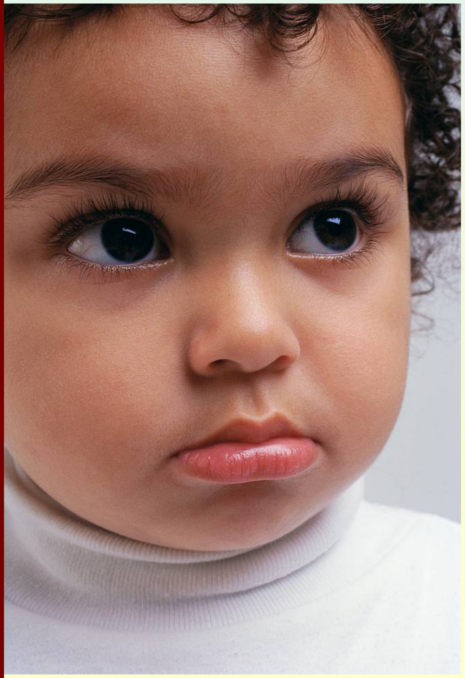
Still Toxic After All These Years . . .

Air Quality, Environmental Justice and Health

Prepared by:

Manuel Pastor
James Sadd
Rachel Morello-Frosch

A Presentation in Two Parts



- What's the Problem? Example of recently completed environmental justice analysis of Bay Area using data and techniques developed in CARB project: a "framework study" offering a multivariate look at two databases and relationship to social ecology

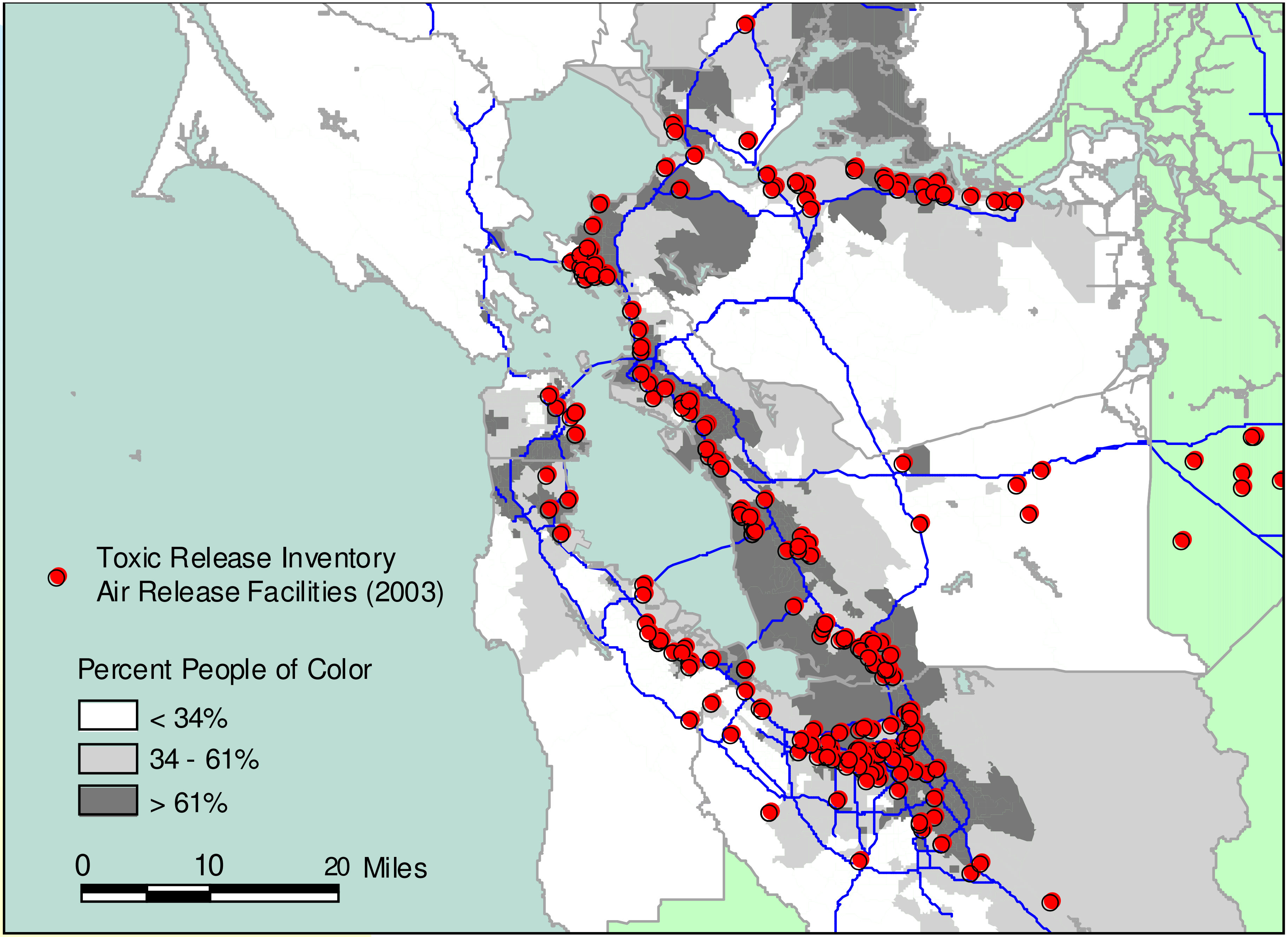
  - What's the Impact? Example of in-process analysis of birth outcomes using data and techniques developed in CARB project: a "health impact" study taking into account particulates, confounding factors, and mediating influences – a base for the RARE work to be sponsored by USEPA.

Framework Study: Data Sources

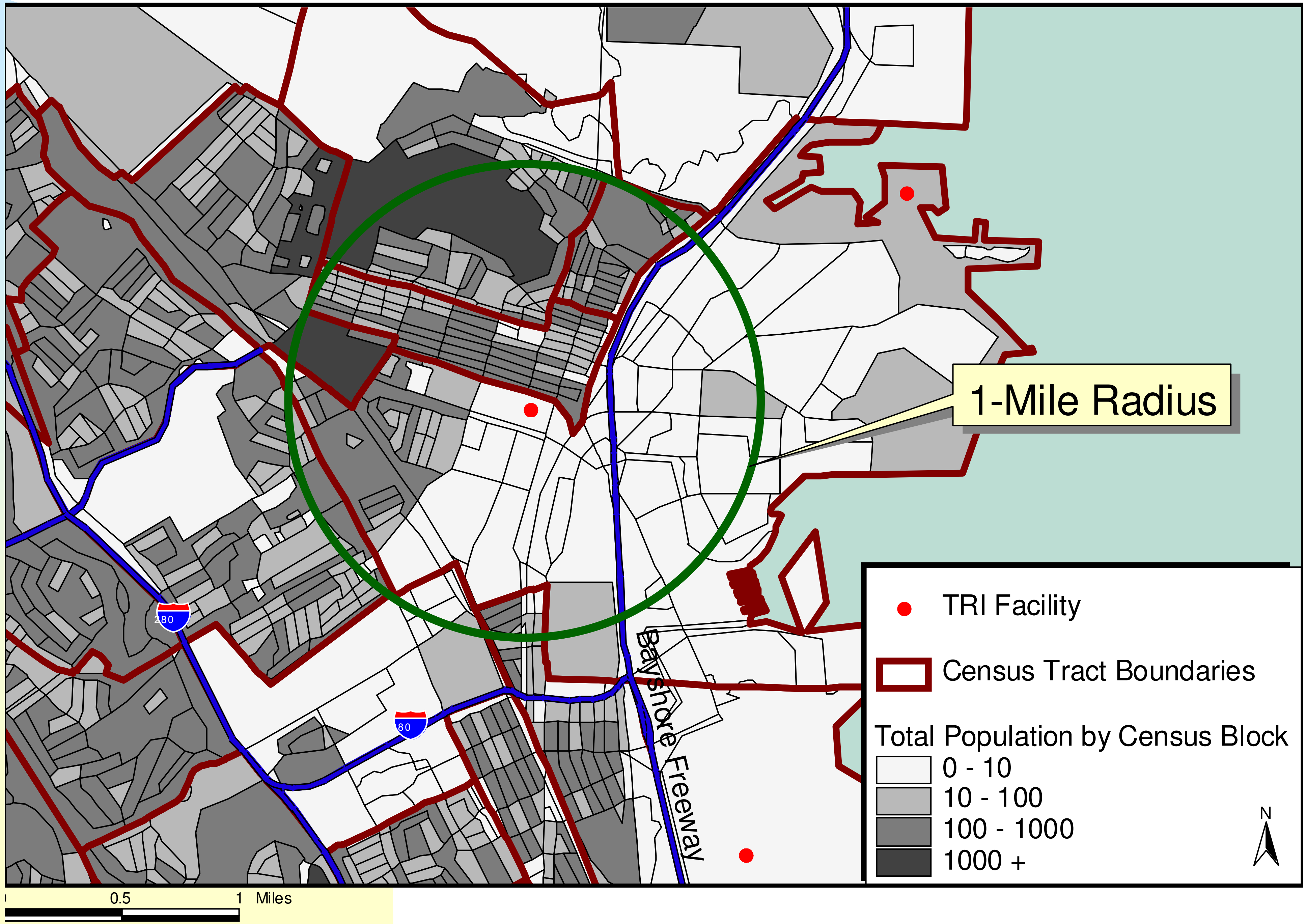
- Toxic Release Inventory – annual self-reports from point facilities, with analysis attempting to separate out carcinogenic releases, and facilities geo-coded as of 2003. The TRI data is standard in national studies although much analysis is flawed due to poor geographic matching.
    - NATA – National Air Toxics Assessment (1999). Takes into account national emissions database with modeling of stationary, mobile, and point sources. Public available NATA fails to account for cancer risk associated with diesel; we apply risk factors to modeled diesel to complete the California picture.

At First Glance . . .

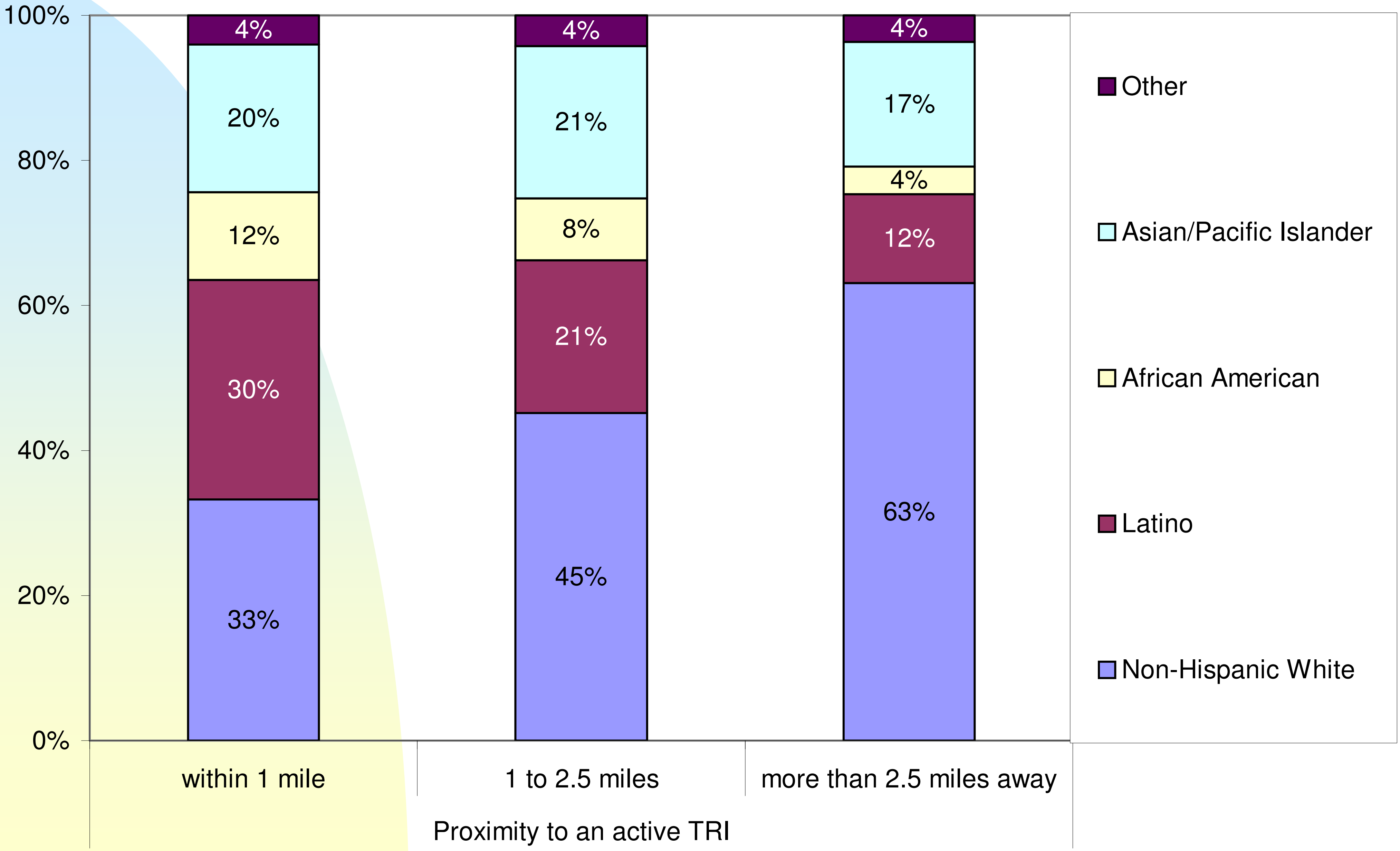
TRI Facilities Relative to Neighborhood Demographics



How do we determine TRI proximity?
The one-mile case



Population by Race/Ethnicity (2000) and Proximity to a TRI Facility with Air Releases (2003) in the 9-County Bay Area



Why the Pattern?

Land Use Perspective:

- Hazards located where industrial facilities are clustered
- People of color just happen to live near industrial employment opportunities

Income View:

- More hazardous land uses tend to be where income levels and property values are lower
- Reflects normal market system

Power Dynamic:

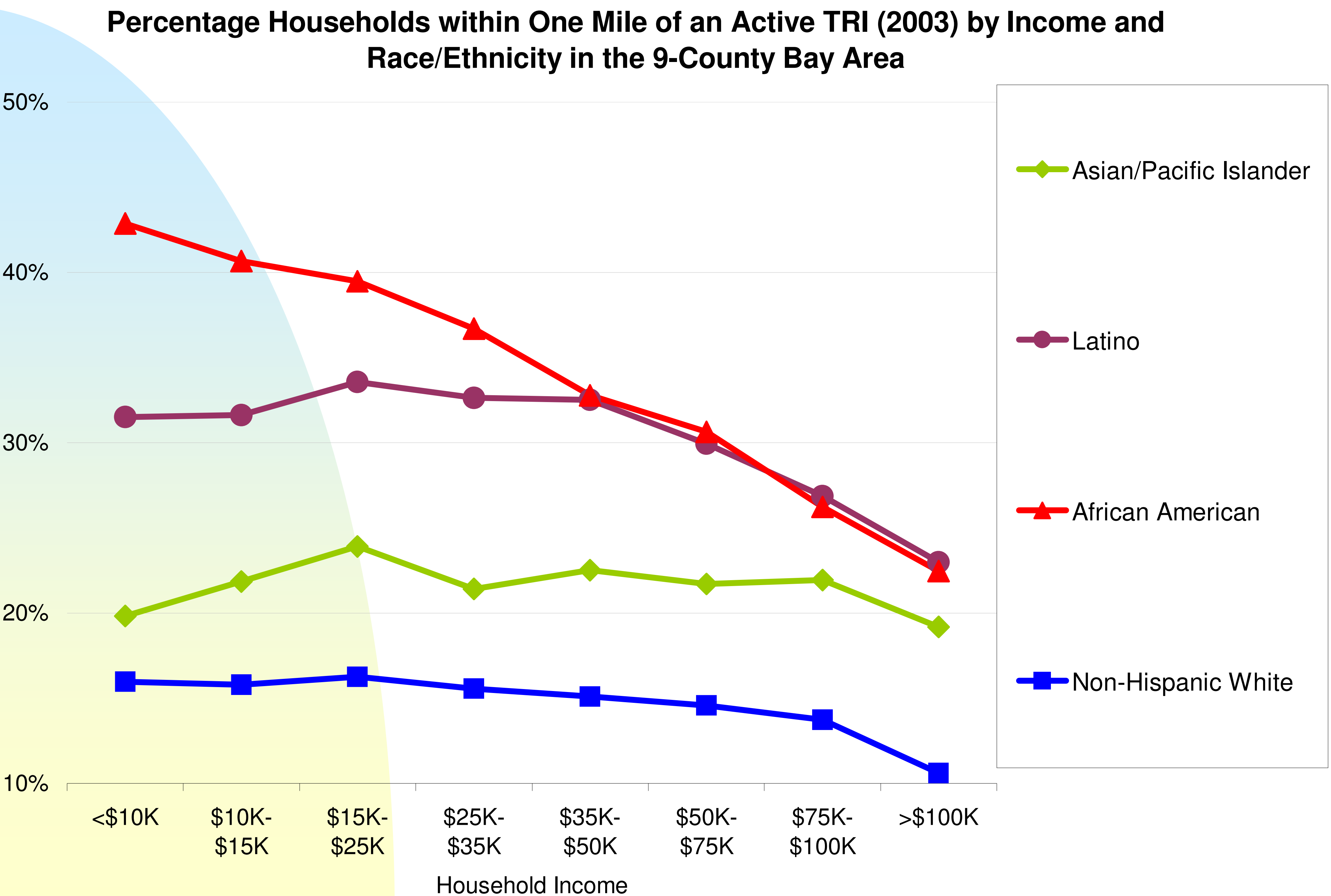
- Where communities are unable to resist and affect regional politics are where hazards end up

TRI Facilities Relative to Neighborhood Demographics Aside from Race

Differences by Proximity:

	TRI Proximity		
	Less than 1 mile	*Between 1 mile and 2.5 miles*	*More than 2.5 miles away*
Percent persons in poverty	12%	9%	6%
Median per capita income	$19,702	$25,140	$34,187
Percent home owner	52%	57%	61%
Percent industrial, commercial and transportation land use	17%	9%	5%
Population density (persons per square mile)	9,202	10,107	9,748
Percent employed in manufacturing	19%	16%	12%
Percent recent immigrants (1980s and later)	26%	21%	15%

But It Isn't Just Income . . .



TRI Air Releases: Race, Income, and Land Use Together

Multivariate analysis of proximity to a TRI facility:

San Francisco 9-County Bay Area:
Probability of a Tract Being Located Within 1 *Mile* of an *Active TRI*
(Multivariate Logistical Model)

Model Variables	Coeff. Sign	Stat. Sig.	Coeff. Sign	Stat. Sig.
% owner occupied housing units	-	**	-	
ln(per capita income)	-	***	-	***
ln(population density)	-	**	-	**
% manufacturing employment	+	***	+	***
% African American	+	***	+	***
% Latino	+	***	+	**
% Asian/Pacific Islander	-		-	
% linguistically isolated households			+	*
	N = 1403		N = 1403	

* indicates significance at the .10 level;
** indicates significance at the .05 level;
*** indicates significance at the .01 level

What About Ambient Air Toxics?

- This category of pollutants come from a diverse array of sources
  - Stationary: large industrial facilities and smaller emitters, such as auto-body paint shops, chrome platers, etc.
  - Mobile: Cars, trucks, rail, aircraft, shipping, construction equipment

- Important because largest proportion of estimated cancer risk (70% in the Bay Area) is related to mobile emissions

U.S. EPA's National Air Toxics Assessment (NATA)

Gaussian dispersion model estimates long-term annual average outdoor concentrations by census tract for base year 1999.

Concentration estimates include:

- 177 air toxics (of 187 listed under the 1990 Clean Air Act)
- Diesel particulates

The model includes ambient concentration estimates from mobile and stationary emissions sources:

Manufacturing (point and area)

e.g., refineries, chrome plating

Non-Manufacturing (point and area)

e.g., utilities, hospitals, dry cleaners

Mobile (on road and off road)

e.g., cars, trucks, air craft, agricultural equipment

Modeled air pollutant concentration estimates allocated to tract centroids.

Estimating Cancer and Respiratory Risks Associated with Ambient Air Toxics Exposures

- Risk estimates are derived from NATA (described earlier) with risks and respiratory hazard ratio based on U.S. EPA and California Risk Guidelines for risk assessment
- Assumes exposures are chronic over a lifetime
- Risks are additive across pollutants
- An ecological study – study of risks associated with a place

Estimating Cancer Risk

Lifetime cancer risk calculated for each pollutant with toxicity information:

$$R_{ij} = C_{ij} * IUR_j$$

R_{ij} = individual lifetime cancer risk from pollutant j in census tract i.

C_{ij} = concentration of HAP j in *ug*/m^3 in census tract i.

IUR = Inhalation Unit Risk: cancer potency associated with continuous lifetime exposure to pollutant j in $(ug/m^3)^{-1}$

Risks summed across pollutants to derive estimate of cumulative lifetime cancer risk

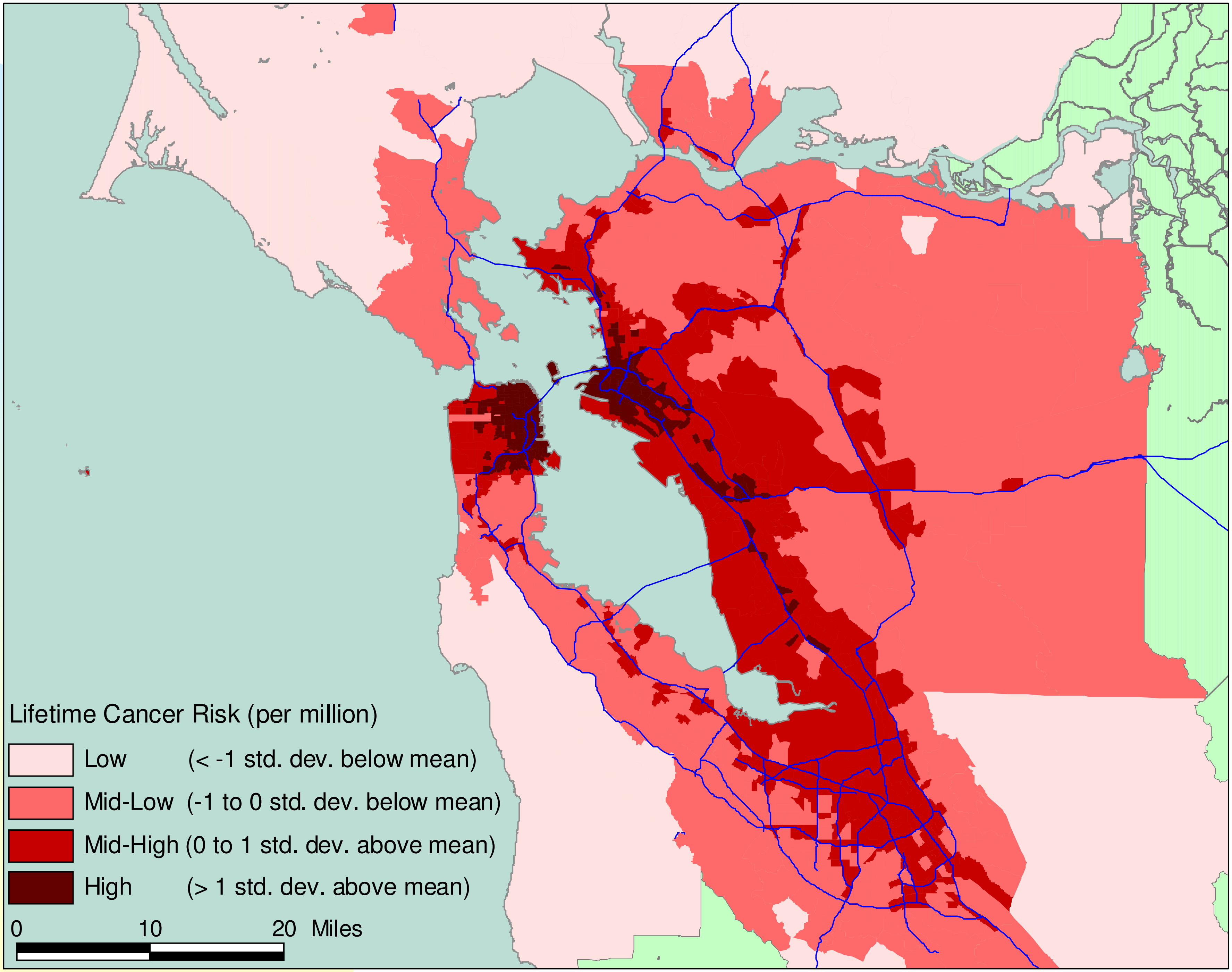
Assessing Respiratory Hazard

- Pollutant concentrations are divided by their corresponding Reference Concentration (RfC) to derive a hazard ratio

$$HR_{ij} = C_{ij}/RfC_j$$

- HR_{ij} = hazard ratio for pollutant j in tract i.
- C_{ij} is concentration of pollutant j (*ug*/m^3) in tract i.
- RfC_j is the regulatory benchmark for respiratory effects of pollutant j.
- Hazard ratios are summed across all pollutants to derive a cumulative respiratory hazard index

1999 NATA Estimated Cancer Risk (All Sources) by 2000 Census Tracts, 9-County Bay Area



What's the Pattern?

	Cancer risk			Respiratory Hazard		
	Least risk	*Middle range*	*Most risk*	*Lowest hazard ratio*	*Middle range*	*Highest Hazard ratio*
ercent Anglo	68%	48%	39%	66%	49%	33%
ercent African American	4%	7%	16%	5%	6%	16%
ercent Latino	17%	20%	17%	18%	19%	24%
ercent Asian Pacific Islander	7%	21%	24%	7%	22%	23%
ercent Other	4%	4%	4%	4%	4%	4%
ercent home owner	70%	61%	28%	71%	59%	34%
edian per capita income	$28,231	$28,187	$22,973	$27,137	$29,329	$20,487
ercent persons in poverty	7%	8%	15%	7%	8%	15%
opulation density ersons per square mile)	2,929	8,175	24,194	2,603	9,346	19,425
ercent industrial, commercial nd transportation land use	3%	8%	17%	4%	8%	20%
ercent recent immigrants 980s and later)	10%	21%	24%	10%	21%	26%

Race, Income, and Land Use Together . . .

San Francisco 9-County Bay Area:
Modeling Estimated Excess Cancer Risk and Respiratory Hazard
(Multivariate OLS Model)

	Cancer Risk				Respiratory Hazard			
Model variables	Coeff. Sign	Stat. Sig.	Coeff. Sign	Stat. Sig.	Coeff. Sign	Stat. Sig.	Coeff. Sign	Stat. Sig.
% owner occupied housing units	-	***	-	***	-	***	-	***
relative per capita income (tract/state)	+	***	+	***	+	***	+	***
relative per capita income squared	-	***	-	***	-	***	-	***
ln(population density)	+	***	+	***	+	***	+	***
% industrial/commercial/transportation land use	+	***	+	***	+	***	+	***
% African American	+	***	+	***	+	***	+	***
% Latino	+	***	+	**	+	***	+	***
% Asian/Pacific Islander	+	***	+	***	+	***	+	***
% linguistically isolated households			+	***			-	
* indicates significance at the .10 level; ** indicates significance at the .05 level; *** indicates significance at the .01 level	N = 1402		N = 1402		N = 1402		N = 1402	

What It Is . . . And What It Isn't

FAQ –Occasionally Given Responses . . .

- What not use monitored rather than modeled emissions?
  - Looking for hotspots versus looking for averages – and "coverage" is better
  - Is there systematic bias?
- What about other datasets?
  - ARB Aspen data – similar results
  - CARE data – coming attractions . . .
- What about mobile versus stationary sources?

What It Is . . . And What It Isn't

Caveats to Results

- Recognize that this is a "snapshot" – albeit multivariate of the region. The results do not imply causality but describe the pattern.
- In particular, this is not time series data and so provide little insight into move-in versus siting dynamics (although still relevant to health disparities).
- Better land use data would improve accuracy and be useful for policy.
- Technical asides:
  - Collinearity is a challenge for some variables, particularly linguistic isolation
  - No controls for spatial autocorrelation; this would likely weaken results although past analysis (and strength of t-scores) suggests not to insignificance.

Environmental Justice and Health Outcomes

- Influence of environmental justice framework on environmental health science and regulation
  - Cumulative impact
  - Community & individual vulnerability/resilience
- Synergies between these factors that shape environmental health disparities
  - Segregation as a case study of area-level inequality in pollutant exposures
  - Birth outcomes as potential area for examining synergies between stressors and pollution exposures

Areas of Scientific Contention in Environmental Justice

EJ advocates have pushed researchers and regulators to operationalize the dynamics of:

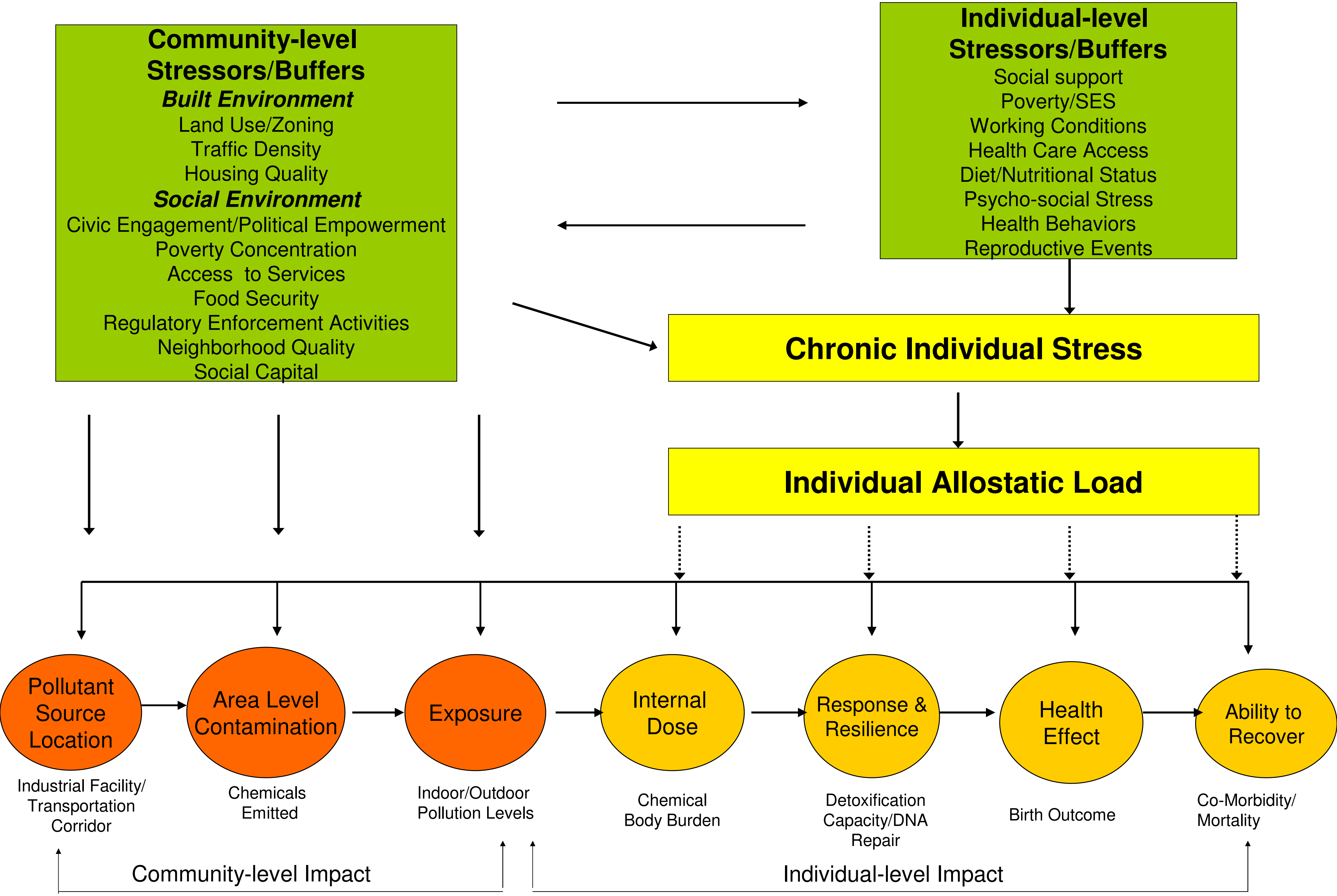
- ***Cumulative impact*** from multiple environmental hazards exposures faced by communities of color and the poor where they live, work, and play.
- ***Community vulnerability*** to the adverse health effects of pollutants due to simultaneous exposures to psycho-social and physical stressors
  - (e.g. poverty, material deprivation, malnutrition, discrimination)

Regulatory agency response:

- California Environmental Protection Agency Environmental Justice Action Plan
- U.S. EPA Framework for Cumulative Risk Assessment
  - DeFur et al. (2007) Vulnerability as a Function of Individual and Group Resources in Cumulative Risk Assessment, *Environmental Health Perspectives* 115(5)

How Community and Individual Stressors/Buffers Combine to Shape Exposures and Susceptibility to Environmental Hazards

(Morello-Frosch & Shenassa, EHP, 2006)

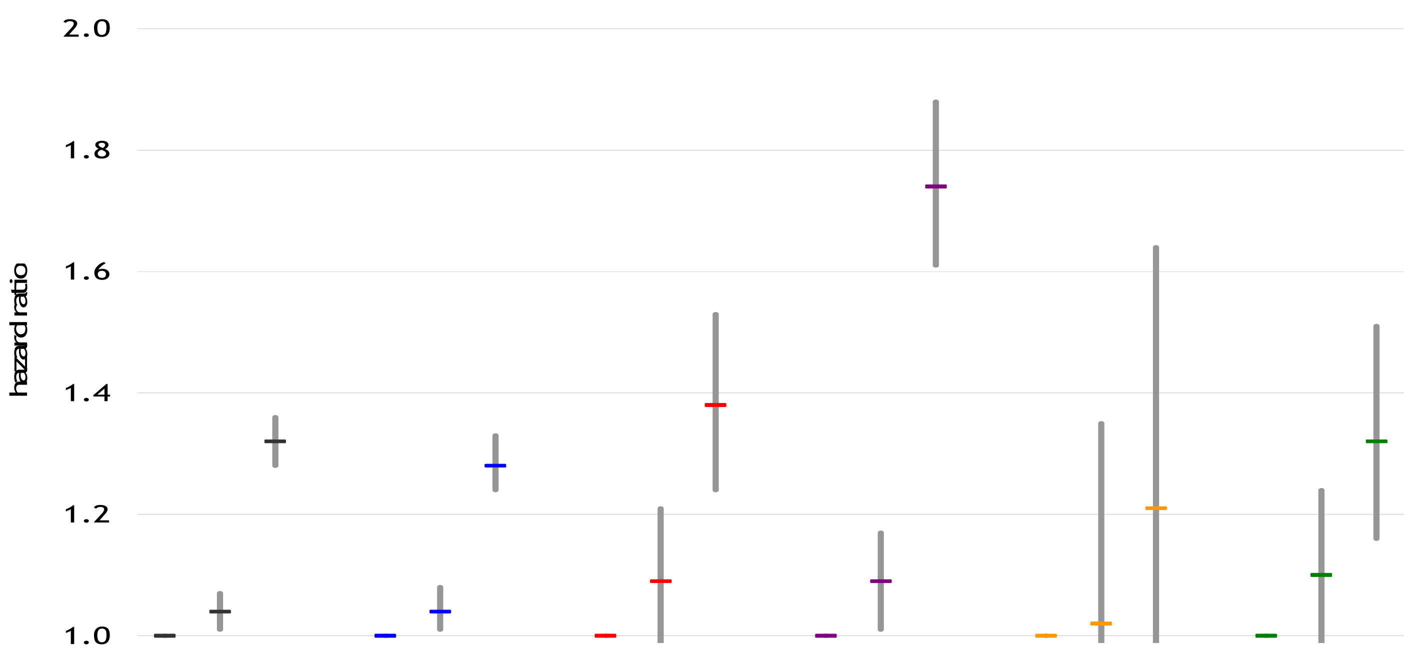


Relative estimated lifetime cancer incidence associated with ambient air toxics continental United States metropolitan areas (adjusted model)

model adjusted for state regional grouping; metropolitan area population size; county voter turnout; census tract population density, poverty rate, and material deprivation

	highly segregated		extremely segregated	
	hazard ratio	95% conf. interval	hazard ratio	95% conf. interval
total population	1.04	(1.01 - 1.07)	1.32	(1.28 - 1.36)
non-Hispanic Whites	1.04	(1.01 - 1.08)	1.28	(1.24 - 1.33)
non-Hispanic Blacks	1.09	(0.98 - 1.21)	1.38	(1.24 - 1.53)
Hispanics (all races)	1.09	(1.01 - 1.17)	1.74	(1.61 - 1.88)
non-Hispanic American Indians & Alaska Natives	1.02	(0.77 - 1.35)	1.21	(0.90 - 1.64)
non-Hispanic Asians & Pacific Islanders	1.10	(0.97 - 1.24)	1.32	(1.16 - 1.51)

***Risk Ratios use low segregation as reference group**



Individual and area-level drivers of environmental health inequalities – birth outcomes and air pollution (course PM)

Mural Photo: R. Morello-Frosch

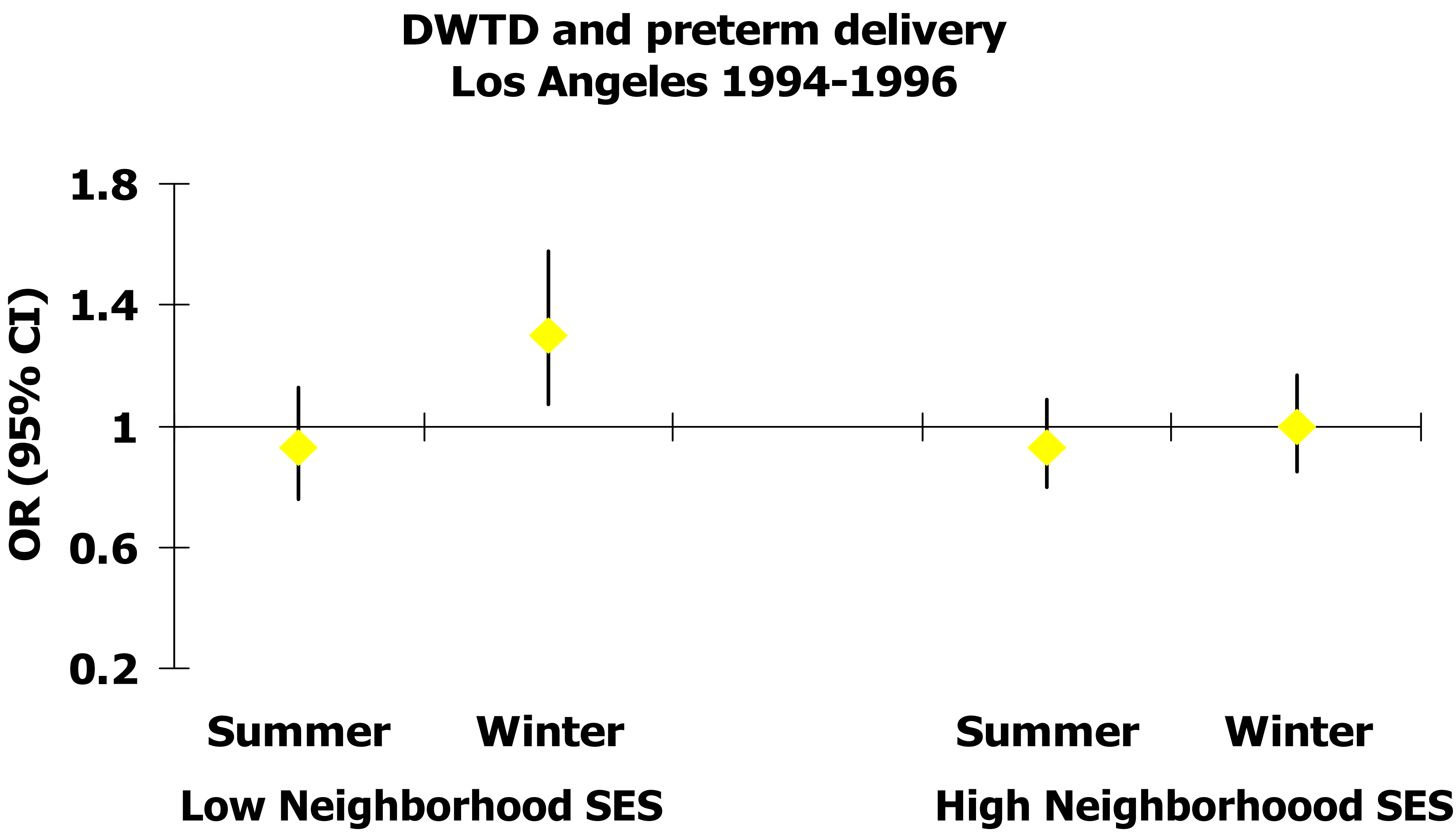
Individual stressors can:

- Affect birth outcomes directly *(well studied)*
  - e.g., health behaviors, inter-pregnancy interval, access to adequate health care, poverty, discrimination (using race as a crude proxy)
- Enhance individual susceptibility to the toxic effects of pollutants *(not extensively studied)*
  - Bell et al., *EHP*, 2007: effect modification by race for association between $PM_{2.5}$ and decrease in birth weight among black versus white mothers

Place-based stressors can:

- Affect birth outcomes directly *(fairly well studied)*
  - e.g. neighborhood poverty, material deprivation, income inequality, and segregation
- Enhance susceptibility to the toxic effects of pollutants *(not extensively studied)*
  - Ponce et al., *EHP*, 2005: effect modification with neighborhood disadvantage for association between traffic density and risk of pre-term birth during winter season

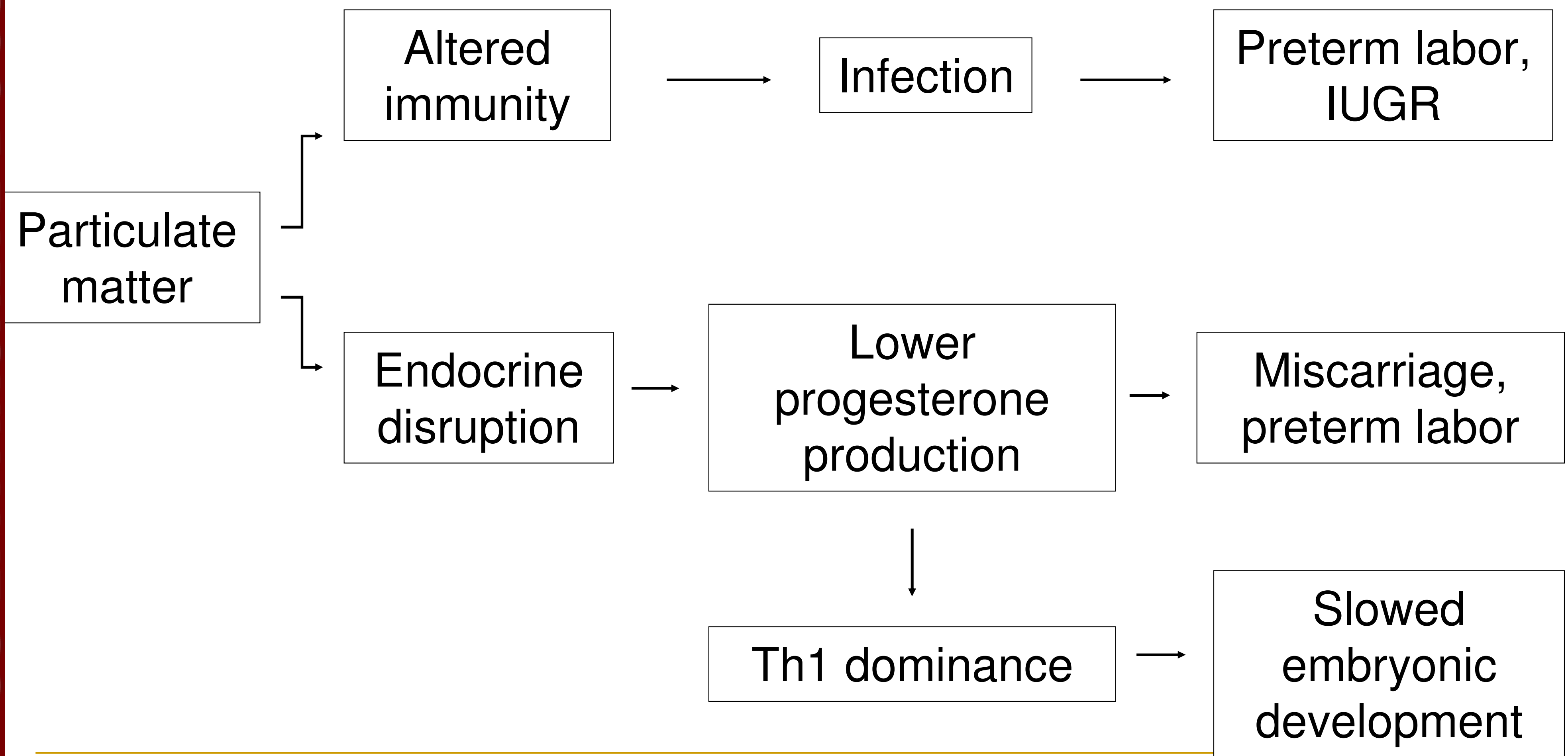
Effect modification: Ponce et al EHP (2005)



Relationship between PM_{course} and birth weight

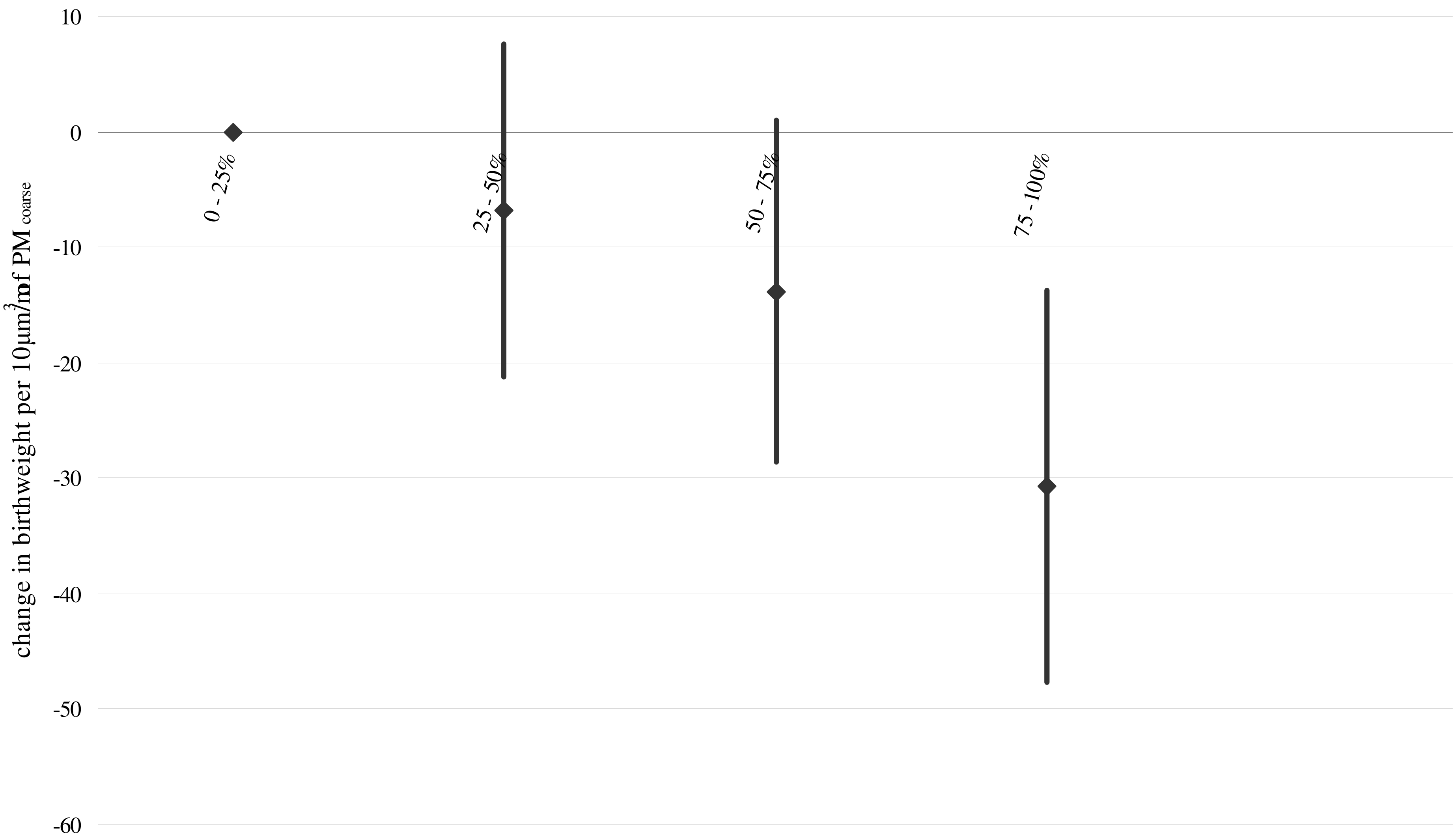
- California Births from 1996-2003
- Air pollution estimates for each live birth in the dataset, according to the mother's residence at the time of birth within 2 kilometers of a CalAIRS monitor
- Developed single and multiple pollutant models to assess air pollution effects on birth weight
- Used individual and area-level SES measures to examine confounding and effect modification

Possible Biological Mechanisms - PM



Ritz, ISEE 2007

Change in birthweight, per 10 µg/m^3 of coarse particulate matter, assessed within 2km, by quartiles of exposure



Change in birthweight, per 10 µg/m^3 increase in coarse particulate matter

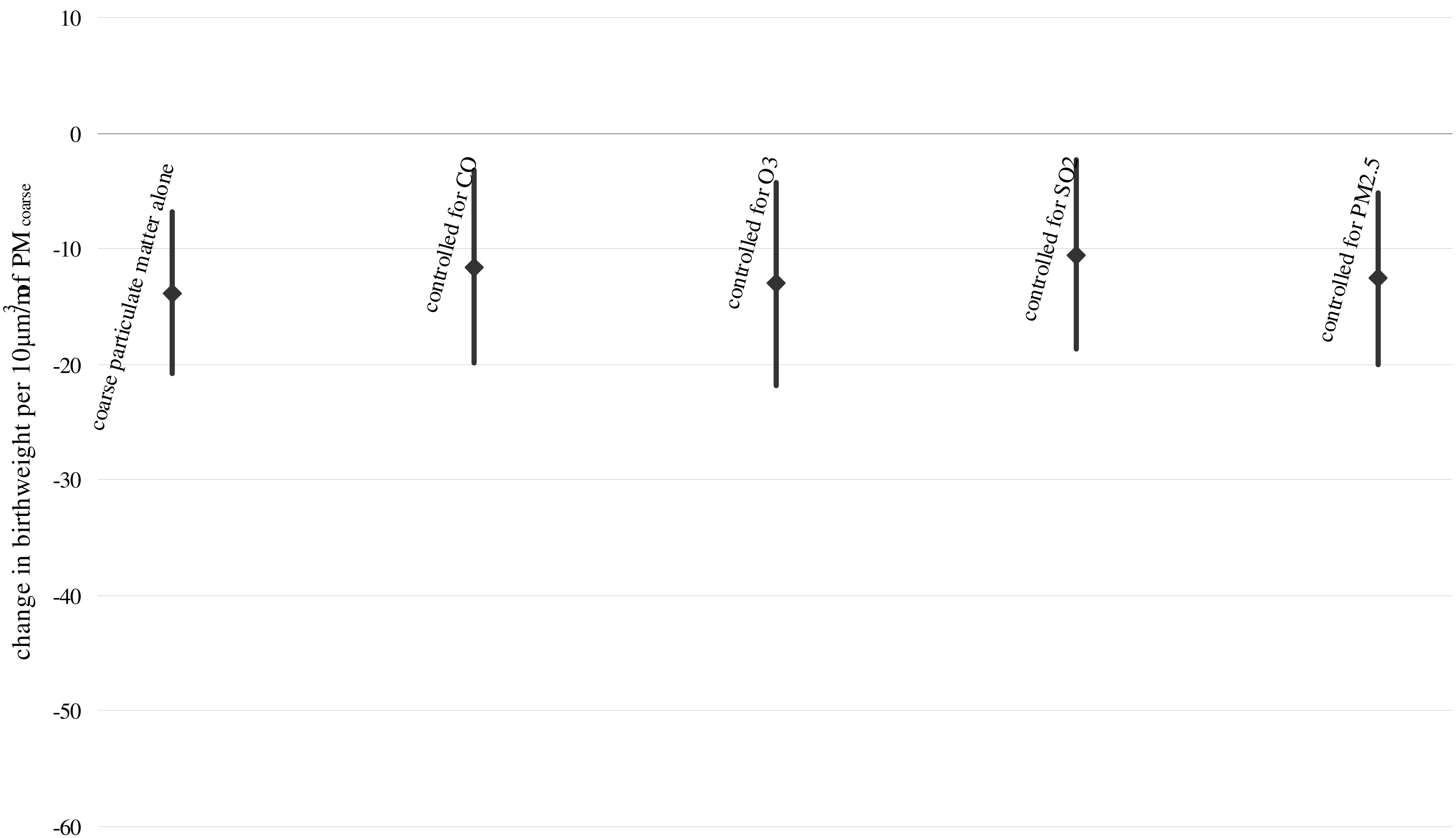
(within 2km distance of monitor)

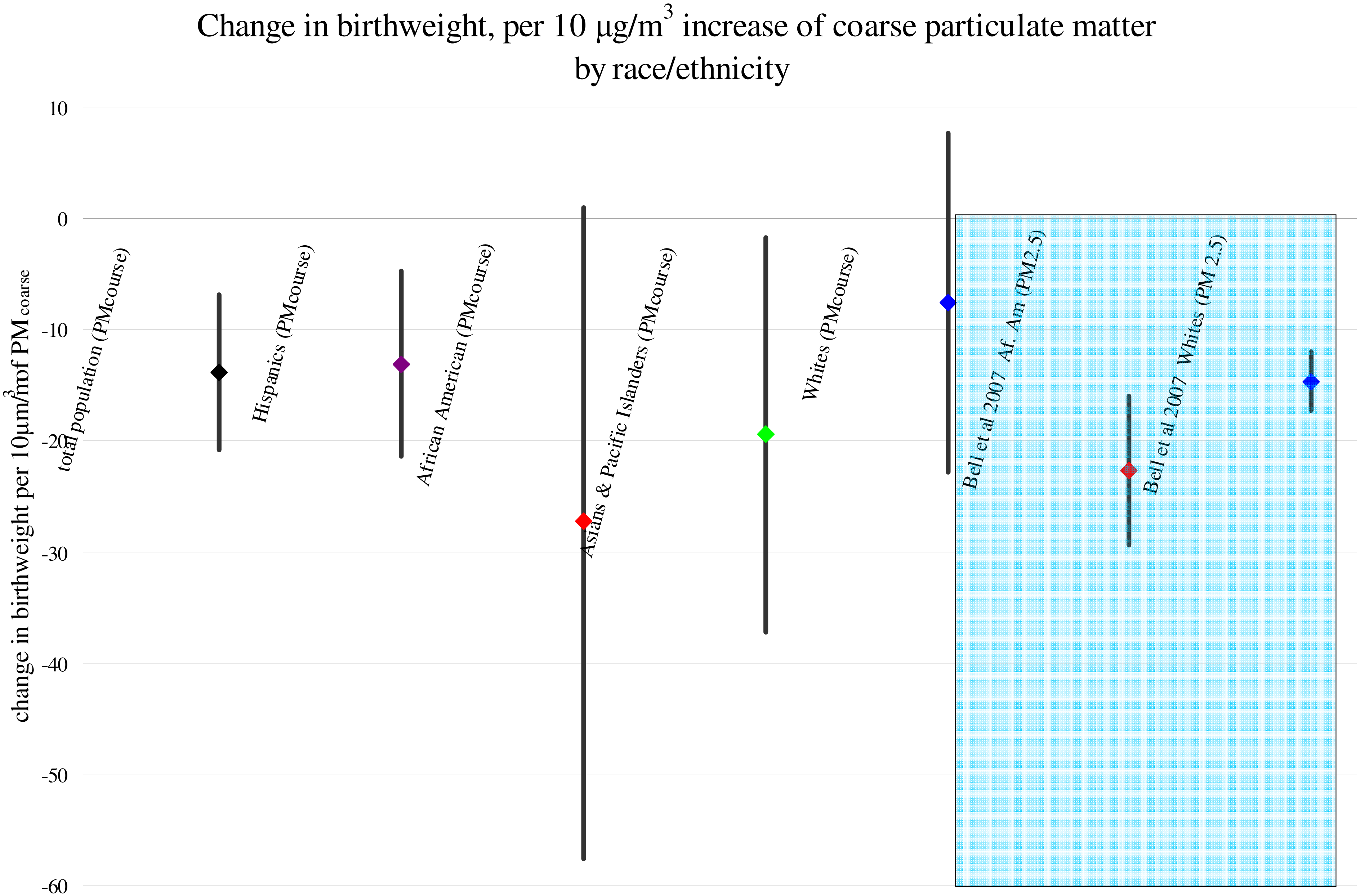
Individual factors = maternal race, marital status, education, age, parity, gestational age, infant sex, prenatal care, pregnancy risk factors, season and year of birth.

Neighborhood factors = unemployment, education, poverty, home ownership

N= 2,579,123 births

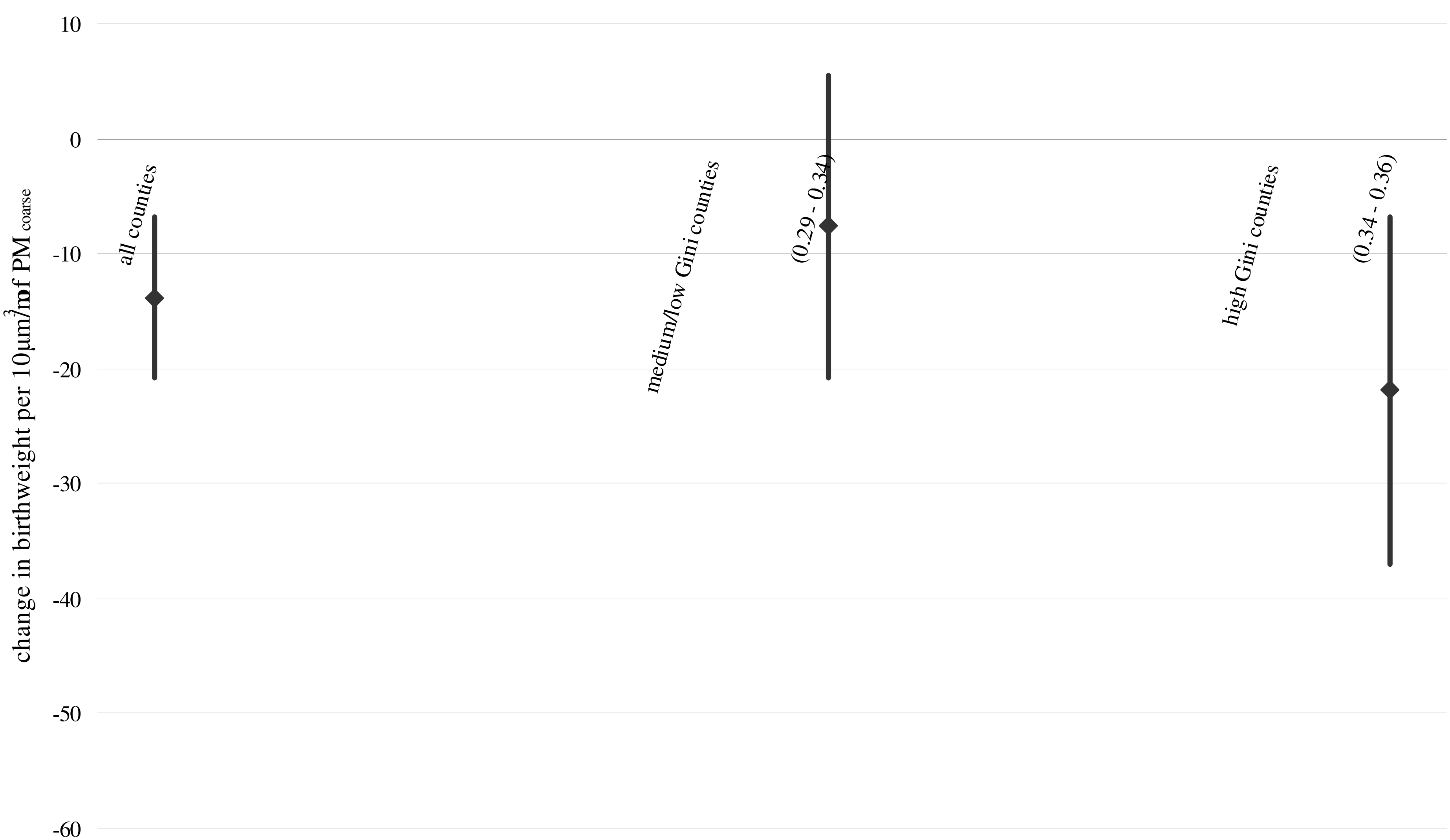
Change in birthweight, per 10 µg/m^3 of coarse particulate matter, assessed within 2km, controlled for other pollutants





Change in birthweight, per 10 μg/m3 increase of coarse particulate matter by race/ethnicity
10
0
-10
-20
-30
-40
-50
-60
change in birthweight per 10μm/m3 of PM coarse
total population (PMcourse)
Hispanics (PMcourse)
African American (PMcourse)
Asians & Pacific Islanders (PMcourse)
Whites (PMcourse)
Bell et al 2007 Af. Am (PM2.5)
Bell et al 2007 Whites (PM 2.5)

Change in birthweight, per 10 $\mu g/m^3$ of coarse particulate matter, by county income inequality



Implications for future work

- Evidence suggests spatial forms of social inequality are associated with:
  - Worse environmental quality across demographic lines
  - Increased racial inequalities in pollution burdens
- Indicators of social inequality and discrimination may modify pollution/health outcome relationships

Methodological questions to consider:

- When to use individual versus area – level measures of SES, discrimination, poverty, etc.
  - Indicators for institutional processes or surrogates for individual measures for which we do not have data?
- How to integrate area – level measures of social inequality, into health outcome studies
  - Effect modification versus confounding

Implications (cont.)

Macro-level Questions :

- Development of policy-relevant surrogates for exposure measures in health outcome studies?
  - E.g. traffic data as a surrogate for pollution exposure
- Examine different geographic scales that may be more relevant for regulation and policy?
  - E.g. zoning and facility siting decisions affect pollution stream distributions among diverse communities and tend to operate regionally
  - Intervention points would focus on -- land use planning, industrial and transportation development

What Is To Be Done?

Four Principles for Policy

- Consider *cumulative impacts* – regulate not facility by facility but in a holistic manner that take community as the basic unit
- Take into account *social vulnerability* – make the highest priority communities with both high risk and the least resources for health care
- Promote *meaningful community participation* – involve people at relevant points, provide information in appropriate languages and in non-technical speak
- Take *meaningful action* – precaution dictates that we need not wait for unequivocal proof to act in ways consistent with preventative health measures