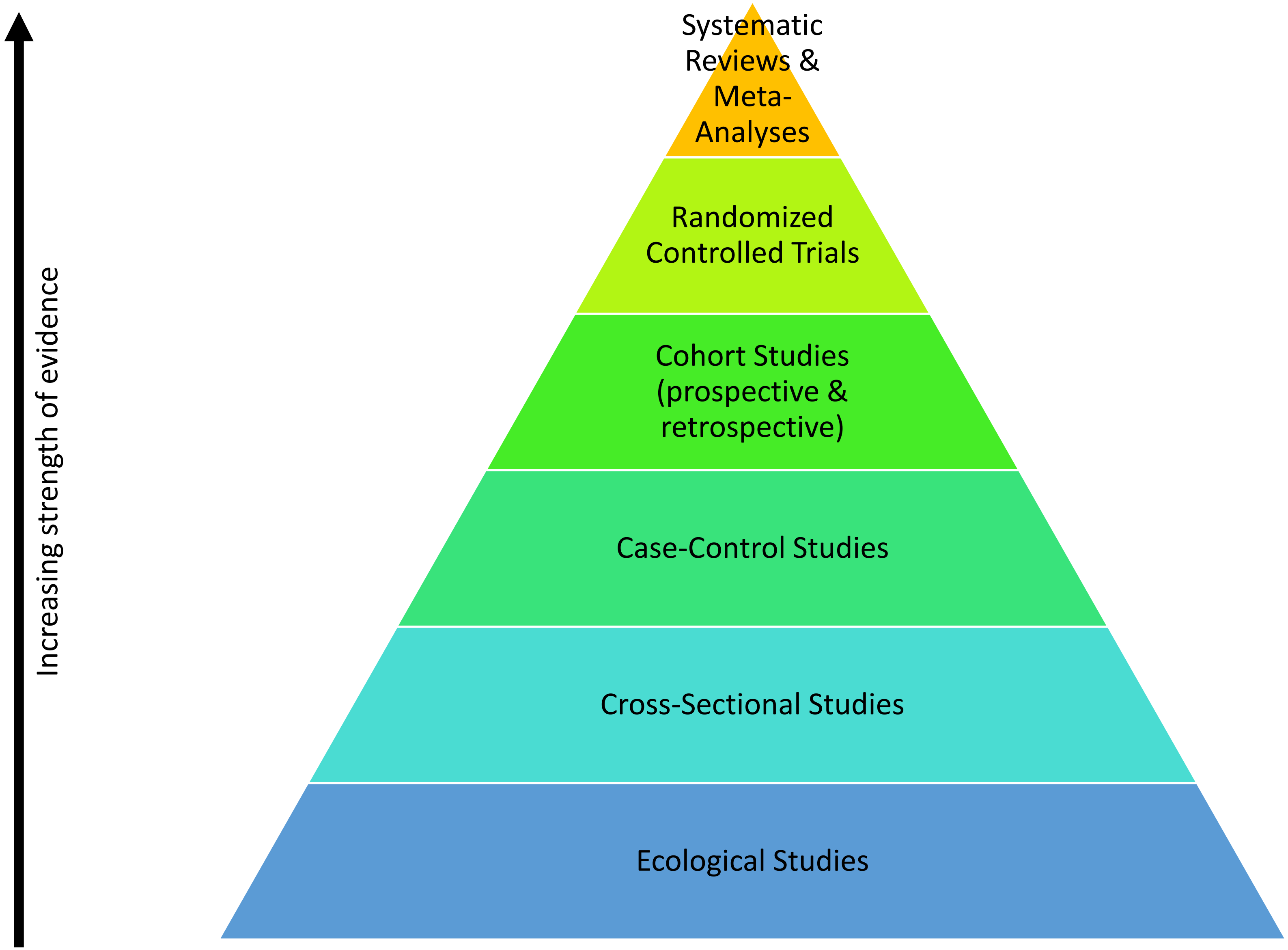
Claire M. Hubbard Professor of Health and Environment

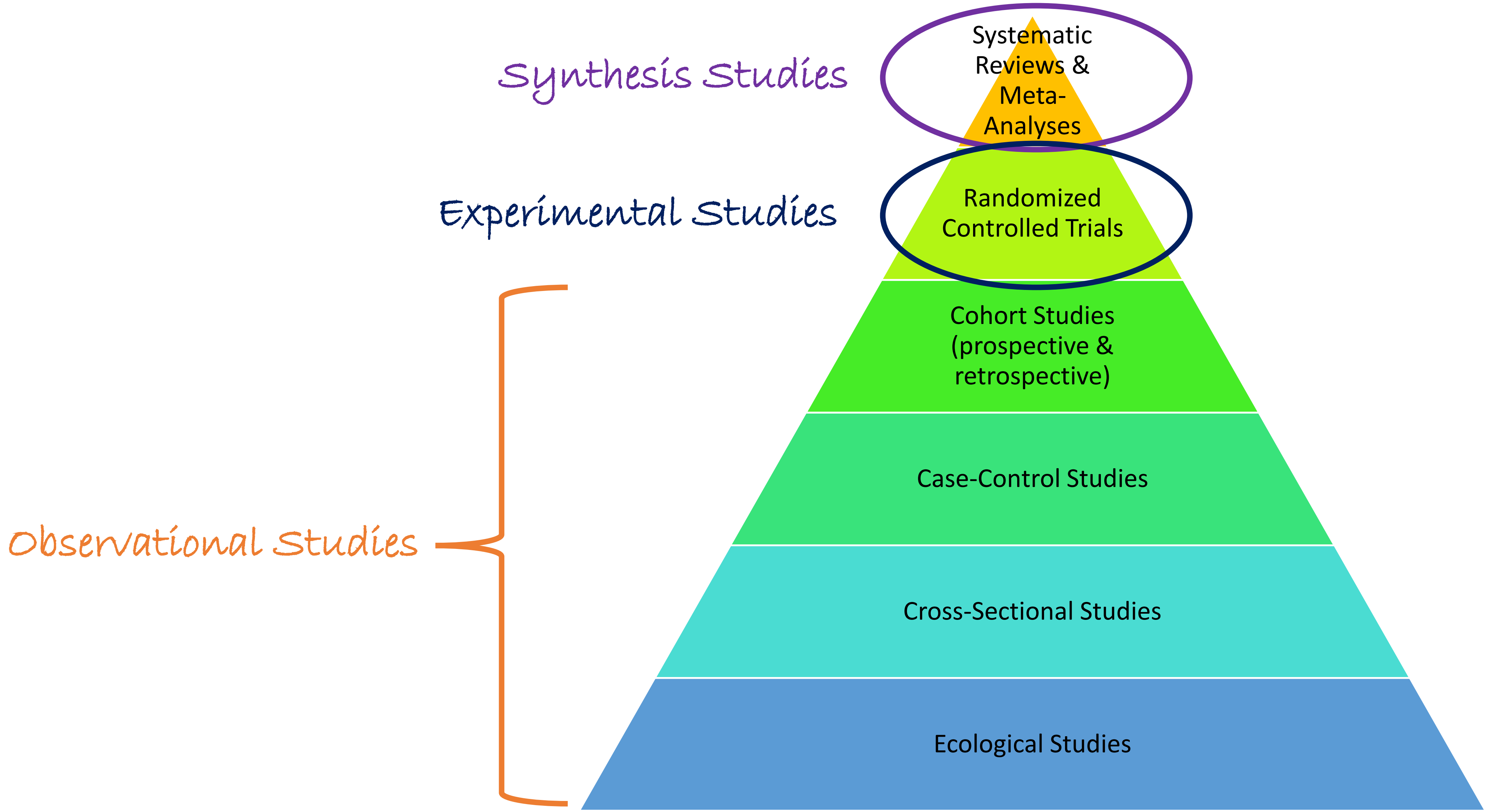
Learning Objectives

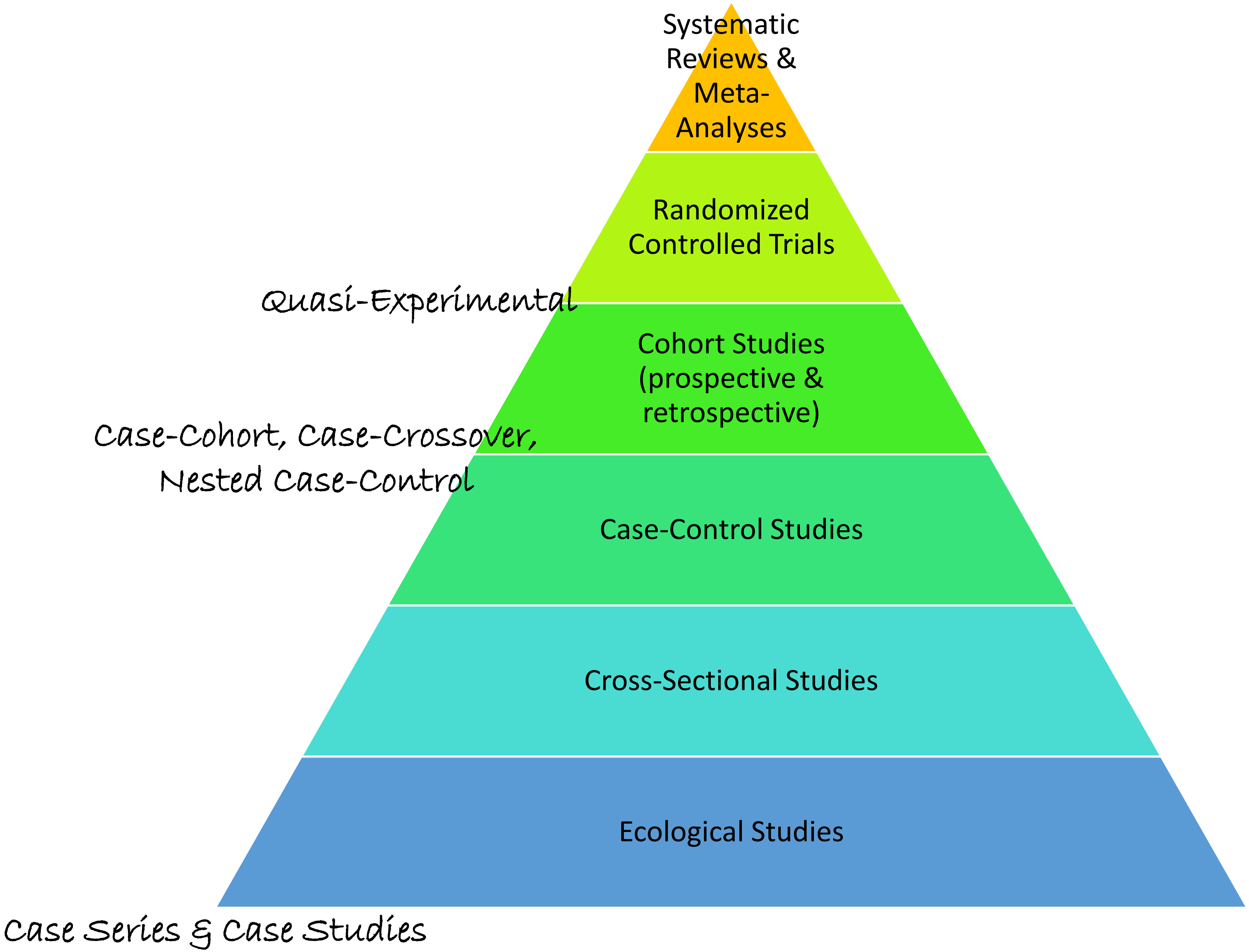
- Identify common study designs used in climate and health epidemiology
- Understand issues of bias and confounding in climate and health epidemiologic studies
- Examine examples of epidemiologic studies in understanding the impacts of climate change on human health

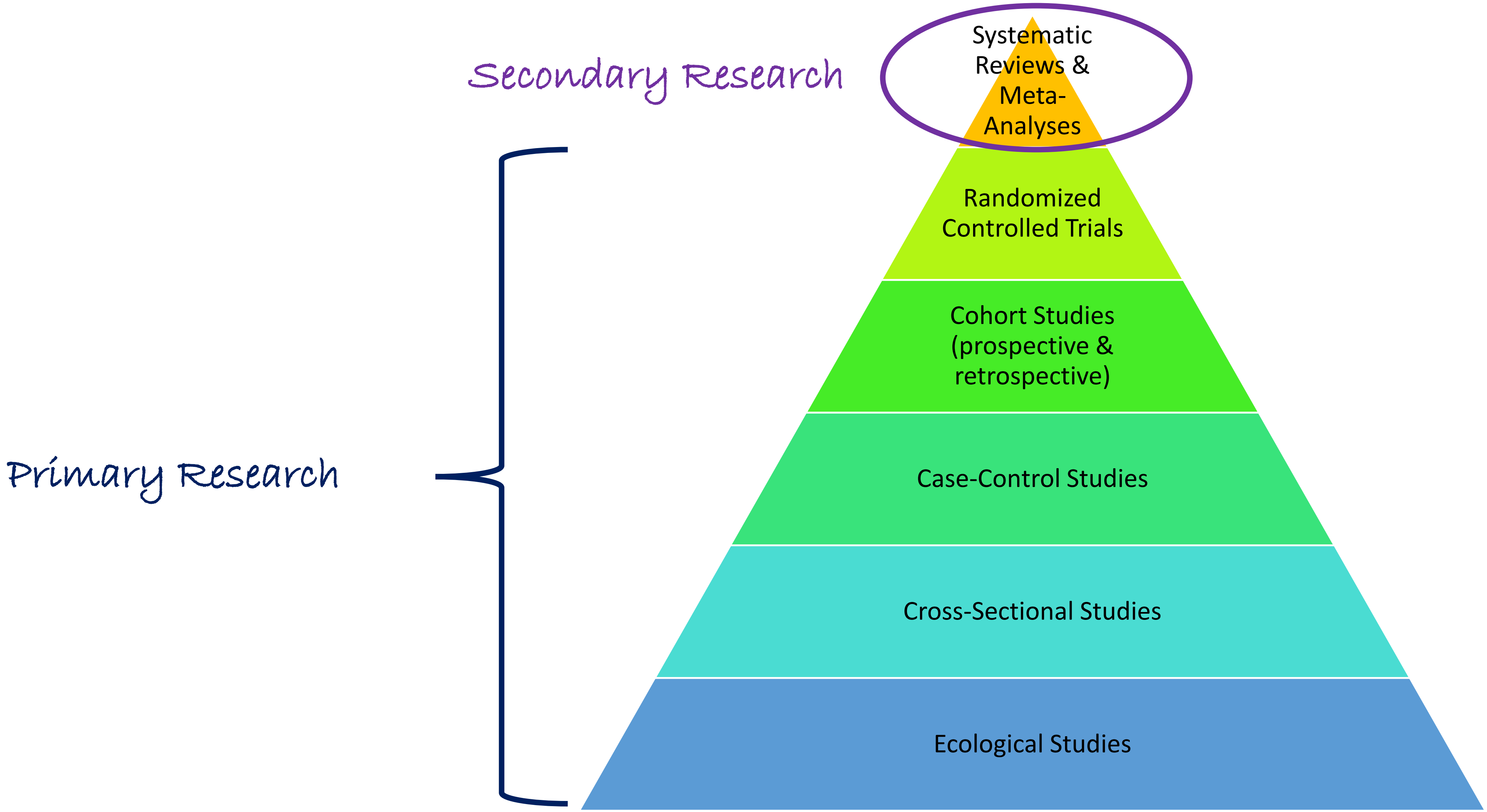
Strength of the Evidence, Epidemiologic Study Designs, & Design Issues

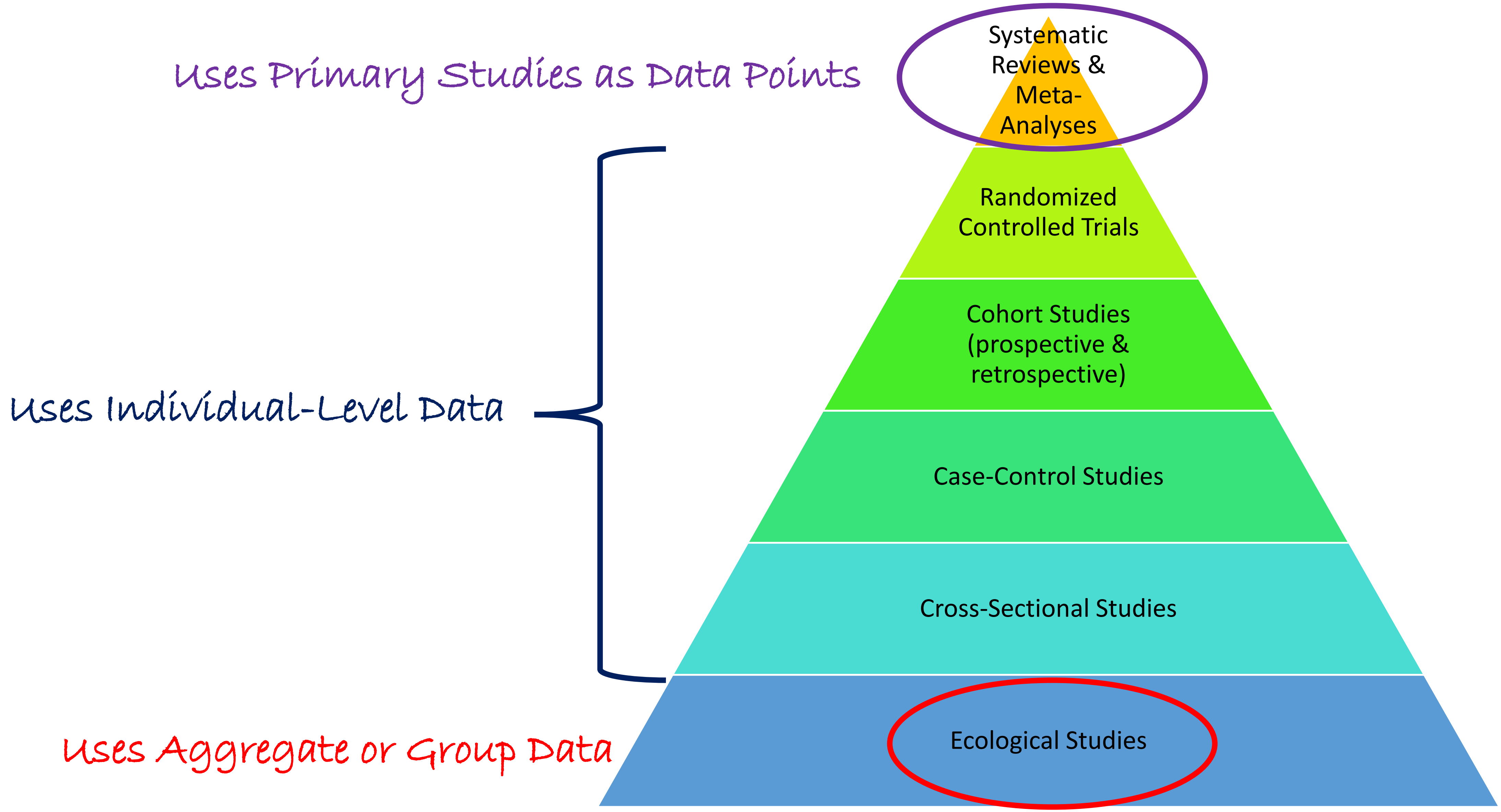
Strength of Evidence from Health Research

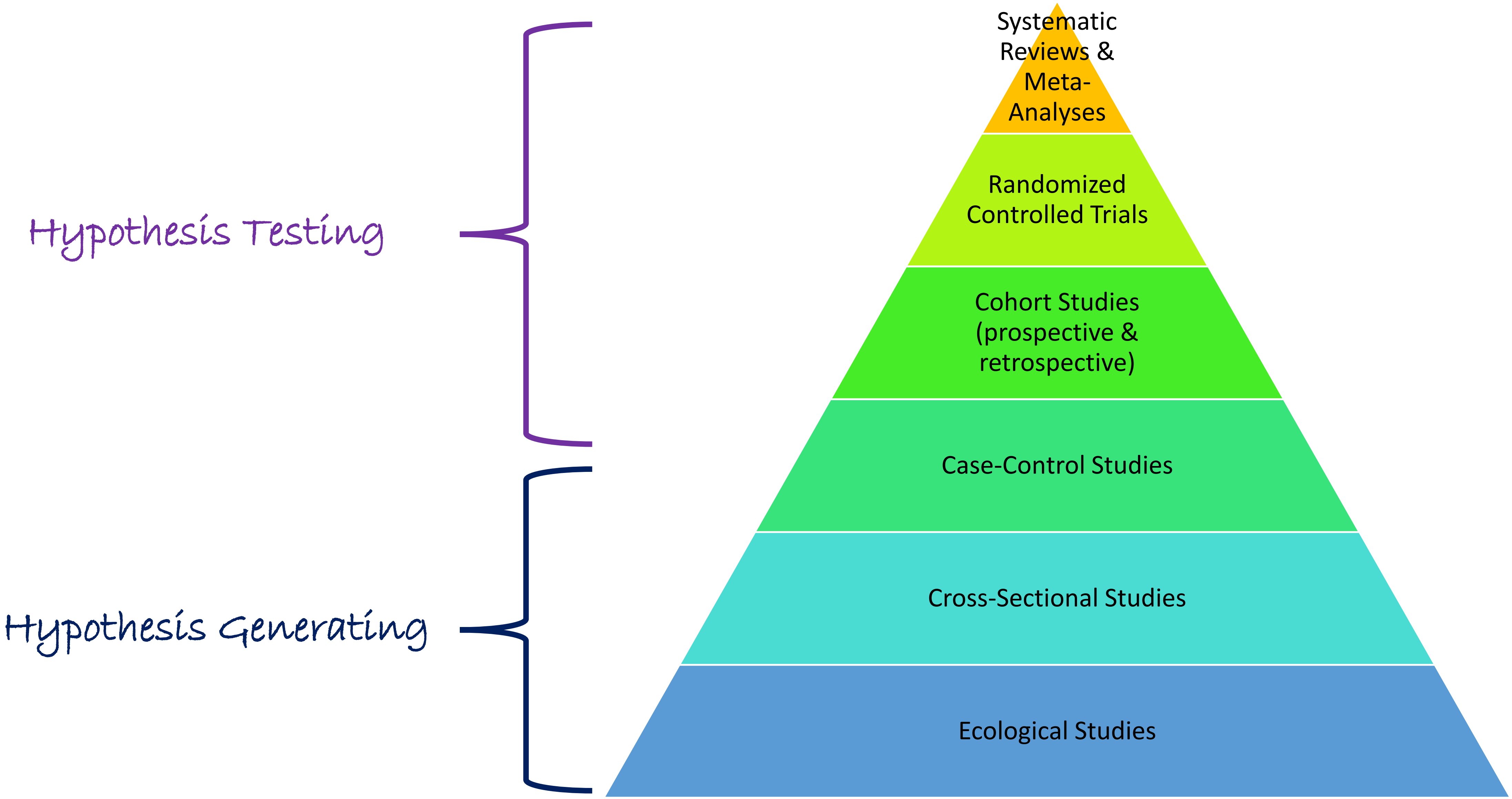



Synthesis Studies
Systematic Reviews & Meta-Analyses
Experimental Studies
Randomized Controlled Trials
Cohort Studies (prospective & retrospective)
Case-Control Studies
Cross-Sectional Studies
Ecological Studies
Observational Studies


Systematic Reviews & Meta-Analyses
Randomized Controlled Trials
Quasi-Experimental
Cohort Studies (prospective & retrospective)
Case-Cohort, Case-Crossover, Nested Case-Control
Case-Control Studies
Cross-Sectional Studies
Ecological Studies
Case Series & Case Studies


Secondary Research
Systematic Reviews & Meta-Analyses
Randomized Controlled Trials
Cohort Studies (prospective & retrospective)
Primary Research
Case-Control Studies
Cross-Sectional Studies
Ecological Studies


Uses Primary Studies as Data Points
Systematic Reviews & Meta-Analyses
Randomized Controlled Trials
Cohort Studies (prospective & retrospective)
Uses Individual-Level Data
Case-Control Studies
Cross-Sectional Studies
Uses Aggregate or Group Data
Ecological Studies


Hypothesis Testing
Hypothesis Generating
Systematic Reviews & Meta-Analyses
Randomized Controlled Trials
Cohort Studies (prospective & retrospective)
Case-Control Studies
Cross-Sectional Studies
Ecological Studies

Characteristics of Epidemiologic Study Designs

Systematic Reviews and Meta-Analysis

- Systematically combining data from all eligible primary studies

Experimental Studies

- Investigator manipulates the exposure

Cohort Studies

- Individuals chosen on exposure and followed over time for disease

Case-Control Studies

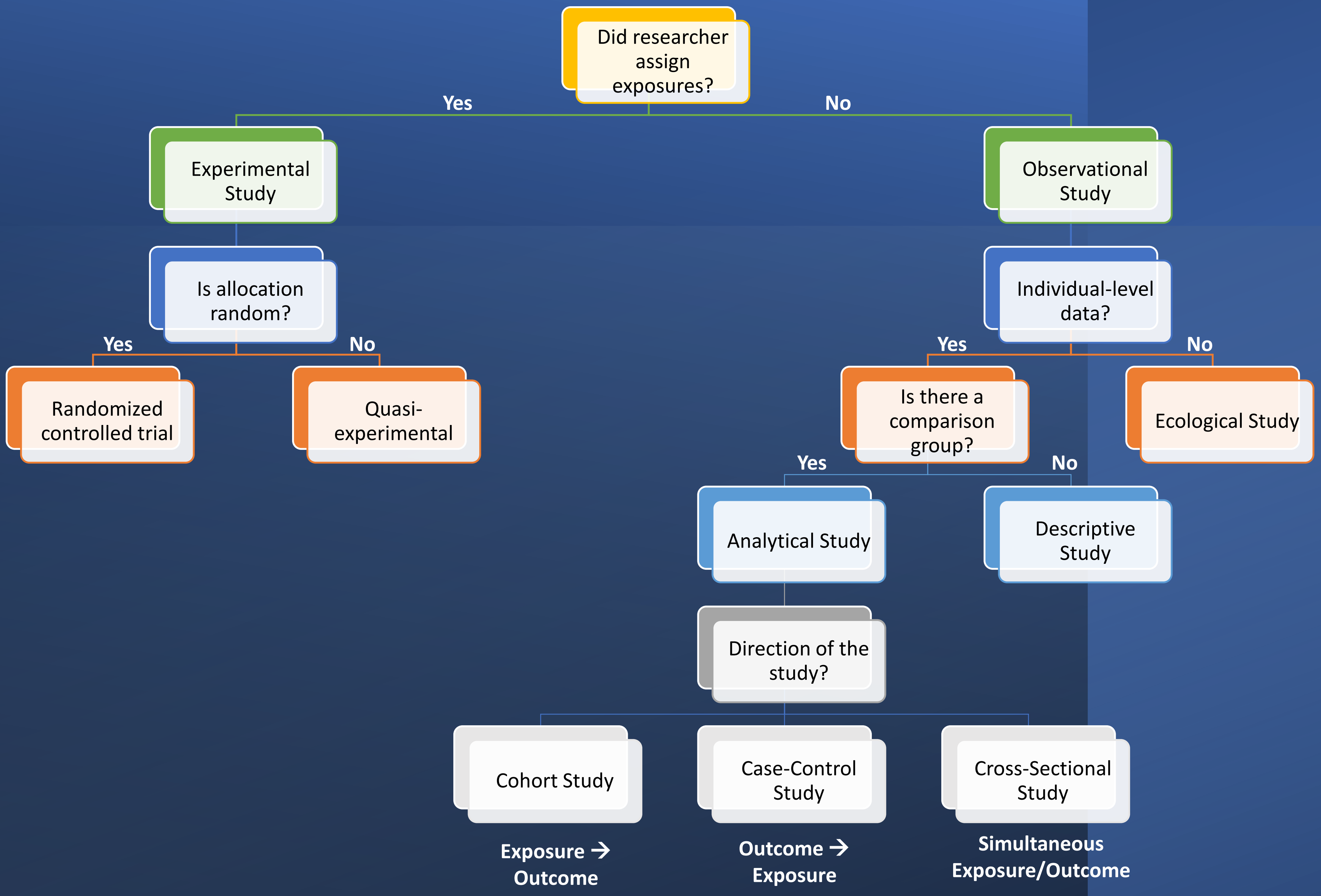
- Individuals chosen on disease and investigator looks back in time for exposure

Cross-Sectional Studies

- Snapshot of exposure and disease at the same time

Ecological Studies

- Aggregate measures (group characteristics) of exposure and disease


Did researcher assign exposures?
Yes
No
Experimental Study
Observational Study
Is allocation random?
Individual-level data?
Yes
No
Yes
No
Randomized controlled trial
Quasi-experimental
Is there a comparison group?
Ecological Study
Yes
No
Analytical Study
Descriptive Study
Direction of the study?
Cohort Study
Case-Control Study
Cross-Sectional Study
Exposure → Outcome
Outcome → Exposure
Simultaneous Exposure/Outcome

Why do we need observational studies?

While experimental studies are designed to minimize confounding and bias,

Observational studies overcome many of the limitations of RCTs like…

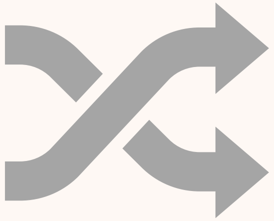
- Ethical issues (harmful exposures)
- Cost and time (longer follow-up)
- Participant selection
- Limited external validity

Can examine small risks with great public health impact

Bias and Confounding

Bias – any systematic error

- Selection bias
  - The way subjects are selected for inclusion
- Information bias
  - Any flaw in measurements



Confounding – distortion by some third factor

- Not an error in design
  - Only a problem if you don't address it
- Real and meaningful finding

Common Climate and Health Epidemiology Study Designs

Common Study Designs

Experimental Studies

Observational Studies

Limitations in Climate and Health Research

Exposure Measurement	Disease Measurement
• Indirect or surrogate measures of exposure/dose available • Uncertain exposure pathways • No real “unexposed” group, probable low-dose exposure in most settings • Often not possible to establish dose-response	• Long and variable latency periods • Non-specific effects • Small population of interest • Low disease frequency • Observer bias in reporting symptoms or disease occurrence

Observational Designs

COHORT STUDIES

CASE-CONTROL STUDIES

CROSS-SECTIONAL STUDIES

ECOLOGICAL STUDIES

Variations in Ecological Study Designs

Exploratory Study	Compare disease rates across many adjacent areas over same period or across time in one region
Space-Time Cluster Study	Assess interaction between place and time of disease occurrence
Multiple Group Study	Compare association between average exposure level and rate of disease among many groups/areas
Time-Trend Study	Assess association between change in average exposure level and change in disease rate in one area

Limitations in Ecological Study Designs

Ecologic Bias or Ecologic Fallacy

- Associations between groups may differ from associations between individuals within the groups

Reverse Causality

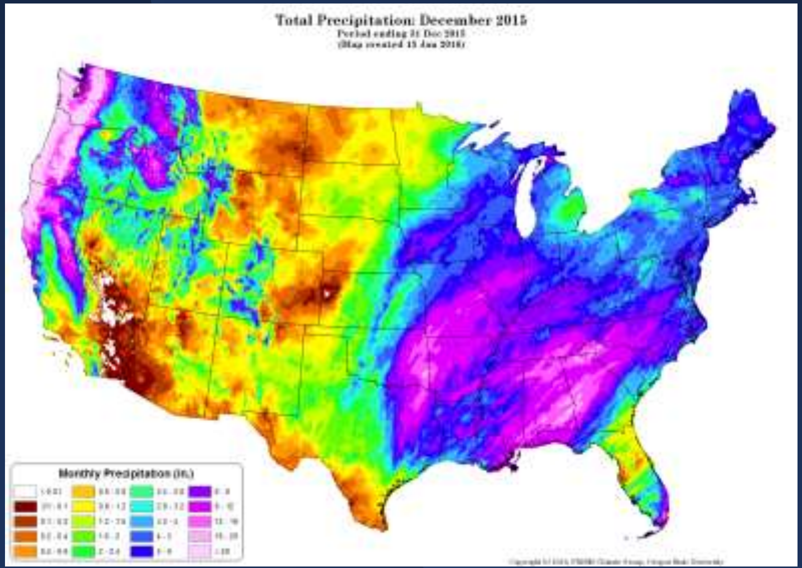
- Temporality might be difficult to establish introducing the possibility that the outcome/disease of interest alters the risk of exposure

Confounding and Effect Modification

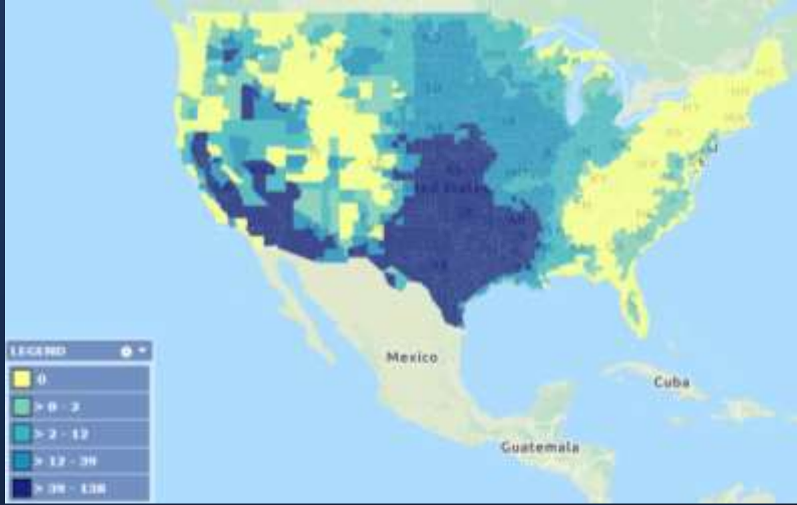
- Adjustment for confounding and effect modification is more difficult and group-level data for this is also subject to ecologic fallacy

Epidemiologic Tools for Climate and Health Studies

Data Sources



http://www.prism.oregonstate.edu/explorer/



https://ephtracking.cdc.gov/showClimateChangeIndicators

Health & Vulnerability Data

Primary Sources	Secondary Source Examples	Supporting Source Examples
• Notifiable disease registries • Vital statistics • Emergency department and hospital discharge • Syndromic surveillance	• Poison control centers • Worker compensation claims • Prescription drug monitoring	• Environmental Public Health Tracking Network • United States Census Bureau

Climate Data Sources

Global and National Resources

- World Meteorological Organization
- National weather data
  - National Oceanic and Atmospheric Association/National Weather Service
  - Oregon State University PRISM Climate Group

Coastal Resources

- Comprehensive Surge Database (SURGEDAT)
- Surging Seas, Climate Central
- Sea Level Rise and Coastal Flooding Impacts Viewer

Local Resources

- Local weather networks and citizen science
  - New York City Panel on Climate Change (NPCC)
  - North Carolina Environment and Climate Observing Network (ECONet)
  - Florida Automated Weather Network (FAWN)
  - CoCoRaHS

Data Analysis and Methods

Vulnerability Assessments

Exposure-Response Functions

Disease Burden Projections

Vulnerability Assessment

- Spatial analysis of future climate hazards and social/medical vulnerability
- Use indices or individual indicators
- Intersectionality of hazard and vulnerability is the target

Exposure-Response Functions: Causal Pathway Considerations

- What makes sense (mechanistically)?
- What have other people used (i.e., literature review)?
- What is available? And what access do you need?
- What do you have the tools to process?
- What can you best communicate?

Climate, Weather, & Health

Environmental Context

- Land use
- Ecosystem
- Infrastructure
- Geography
- Agricultural production
- Livestock use

Climate Drivers

- Increased temperatures
- Precipitation extremes
- Extreme weather
- Sea level rise

Exposure Pathways

- Extreme heat
- Poor air, food, and water quality
- Changes in infectious agents/distributions
- Population displacement

Health Outcomes

- Heat-related illness
- Cardiopulmonary disease
- Food, water, vector-borne disease
- Mental health impacts

Social & Behavioral

- Age
- Gender
- Race/ethnicity
- Poverty
- Housing & infrastructure
- Education
- Access to care
- Community health infrastructure
- Pre-existing & co-morbid health conditions

Adapted from: USGCRP, 2016: *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. Crimmins, A, et al, Eds. U.S. Global Change Research Program, Washington, DC, 312 pp. http://dx.doi.org/10.7930/J0R49NQX

Linking Climate & Health Data: Methodological Challenges

Defining events

When and where?

Climate thresholds

Historical period of interest

Varied event impacts

Direct vs. indirect impacts

Spatial resolution of data

Mismatched climate and health data resolution

Time and resource limitations

Examples of Climate and Health Epidemiology Studies

Cohort Study Example

Mulchandani *et al. BMC Public Health* (2020) 20:321
https://doi.org/10.1186/s12889-020-8424-3

BMC Public Health

RESEARCH ARTICLE Open Access

The English National Cohort Study of Flooding & Health: psychological morbidity at three years of follow up

Ranya Mulchandani[1,2*], Ben Armstrong[3], Charles R. Beck[1,2,4], Thomas David Waite[1,5], Richard Amlôt[6], Sari Kovats[3], Giovanni Leonardi[6], G. James Rubin[7] and Isabel Oliver[1,2,4]

Study Objectives

“To assess the mental health morbidity at 3 years post-flooding and the impact of persistent flood-related damage in the home.”

“To assess the prevalence change over the three-year period, to identify possible predictors for psychological recovery.”

Study Setting and Subjects

Context

- Widespread river, coastal, surface flooding in England in winter of 2013 and 2014

Cohort

- Adults over 18 years of age residing in selected homes from selected postal codes
- Began as a cross-sectional study but evolved into a prospective cohort
  - Cross-sectional study: 2,126 participants
  - Cohort study: 1,064 participants

Variables

Exposure

- Unaffected: no impacts from flooding
- Disrupted: life was disrupted by the flooding, but no water entered home
- Flooded: water entered at least one room of the home

Outcomes

- Depression: Patient Health Questionnaire (PHQ-2)
- Anxiety: Generalized Anxiety Disorder Scale (GAD-2)
- Post-traumatic stress disorder (PTSD): PTSD Checklist (PCL-6)

Covariates

- Persistent damage
- New episodes of flooding
- Status of insurance
- Secondary stressors
- Demographic characteristics

Results

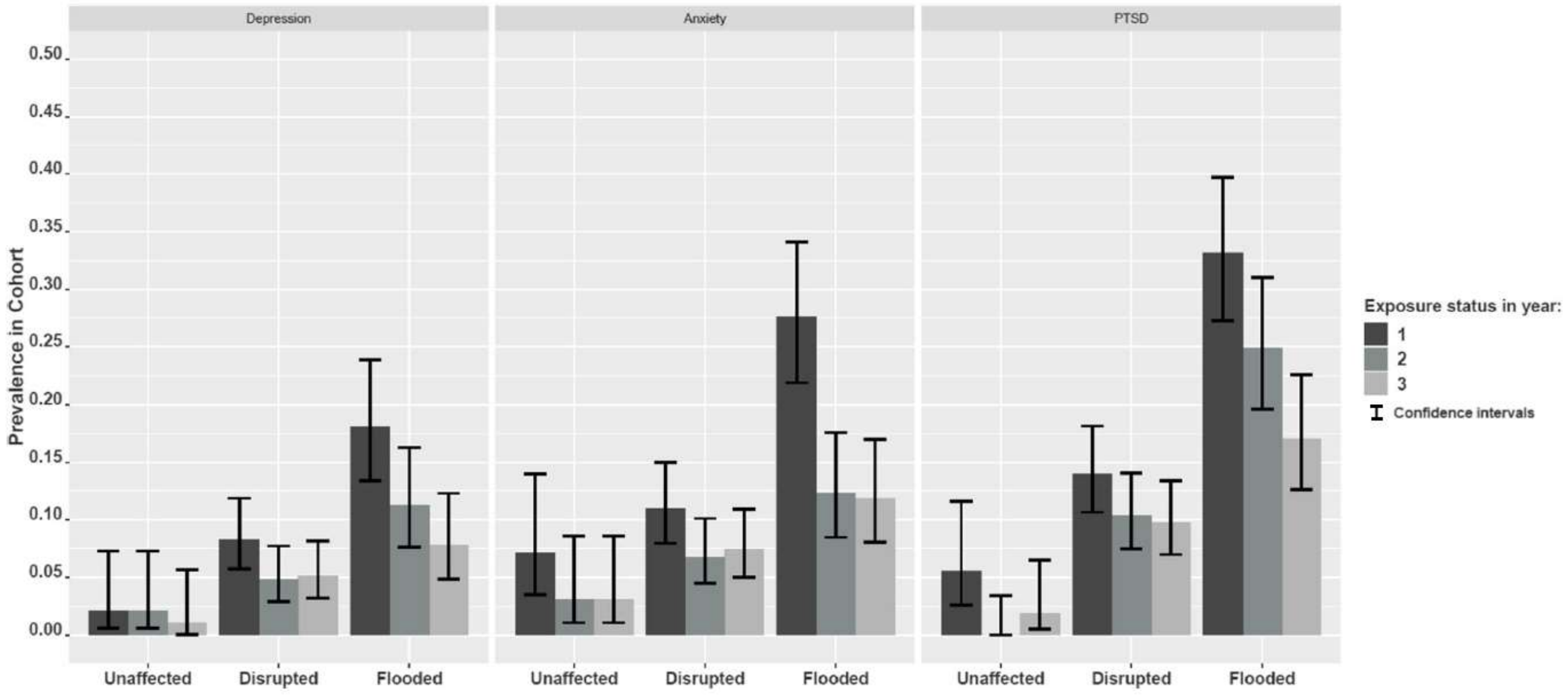


Fig. 1 Prevalence of mental health outcomes by exposure group over 3 years post-flooding of participants who responded all 3 years

Cautionary Tale

- Many studies will suggest that a cohort study approach was used in the title but use another design in reality!

RESEARCH Open Access

Temperature and particulate matter as environmental factors associated with seasonality of influenza incidence – an approach using Earth observation-based modeling in a health insurance cohort study from Baden-Württemberg (Germany)

the preceding quarter. From these data, we aggregated the number of new cases and the number of existing cases per quarter, per 5-digit postcode, and per gender. Sex and age information was abandoned to preclude exposure of personally identifiable information, and to be in keeping with data protection regulations. This approach was necessary in particular for remote areas with low population densities.

Examples

ABSTRACT

Objectives: This study aims to examine the association between self-reported heat stress interference with daily activities (sleeping, work, travel, housework and exercise) and three graded-holistic health and well-being outcomes (energy, emotions and life satisfaction).

Design: A cross-sectional study.

Open Access Research

BMJ open accessible medical research

Heat stress, health and well-being: findings from a large national cohort of Thai adults

Cohort with Case-Control Hybrid Study Example

Research

A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP945.

Ambient Temperature and Stillbirth: A Multi-Center Retrospective Cohort Study

Sandie Ha,[1] *Danping Liu,*[2] *Yeyi Zhu,*[1] *Sung Soo Kim,*[1] *Seth Sherman,*[3] *Katherine L. Grantz,*[1] *and Pauline Mendola*[1]

[1]Epidemiology Branch, Division of Intramural Population Health Research, *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (NICHD), Bethesda, Maryland, USA
[2]Biostatistics and Bioinformatics Branch, Division of Intramural Population Health Research, NICHD, Bethesda, Maryland, USA
[3]The Emmes Corporation, Rockville, Maryland, USA

Environ Health Perspect 2017; https://doi.org/10.1289/EHP945.

Study Objectives

- “To determine the associations between acute and chronic exposures to temperature extremes and stillbirth risk…”
- To estimate “the excess number of stillbirths potentially attributable to extreme temperatures in the United States.”

Study Setting and Subjects

- Combined the Consortium on Safe Labor (CSL) Study with meteorological data from the Weather Research and Forecasting model for this Cohort study
- Cohort
  - All deliveries that occurred ≥ 23 weeks gestation at 12 clinical centers from 2002-2008

Variables

Exposure

- Hourly temperature data at 12x12 km resolution and averaged across hospital referral region
- Chronic exposure: three-month preconception, first trimester, second trimester, entire pregnancy
- Categorized using local temperature distributions to determine deviation from normal
- Acute exposure: one week prior to delivery compared to two control periods

Variables

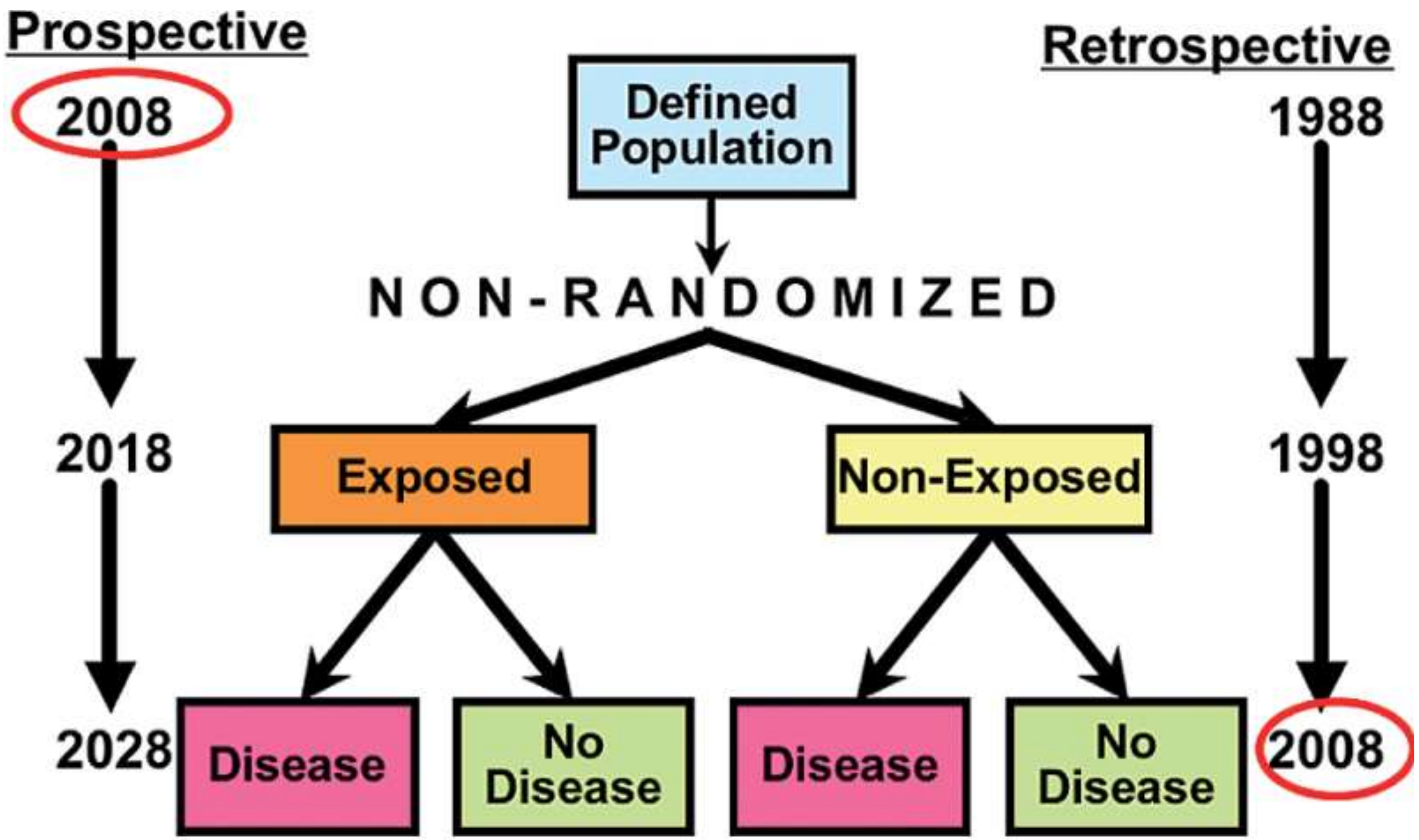
Outcome

- Stillbirth: any fetal death ≥ 23 weeks gestation
- Stratified by type of stillbirth (antepartum and intrapartum)

Covariates

- Relative humidity
- Particulate matter with diameter <2.5 microns (PM2.5)
- Ozone
- Demographic characteristics

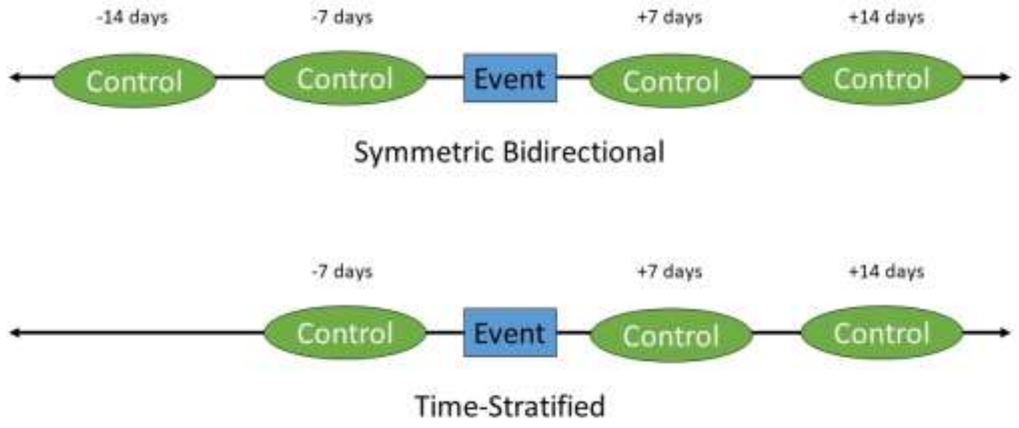
Cohort Study Design



Gordis: Epidemiology, 4th Edition.

Case-Crossover Study

- Developed to study acute transient events
- Like matched CACO: cases serve as own controls
- Case: a person with an acute outcome
- Event/case period: window defined around the outcome of interest
- Control period: chosen within a specific window around the outcome
- Analysis: conditional logistic regression, where each individual (matched pair) serves as a separate stratum



Results: Cohort Study and Chronic Exposure

Table 2. Chronic associations between extreme ambient temperatures and stillbirth among singleton births in the consortium on safe labor, 2002–2008 (cohort analysis).

	Unadjusted		Adjusted[a]		Adjusted[b]	
Exposure windows	OR	95% CI	OR	95% CI	OR	95% CI
Hot						
Preconception	0.91	0.73, 1.13	0.98	0.77, 1.24	1.02	0.80, 1.30
Trimester 1	**0.73**	**0.58, 0.93**	0.83	0.64, 1.07	0.83	0.63, 1.08
Trimester 2[c]	1.13	0.89, 1.44	1.06	0.82, 1.37	1.03	0.78, 1.34
Whole Pregnancy	**3.79**	**3.24, 4.42**	**3.80**	**3.16, 4.56**	**3.71**	**3.07, 4.47**
Cold						
Preconception	**1.25**	**1.03, 1.51**	1.23	0.99, 1.53	1.21	0.97, 1.50
Trimester 1	0.94	0.76, 1.16	0.92	0.72, 1.17	0.91	0.71, 1.16
Trimester 2[c]	0.83	0.63, 1.09	0.90	0.67, 1.20	0.90	0.68, 1.22
Whole Pregnancy	**3.93**	**3.37, 4.58**	**4.54**	**3.78, 5.45**	**4.75**	**3.95, 5.71**

Table 3. Acute association between ambient temperature during the week prior and stillbirth among cases in the consortium on safe labor, 2002–2008 (case-crossover analysis, $n = 987$).

		OR[a]		AR[b]		AR[c]	
Season of delivery	n	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Cold (Oct–Apr)	540	1.00	0.98, 1.02	0	− 1.2, 1.2	0	−0.9, 0.9
Warm (May–Sept)	447	**1.06**	**1.03, 1.09**	**3.8**	**1.8, 5.8**	**2.7**	**1.3, 4.1**

Results: Case-Crossover Study and Acute Exposure

- Ambient temperature in week preceding delivery significantly associated with risk of stillbirth during warm season but not cold season

Ecological Study Example

- To understand the impacts of heat (temperature and heat index) on human health in Florida

Variables & Data Sources

Outcomes: Daily emergency department (ED) data

- May 1 to October 31, 2005-2012
- Date of visit
- Florida residents only

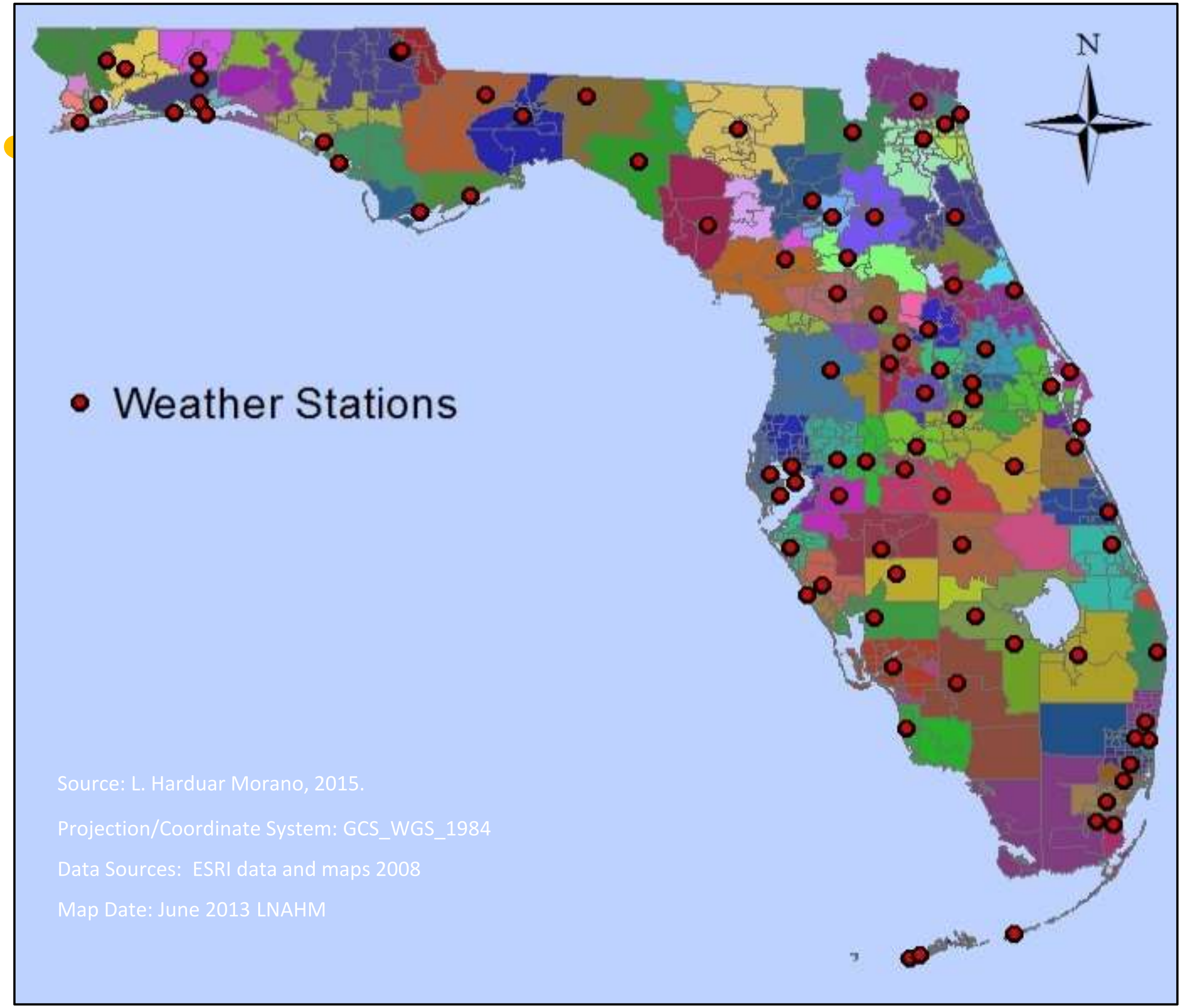
Covariates: American Community Survey (ACS)

- 5-year estimates (2007-2011)
- Assumed constant population over study period

Exposure: Hourly weather data

- National Weather Service (NWS) stations
- Florida Agricultural Weather Network (FAWN) stations

ZIP Codes by Nearest Weather Station



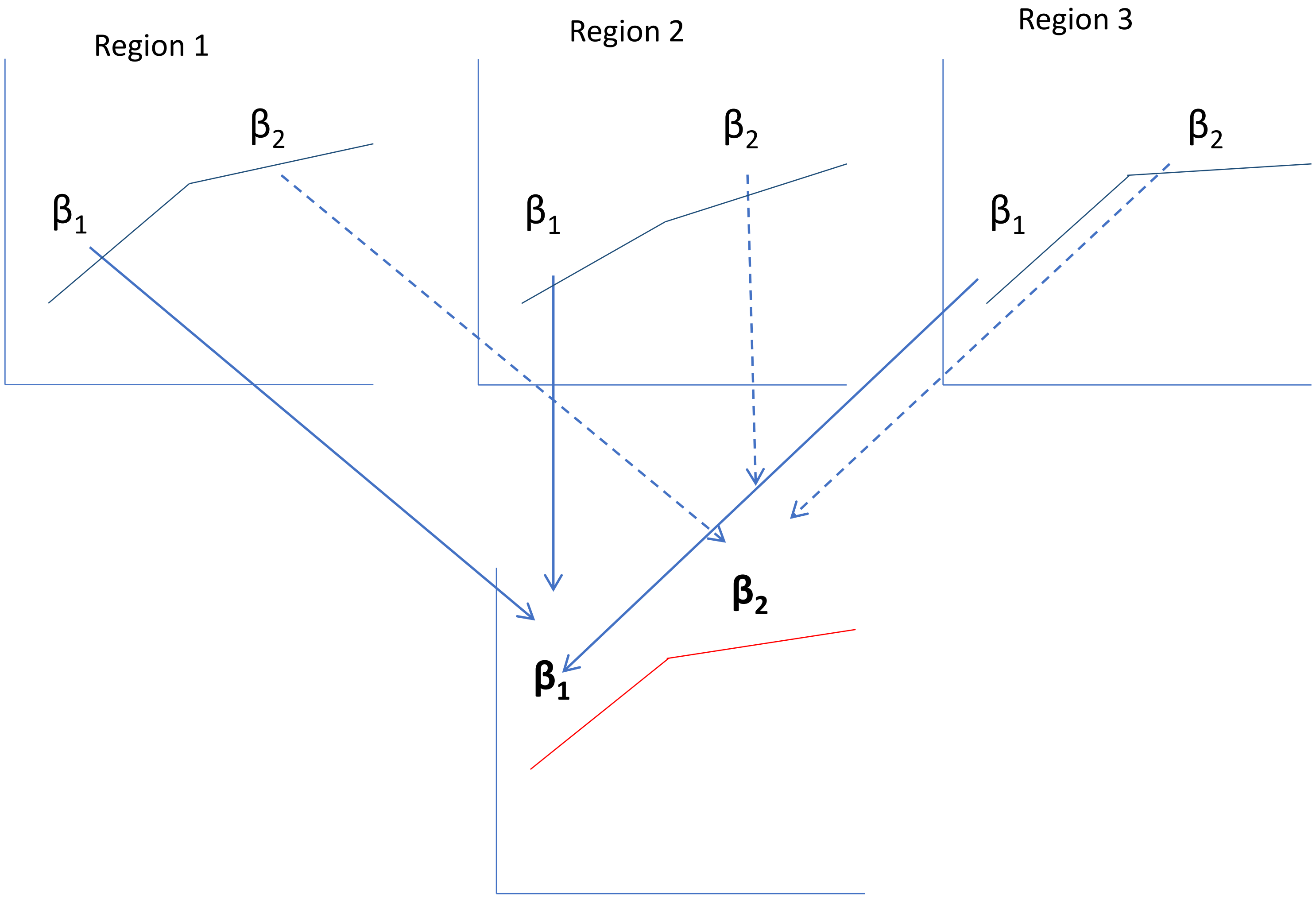
Outcomes: Diagnoses

- Diagnoses codes (ICD-9-CM)
- Heat-related illness (HRI)
  - 992, E900.0, E900.1, E900.9
- Cardiovascular disease (CVD)
  - All CVD: 360-459
  - Acute myocardial infarction: 410
  - Ischemic stroke: 434, 436

Analysis & Model

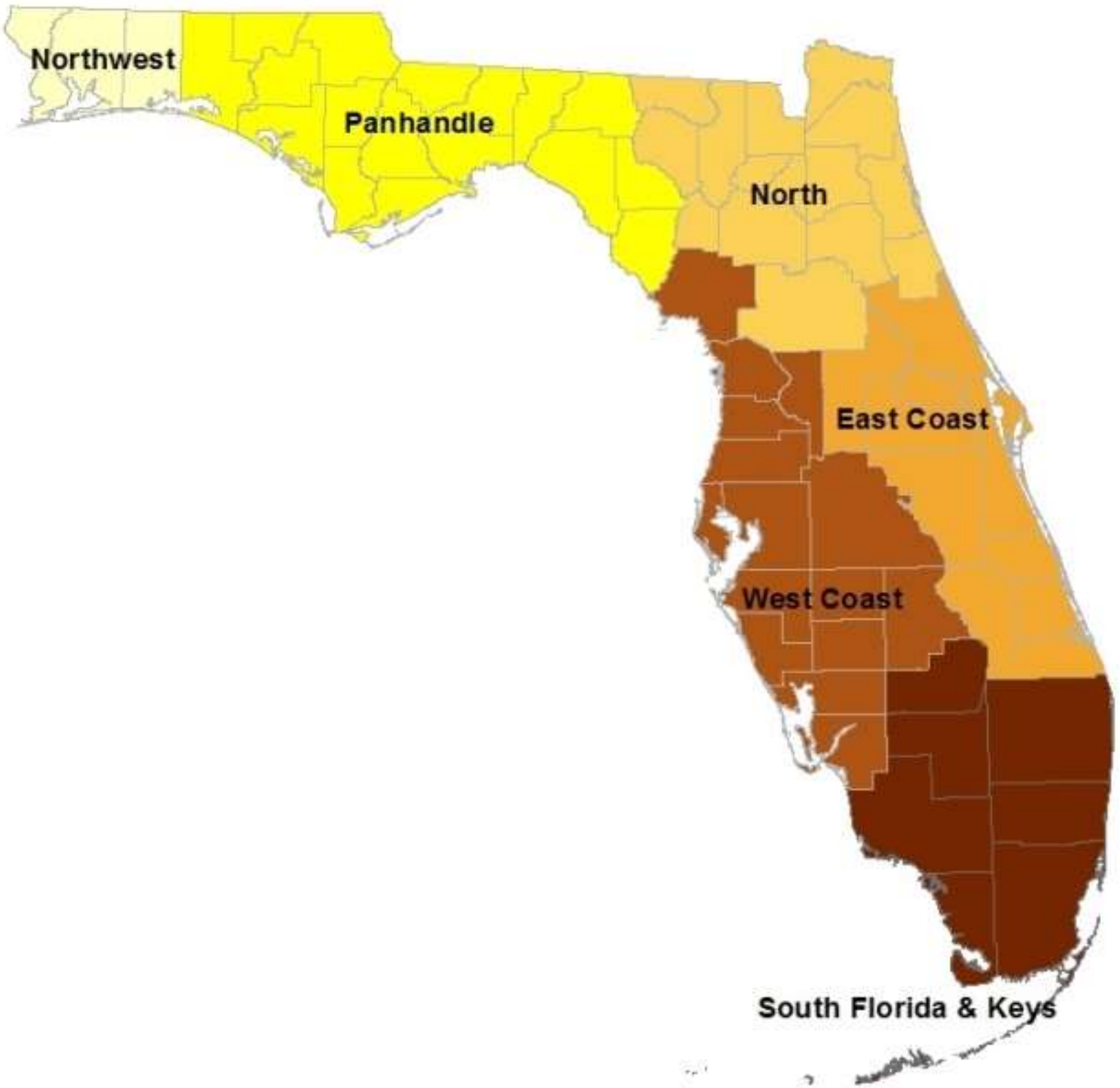
- Two stage analysis
  - Stage 1: Each NWS region →Time series generalized linear model with Poisson distribution
    - Outcome = ED visit counts
    - Exposure = Temperature or heat index
    - Offset = ACS population estimates by ZIP code
    - Adjusted for long- and short-term temporal trends
  - Stage 2: Combined each regional analysis using meta-analysis techniques
    - Outcome = stage 1 exposure parameters
    - Random effects to account for regional differences

Stage 1: Regional Estimates



Stage 2: Summary Result

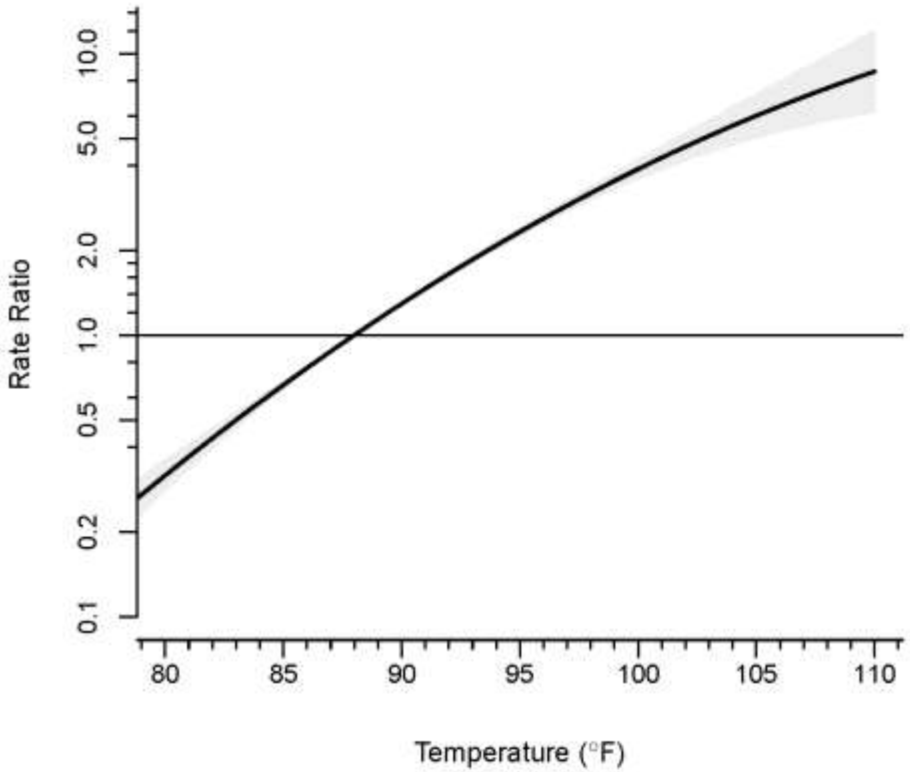
Geographic Resolution: NWS Regions



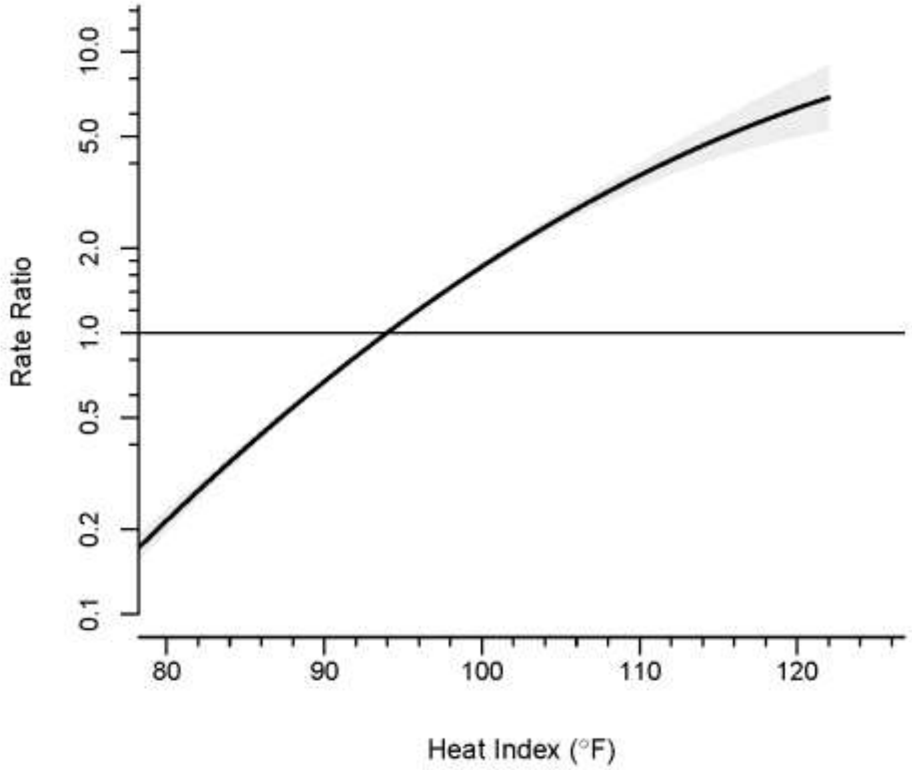
Average Temperature & Heat Index by NWS Region

Region	Temperature (°F)		Heat Index (°F)	
	Mean (SD)	Min-Max	Mean (SD)	Min-Max
Pensacola	86 (6.24)	55-106	92 (9.51)	52-121
Tallahassee	87 (6.31)	54-105	93 (9.24)	52-122
Jacksonville	87 (5.94)	56-106	93 (8.66)	53-122
Melbourne	88 (4.85)	54-101	94 (7.61)	52-122
Tampa Bay	88 (4.47)	50-102	95 (7.18)	48-122
Miami/Key West	88 (3.57)	63-102	95 (6.31)	62-119
All Florida	*88 (4.89)*	*50-106*	*94 (7.68)*	*48-122*

HRI: State

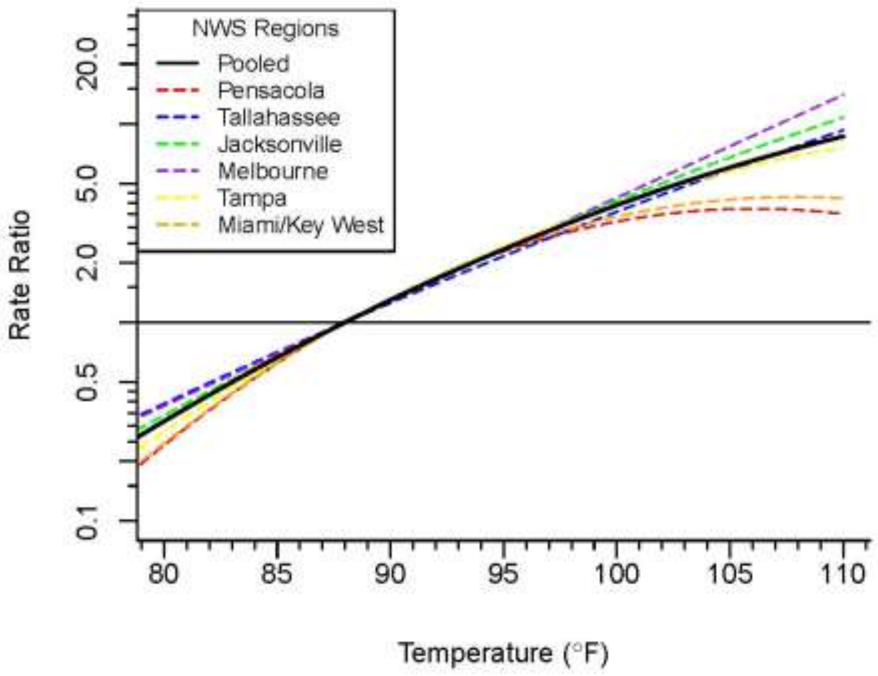


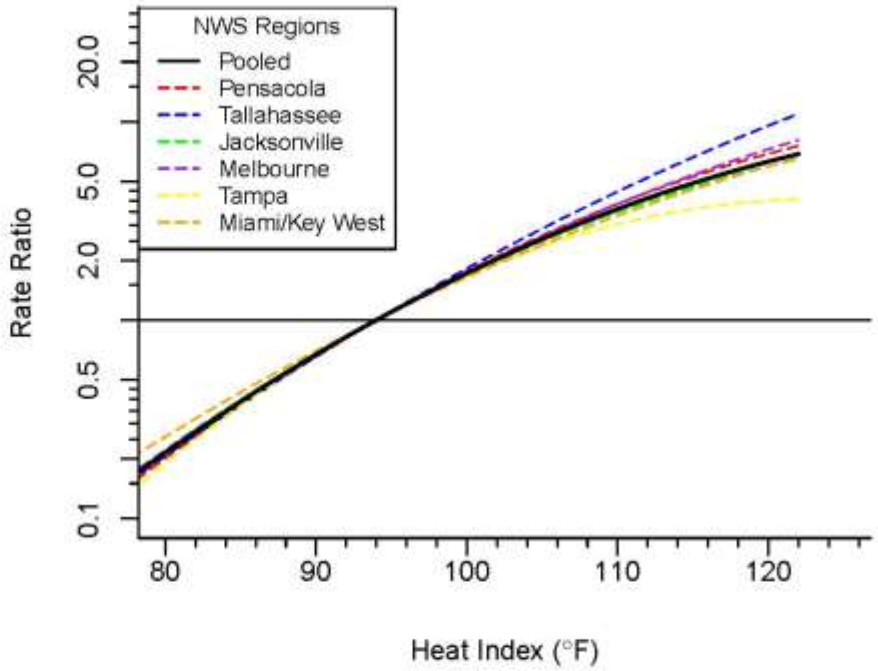
Rate Ratio
10.0
5.0
2.0
1.0
0.5
0.2
0.1
80
85
90
95
100
105
110
Temperature (°F)



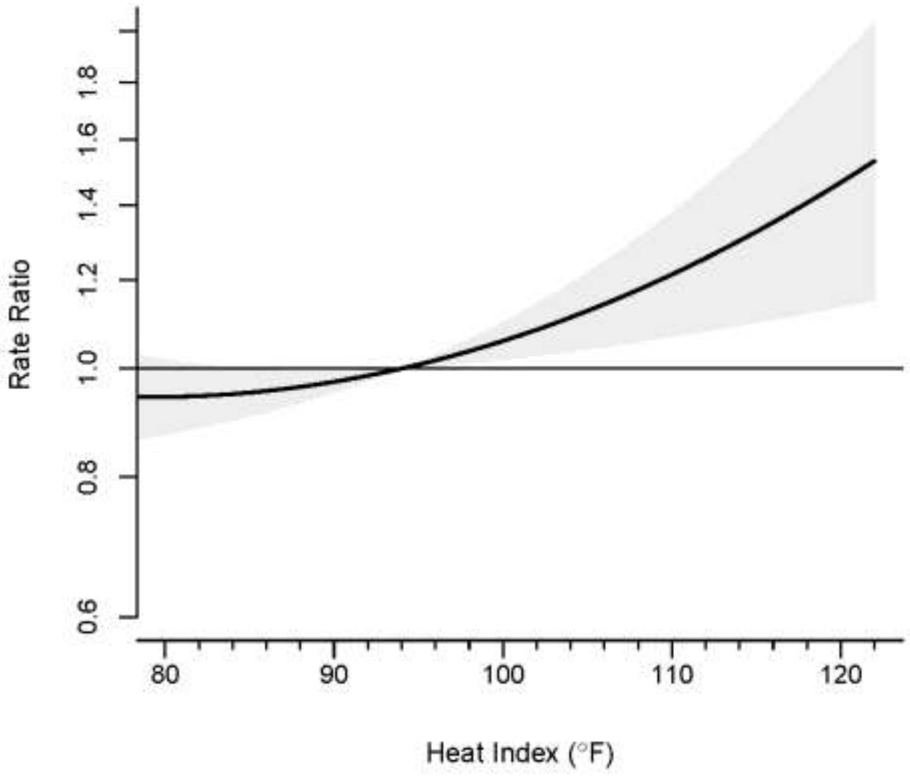
Rate Ratio
10.0
5.0
2.0
1.0
0.5
0.2
0.1
80
90
100
110
120
Heat Index (°F)

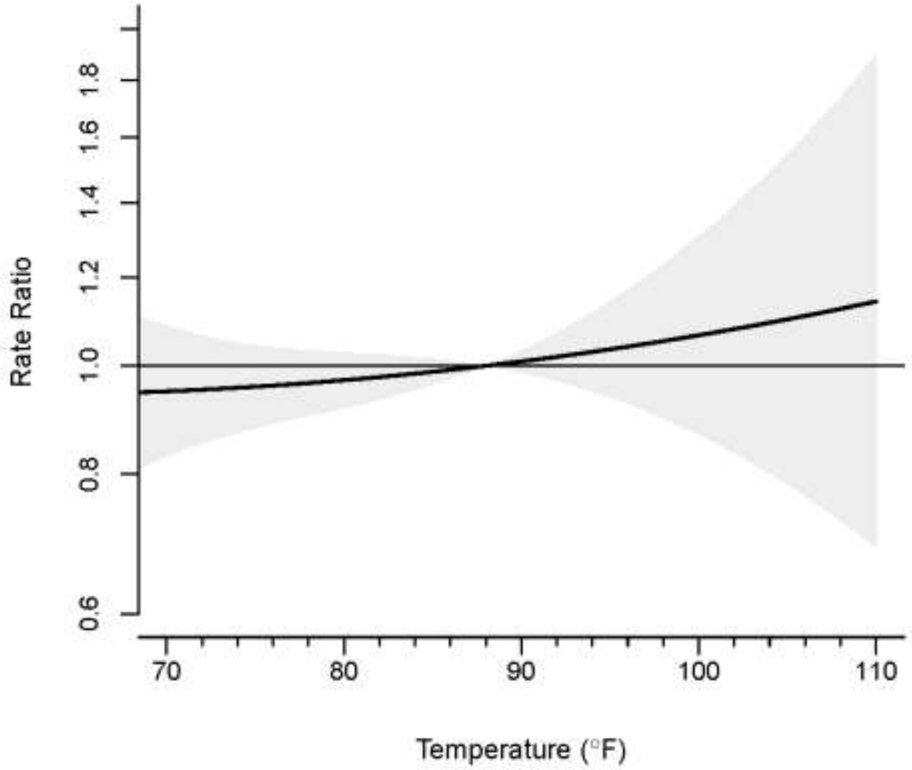
HRI: Regional



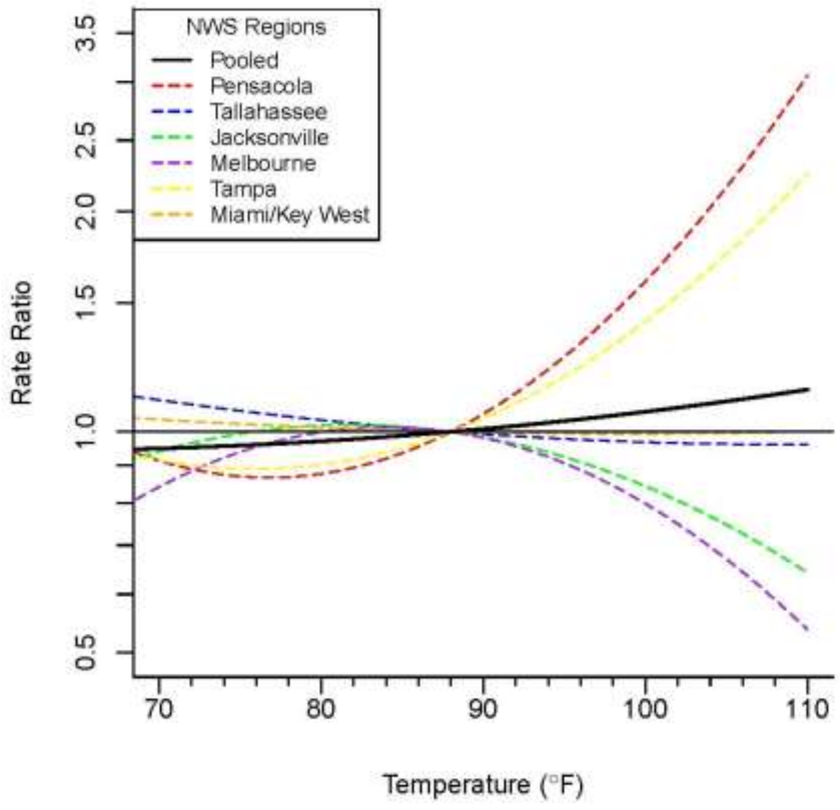


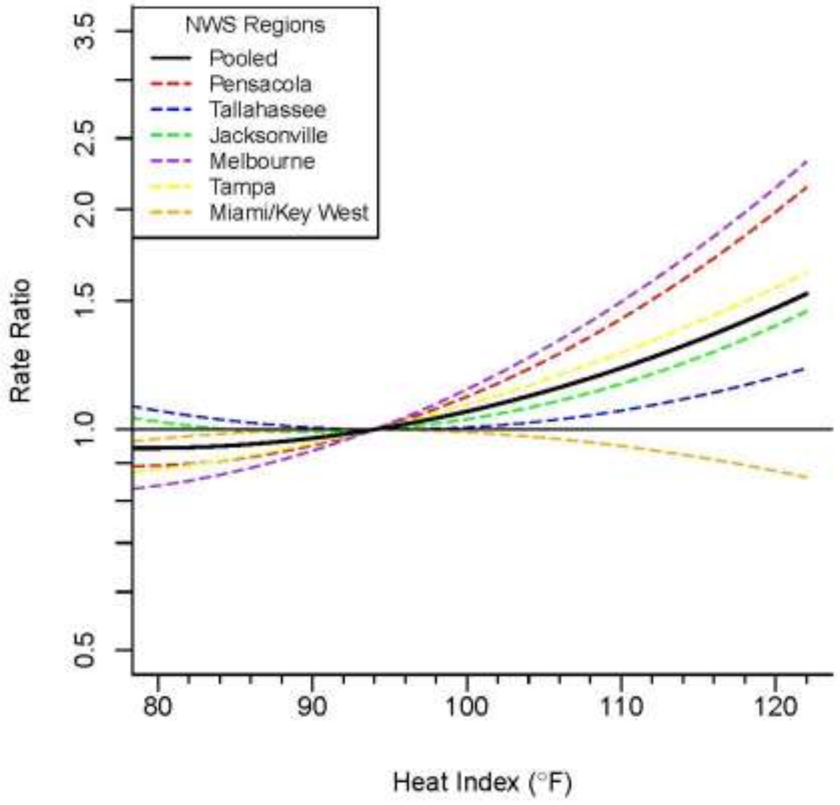
Myocardial Infarction: State



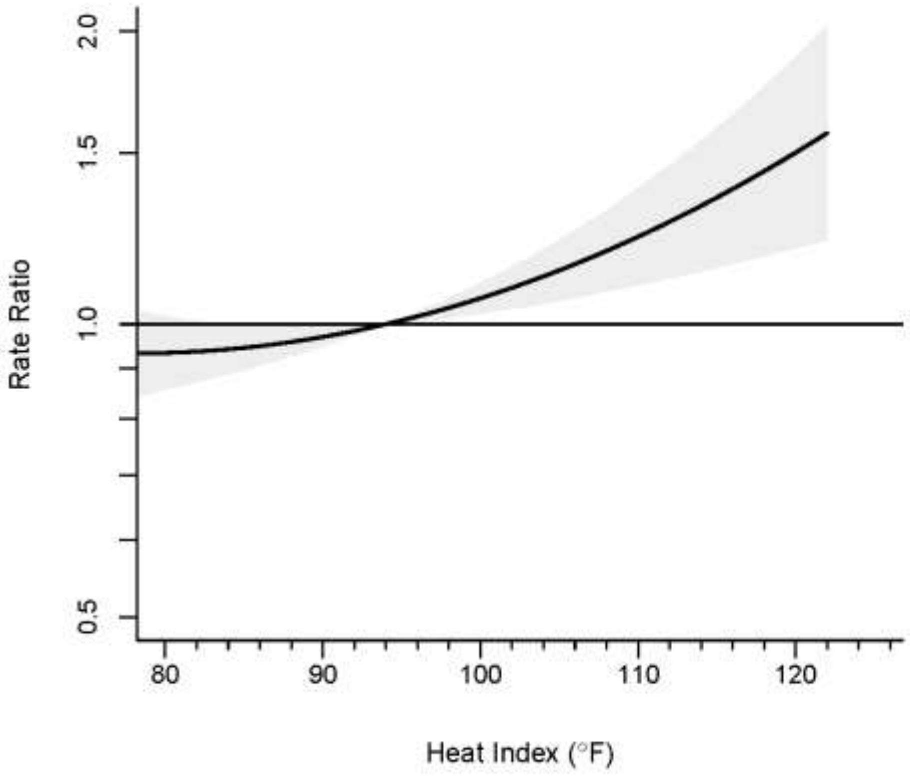


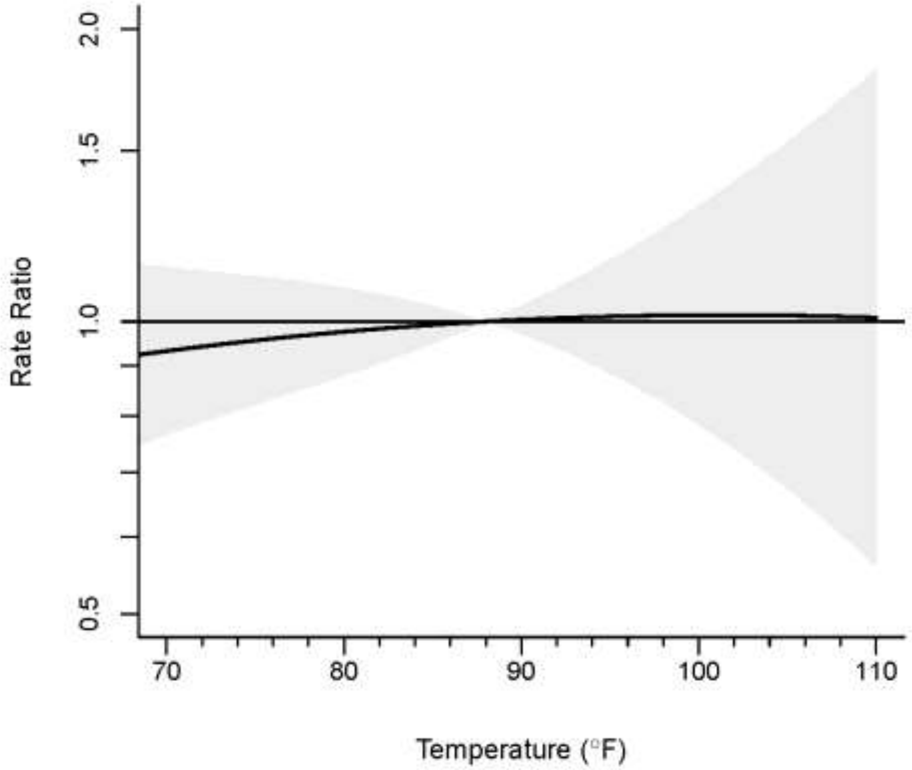
Myocardial Infarction: Regional



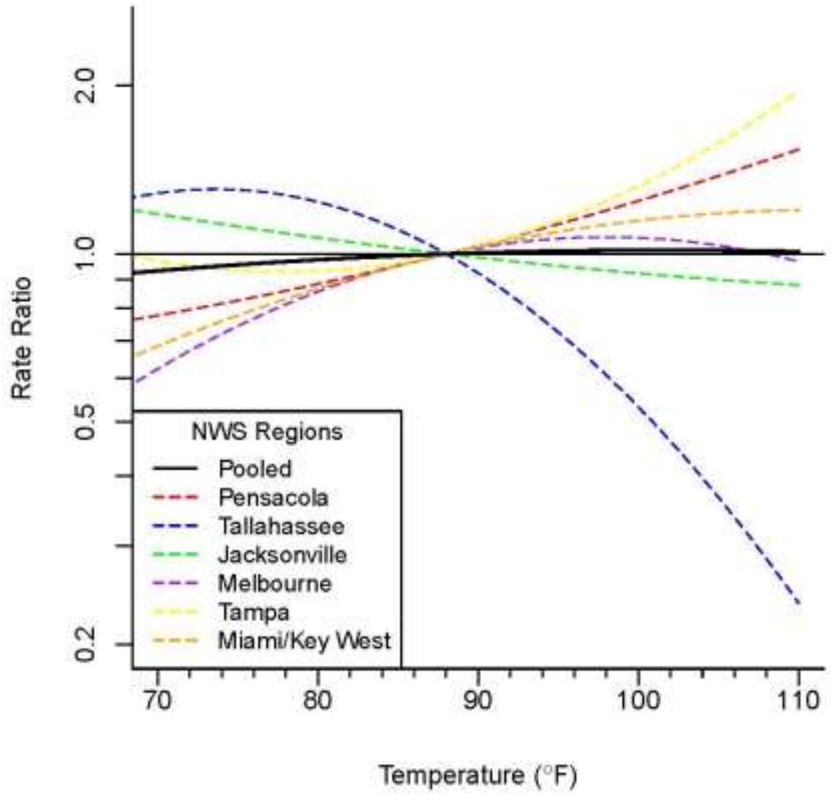


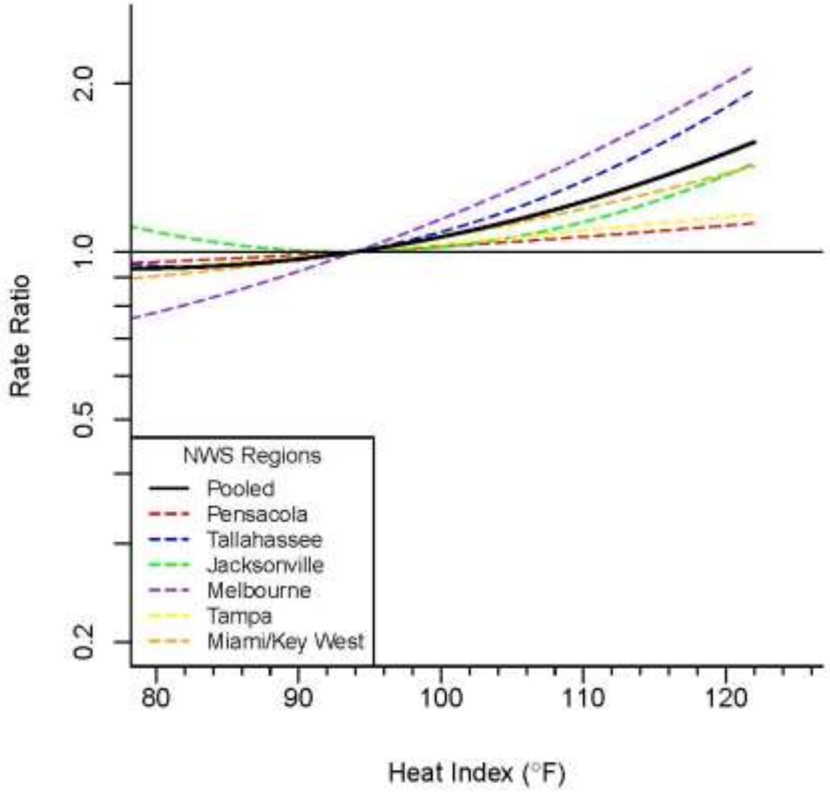
Stroke: State





Stroke: Regional





Conclusions

- Strong positive association between HRI and both temperature and heat index
- Associations between cardiovascular diseases are stronger with heat index than temperature
- No significant associations between daily heat metrics and mental health/behavioral disorders or asthma
- Associations vary by region and exposure

Public Health Applications

- Assess the criteria for National Weather Service heat advisories and warnings and make recommendations based on heat-health relationship
  - The magnitude of effect for the heat-health relationship is smaller for heat index than temperature.
  - The magnitude of effect is larger for occupational HRI than for non-occupational HRI.
  - There is no clear temperature or heat index cut-point where morbidity increases.

Questions?