Separate And Unequal:

The relationship between residential segregation, air toxics and associated cancer risks

Photos: David Woo, Dallas Morning News & GreenAction

Overview

- Previous EJ work and methodological approaches
- Understanding segregation and how it's measured
- Conceptual Framework
- Materials & Methods
  - Segregation
  - National Air Toxics Assessment
- Results
- Limitations
- Implications for research and policy

Air Toxics and Segregation in CA: Background

- Racial/ethnic and income disparities in exposure to air pollutants is well documented
- Few environmental justice studies have elucidated pathways that *explain* how social context shapes these disparities in environmental hazard exposures
- In this study, we examine links between social inequality—in particular, residential segregation—with estimated cancer risks from ambient air pollutants

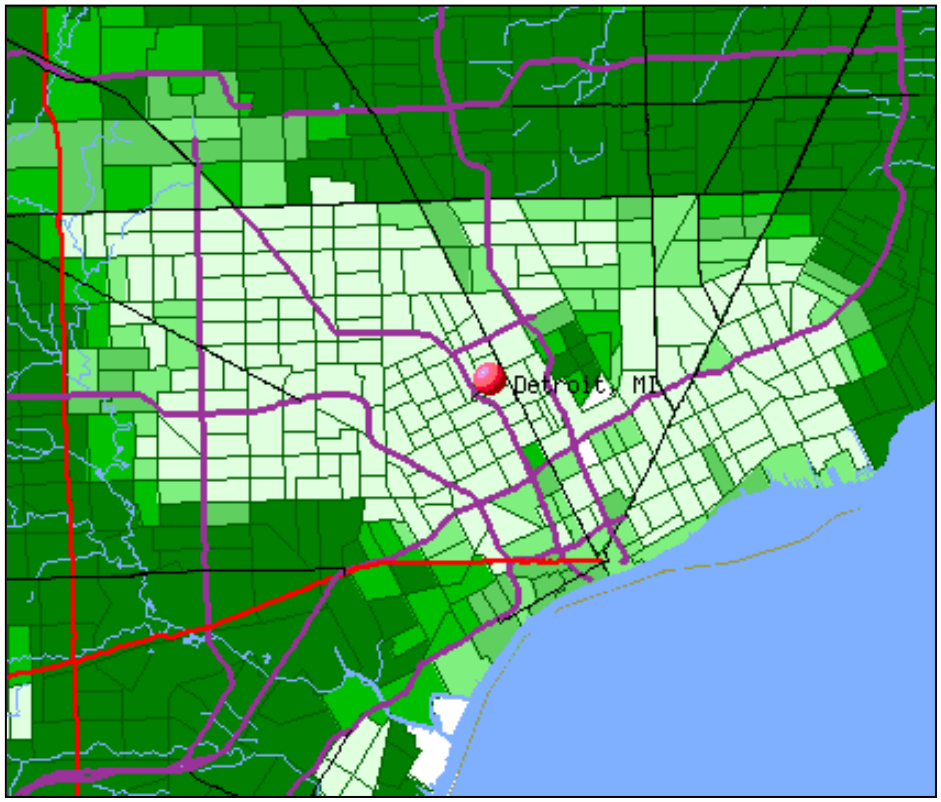
Basics of Segregation

- Describes spatial separation of people by race and (less often) by class
- Concentrates poverty and other psycho-social stressors
- Applies to various contexts
  - Residential
  - Occupational
  - Educational
- Measurement
  - Used to characterize racial inequality within a metro area or region
  - Often focuses on dyadic comparisons (e.g. Black v. White)
  - Can also be considered in context of racial diversity

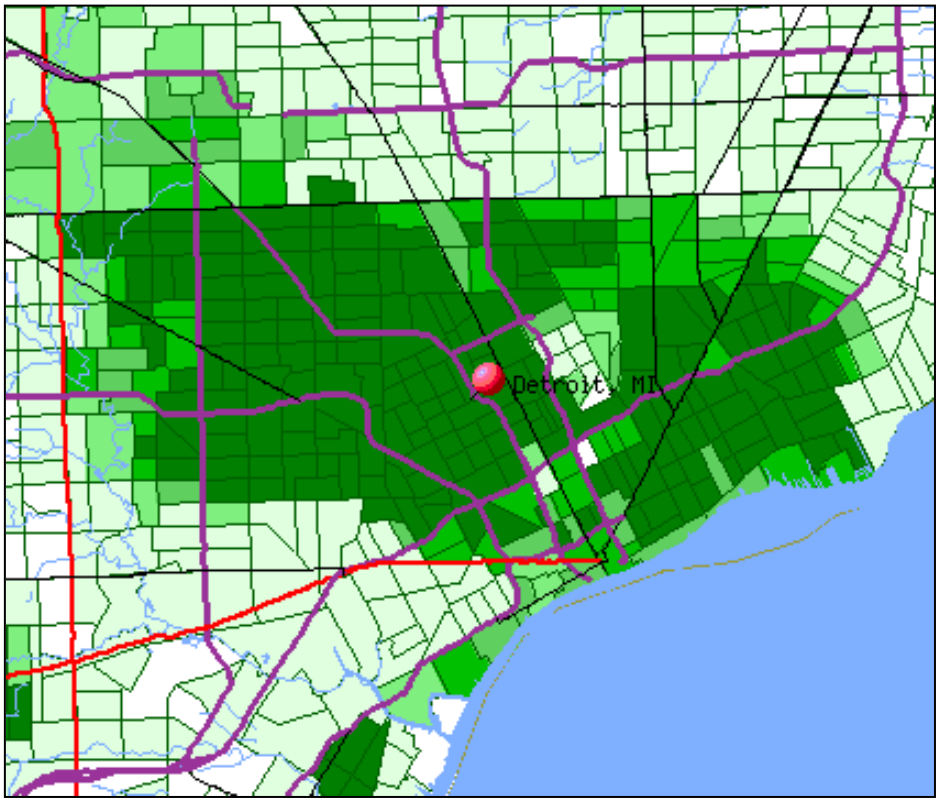
Examining Links Between Segregation, Environmental Inequality

- Health literature points to persistent association between segregation and mortality/morbidity
- Suggests spatially-mediated power distributions across racial and economic lines
- This may shape disparities in pollutant exposures across demographic groups.
- Spatially-mediated differences in environmental regulation and land use policy may impact community environmental health.

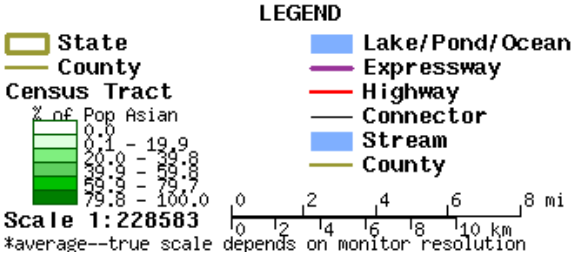
2. Race and Residence: Whites & African Americans, Detroit, MI, 1990



Whites

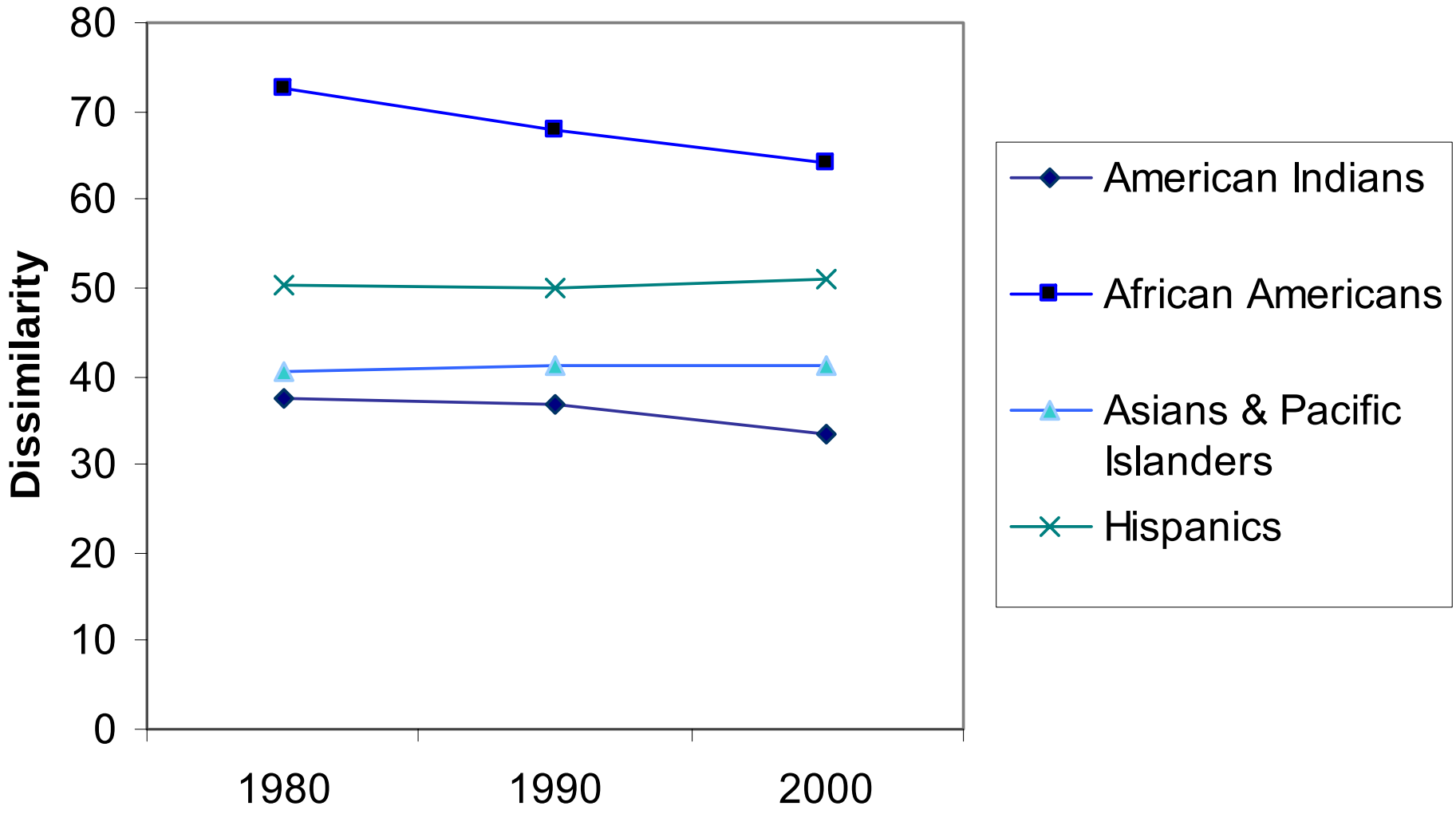


African Americans



Source: Gilbert Gee, University of Michigan

Dissimilarity of Ethnic Minorities to Whites, United States 1980-2000



Source: Gilbert Gee, University of Michigan

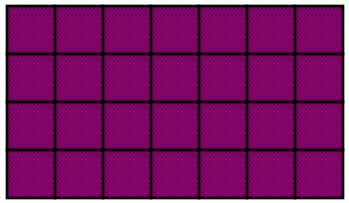
Segregation and Environmental Health Inequality

- Segregation and mortality/morbidity
  - Adult and infant mortality
  - Tuberculosis
  - Exposure to violence & homicide
- Segregation and environmental health disparities
  - Disparities in exposure
    - Hazardous waste
    - Air pollution
  - Regulatory and land use inequities
    - Unequal enforcement
    - Locally unwanted land uses
  - Concentration of stressors that enhance individual and community vulnerability to environmental hazard exposures.
    - Food Insecurity (lack of commercial markets)
    - Lack of access to health care and other services

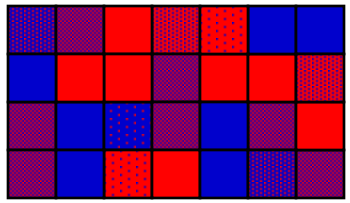
Dimensions of Segregation

- Uneveness
  - Most common measure
  - Dissimilarity Index

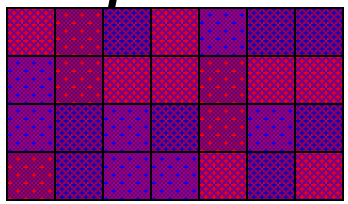
even



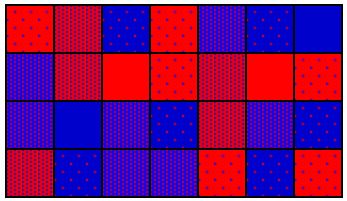
uneven



exposed



isolated



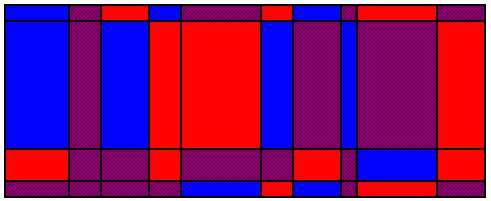
- Isolation / Exposure
  - Probability of "interaction"

  with same or majority racial group
  - Good measure of segregation experience

- *Neighborhood racial composition*
  - *often used as (inappropriate) surrogate*

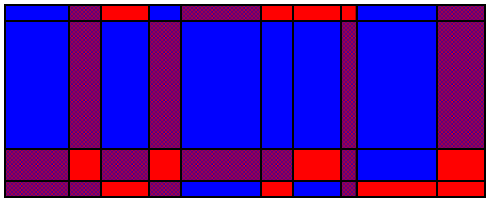
"Spatial" Dimensions of Segregation

- **Concentration-** density of racial group in metro area

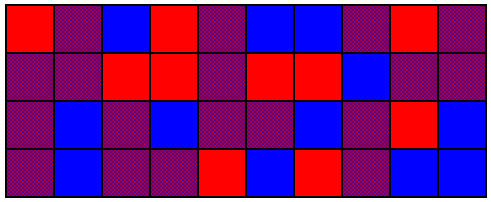


Dispersed

Concentrated

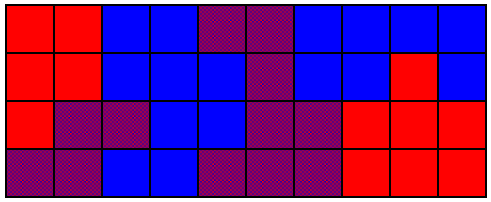


- **Clustering** – are racial groups in "ethnic enclaves?'

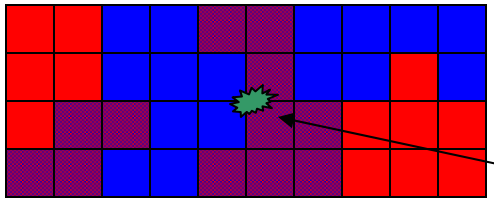


Not Clustered

Clustered

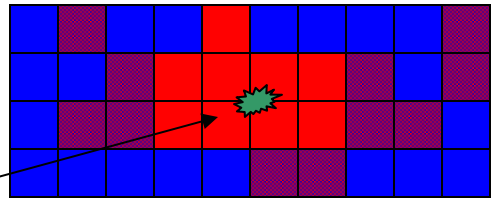


- **Centralization** – are racial groups in city centers?



Not Centralized

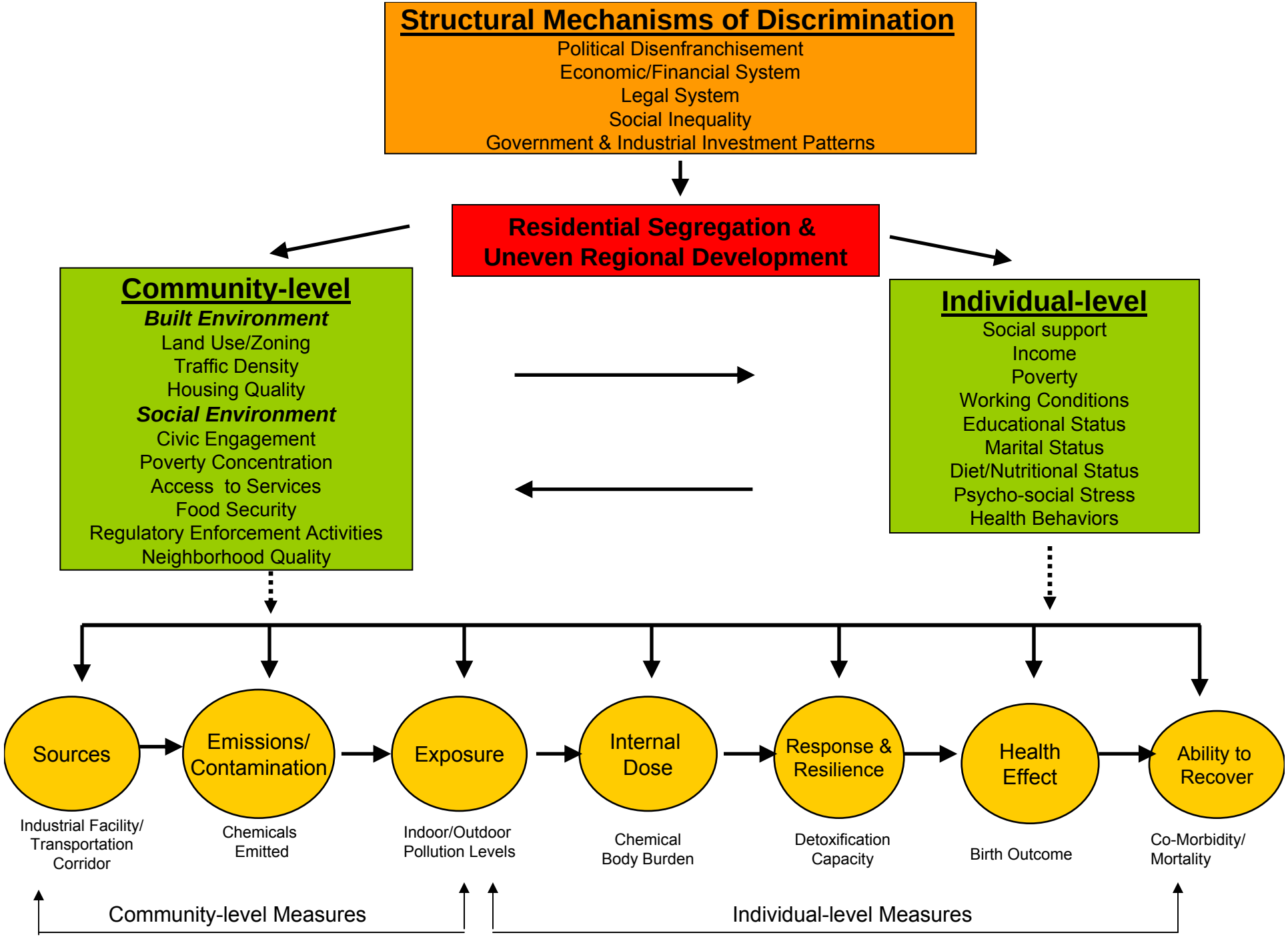
Centralized



Central Business District

Segregation and Environmental Justice

- Highlights links between segregation and political economy of environmental health by asking:
  - How do legacies of discrimination shape current spatial distributions of pollution sources among diverse communities?
  - Are observed pollution – health outcome relationships mediated by segregation?
  - Do segregation patterns affect diverse communities differently?
- Promotes a regional perspective for assessing dynamics of environmental health disparities:
  - Decisions about economic development, land use, transportation planning, and industrial clusters tend to be regional in nature
  - Zoning, siting, and urban planning decisions also tend to be more local


Structural Mechanisms of Discrimination
Political Disenfranchisement
Economic/Financial System
Legal System
Social Inequality
Government & Industrial Investment Patterns
Residential Segregation & Uneven Regional Development
Community-level
Built Environment
Land Use/Zoning
Traffic Density
Housing Quality
Social Environment
Civic Engagement
Poverty Concentration
Access to Services
Food Security
Regulatory Enforcement Activities
Neighborhood Quality
Individual-level
Social support
Income
Poverty
Working Conditions
Educational Status
Marital Status
Diet/Nutritional Status
Psycho-social Stress
Health Behaviors
Sources
Emissions/ Contamination
Exposure
Internal Dose
Response & Resilience
Health Effect
Ability to Recover
Industrial Facility/ Transportation Corridor
Chemicals Emitted
Indoor/Outdoor Pollution Levels
Chemical Body Burden
Detoxification Capacity
Birth Outcome
Co-Morbidity/ Mortality
Community-level Measures
Individual-level Measures

Segregation Measure: Generalized Index of Dissimilarity

Extent of segregation across several demographic groups within a metropolitan statistical area (MSA).

$$D_m = \frac{\frac{1}{2} \sum_i \sum_j \left| N_{ij} - E_{ij} \right|}{N \sum_j P_j (1 - P_j)}$$

- D_m = multi-racial index of dissimilarity.
- N_{ij} = number of people in racial/ethnic subgroup j in census tract i.

  - racial/ethnic subgroups: White, African American, Latino, Asian, Native American.

- E_{ij} = expected number of people in subgroup j in census tract i, under the assumption of no segregation ($N_i * N_j / N$).
- P_j = proportion of people in subgroup j in the whole MSA population (N_j / N).

Dissimilarity Index Cont.

$$D_m = \frac{\frac{1}{2} \sum_i \sum_j |N_{ij} - E_{ij}|}{N \sum_j P_j (1 - P_j)}$$

Numerator = number of people who would have to move from one census tract to another to attain racial/ethnic balance in every census tract within an MSA.

Denominator = maximum possible value of the numerator if each racial/ethnic group were completely segregated from one another in separate neighborhoods.

Index varies from 0 (no segregation) to 1 (completely segregated).

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

Gaussian dispersion modeling estimates long-term annual average outdoor concentrations for 1996 of 36 air toxics and diesel particulates for each census tract.

The model includes mobile and stationary emissions sources:

Manufacturing (point and area)

e.g., refineries, small fabricators, chemical manufacturers

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

Air pollutant concentration estimates allocated to census tract centroids.

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.

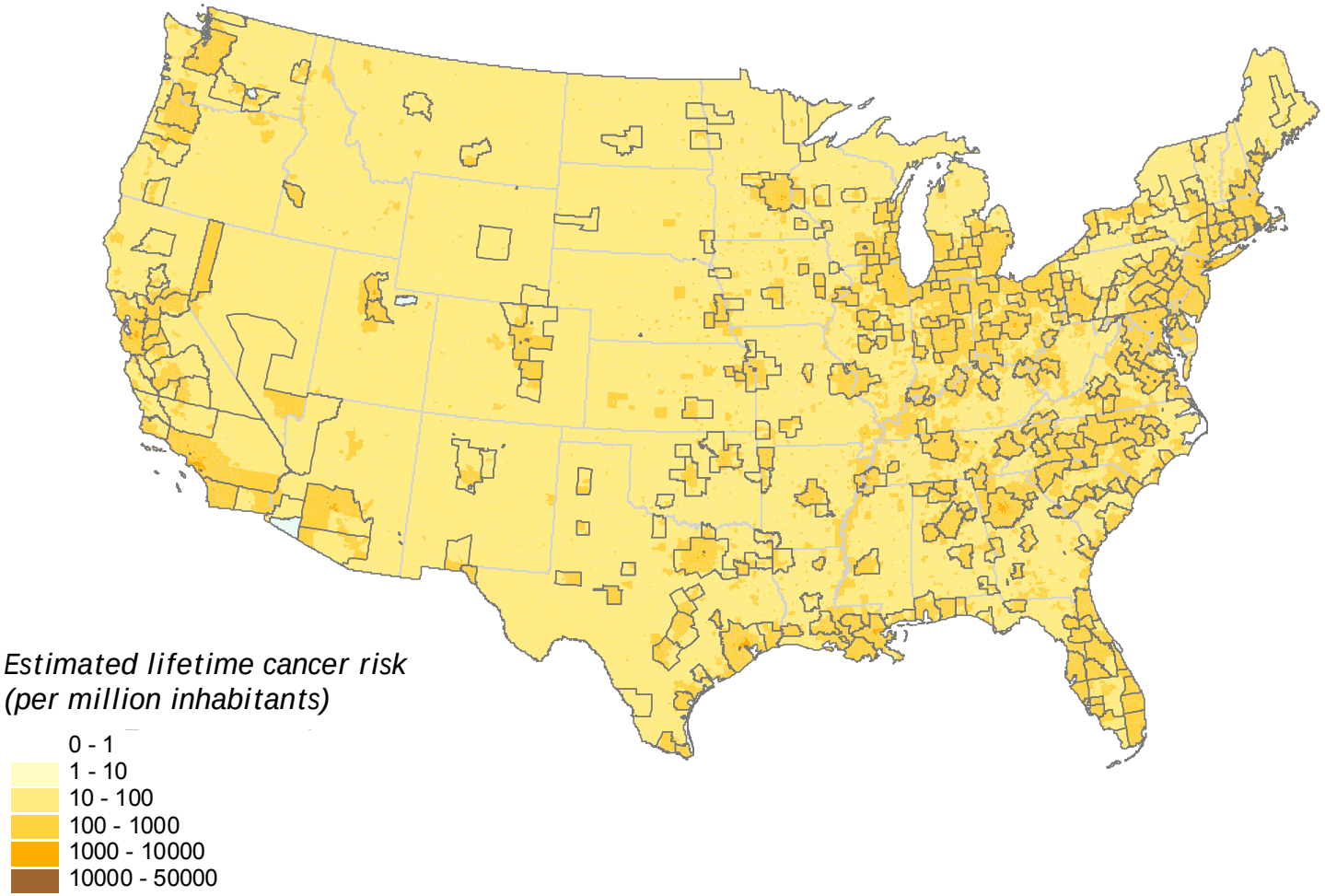
IUR = Inhalation Unit Risk: cancer potency associated with continuous lifetime exposure to pollutant j in $(ug/m^3)^{-1}$

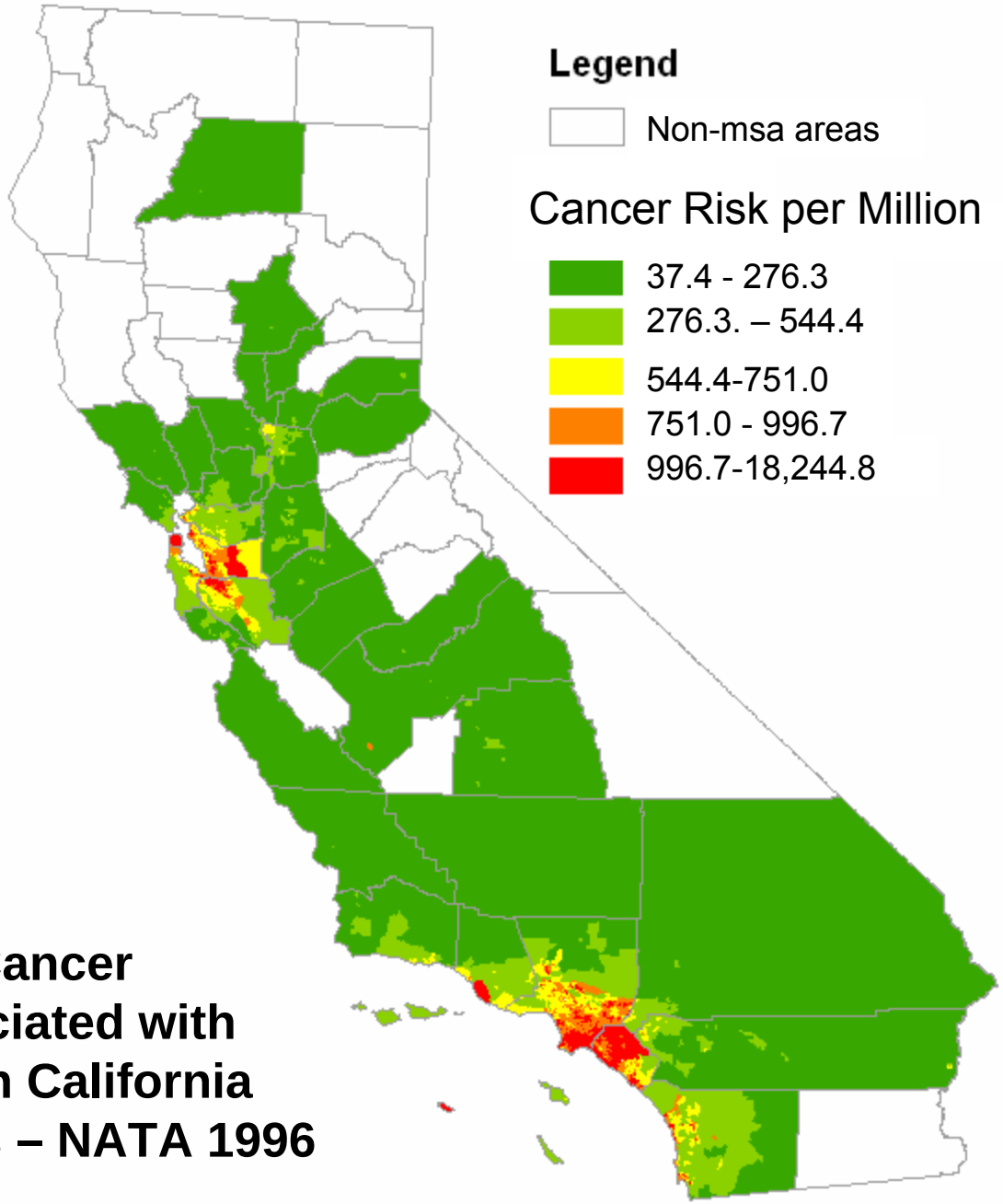
- Risks summed across pollutants

Key Science Policy Assumptions

- Methods based on U.S. EPA's and California's Risk Guidelines for carcinogenic risk assessment
- Air toxics classified by US EPA as known, probable or possible human carcinogens were evaluated
- Cancer potency information for pollutants compiled by US-EPA and Cal-EPA
- Assumes exposures are chronic over a lifetime
- Cancer risks are additive across pollutants

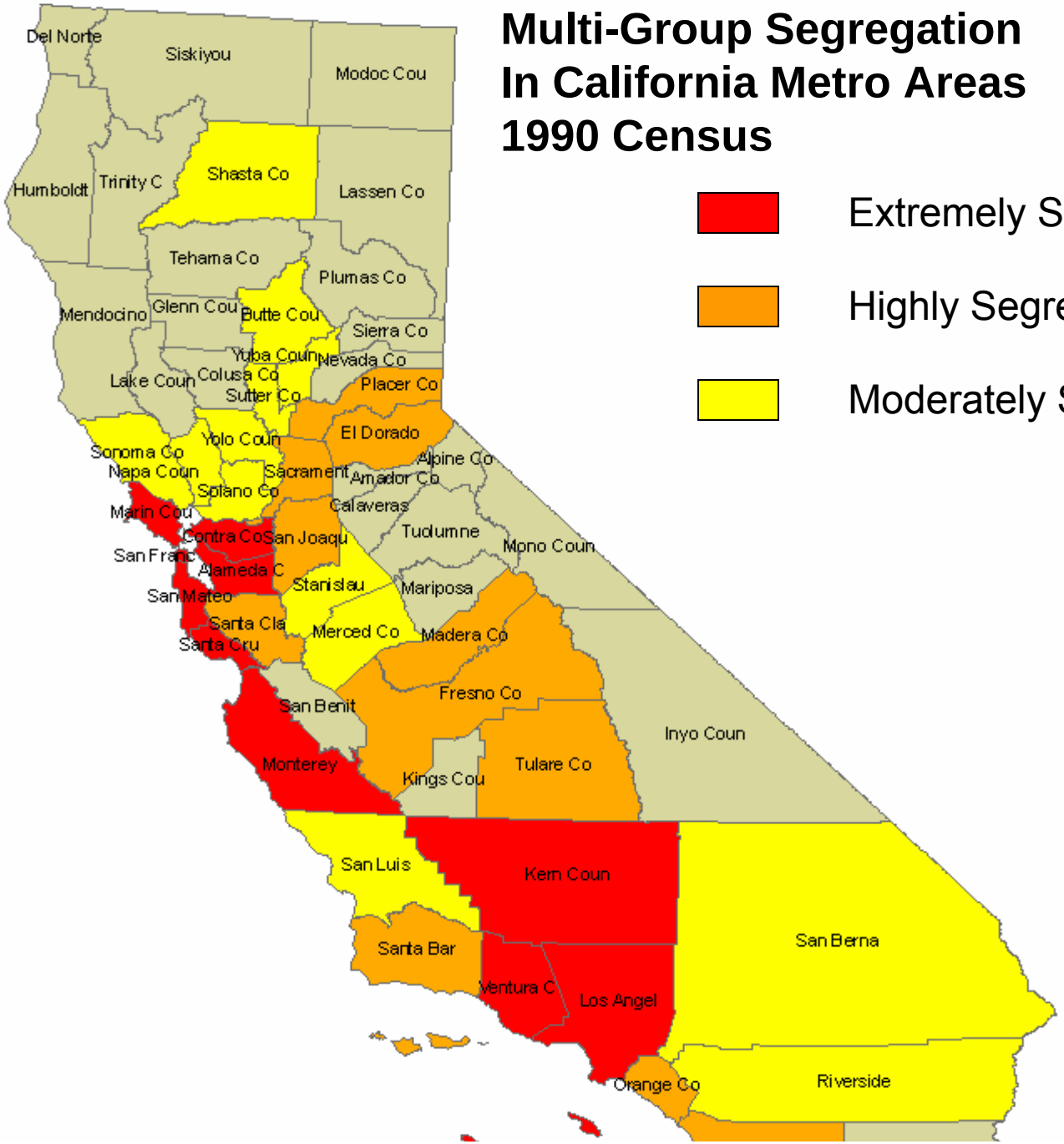
cancer risk-weighted air toxics exposures (all sources), metropolitan statistical areas of the continental United States





Estimated Cancer Risks Associated with Air Toxics in California Metro Areas – NATA 1996

Multi-Group Segregation In California Metro Areas 1990 Census



Extremely Segregated

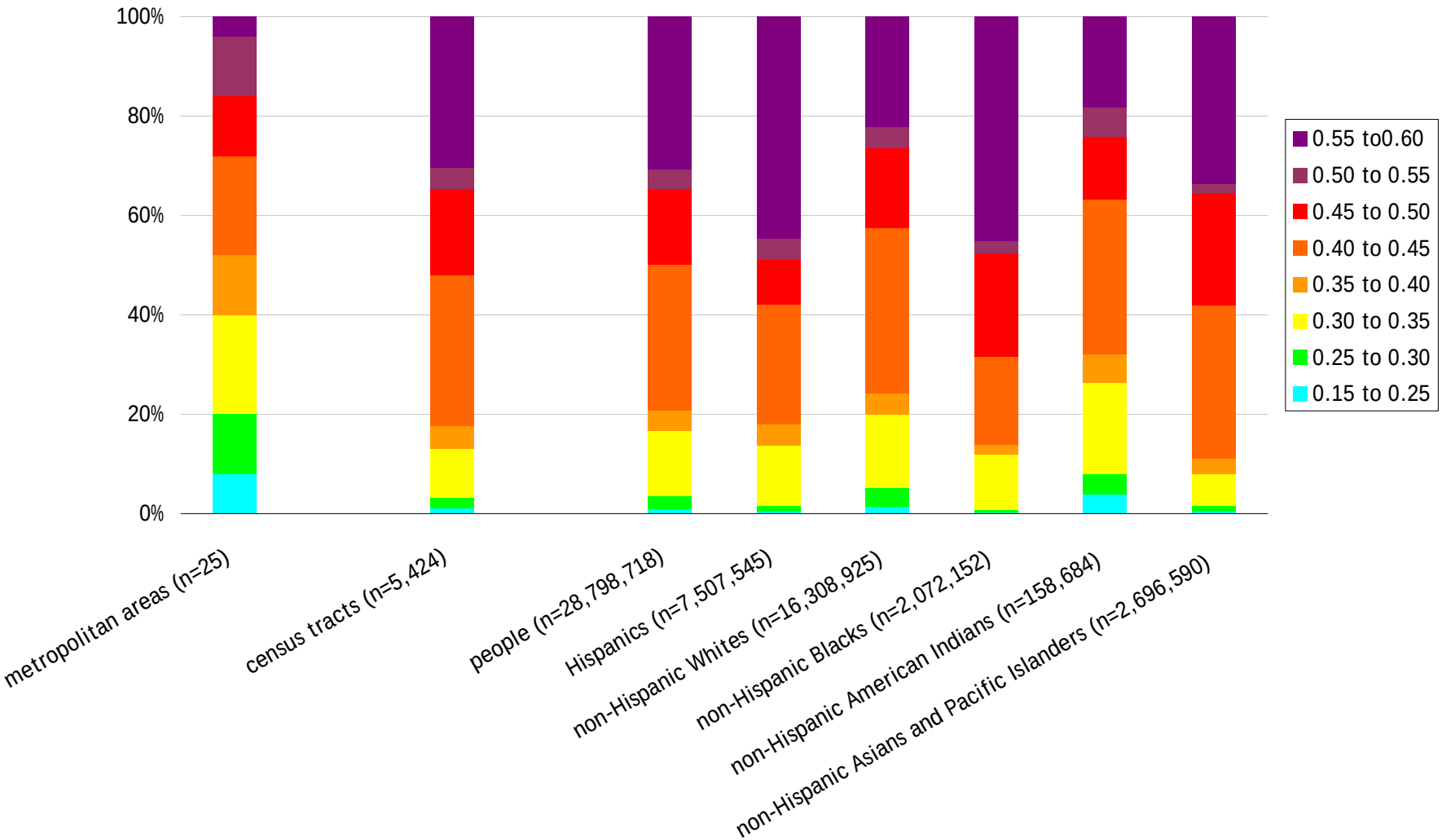
Highly Segregated

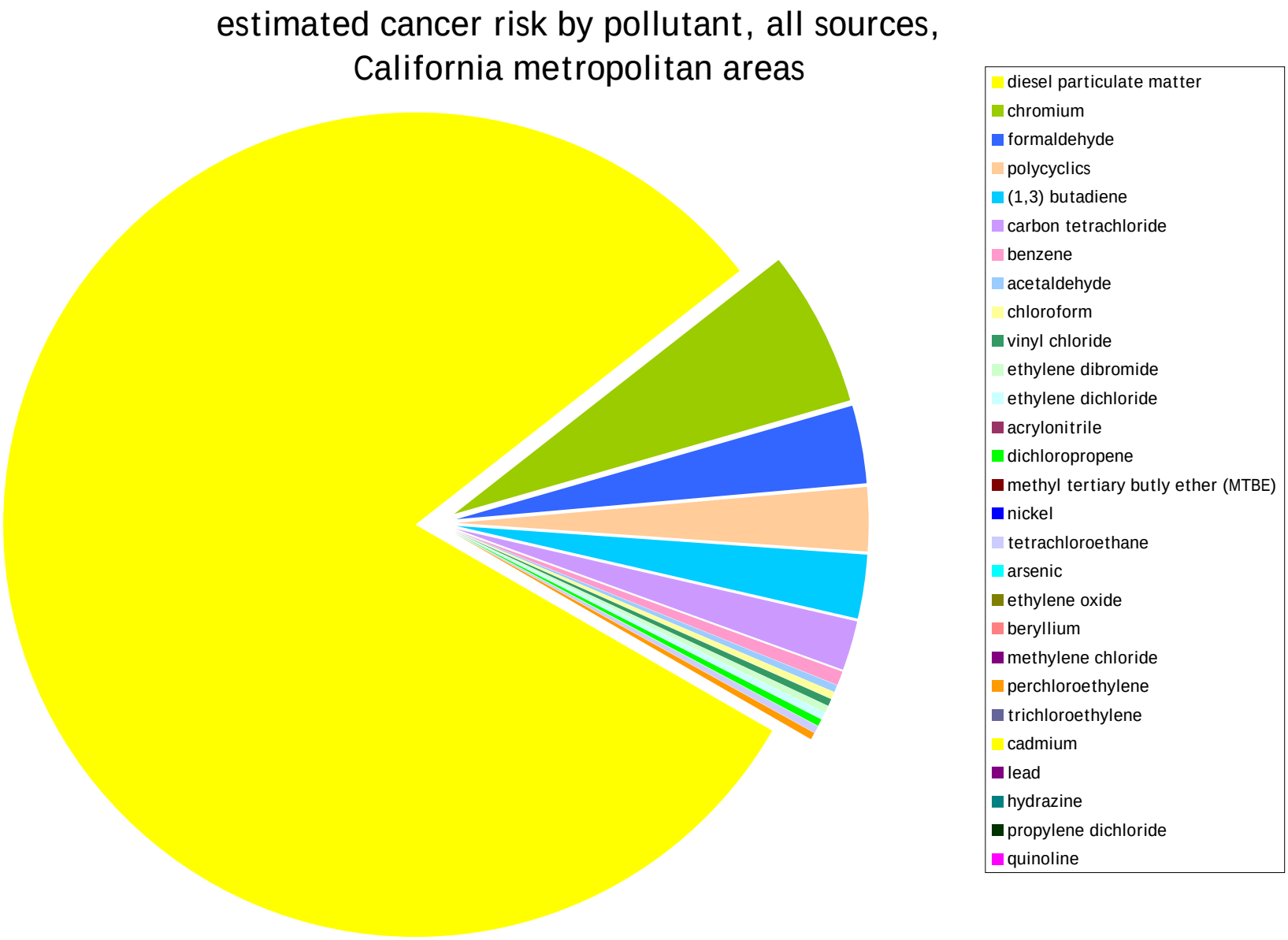
Moderately Segregated

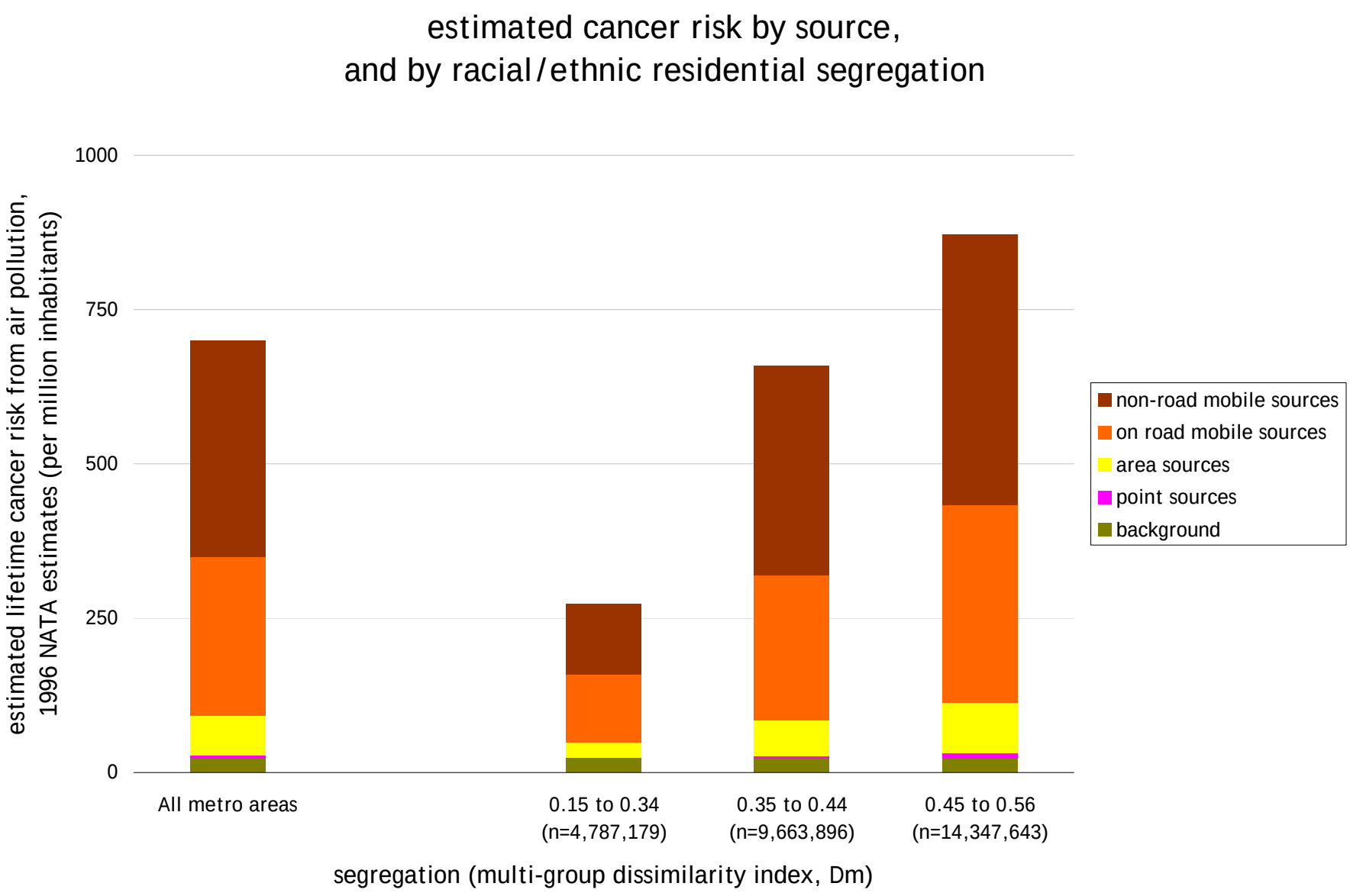
Breakdown of Counties by Segregation Level

Metro Area	Dm	Counties	
Redding	16%	Shasta	moderately segregated
Yuba City	24%	Sutter, Yuba	
Santa Rosa	26%	Sonoma	
Yolo	29%	Yolo	
San Luis Obispo-Atascadero-Paso Robles	29%	San Luis Obispo	
Merced	31%	Merced	
Vallejo-Fairfield-Napa	32%	Napa, Solano	
Chico-Paradise	32%	Butte	
Modesto	33%	Stanislaus	
Riverside-San Bernardino	35%	Riverside, San Bernardino	
Stockton-Lodi	38%	San Joaquin	highly segregated
Visalia-Tulare-Porterville	38%	Tulare	
Santa Barbara-Santa Maria-Lompoc	39%	Santa Barbara	
San Jose	41%	Santa Clara	
Sacramento	42%	El Dorado, Placer, Sacramento	
San Diego	44%	San Diego	
Fresno	44%	Fresno, Madera	
Orange County	45%	Orange	
Oakland	47%	Alameda, Contra Costa	very highly segregated
San Francisco	49%	Marin, San Francisco, San Mateo	
Ventura	49%	Ventura	
Bakersfield	51%	Kern	
Salinas	51%	Monterey	
Santa Cruz-Watsonville	52%	Santa Cruz	
Los Angeles	56%	Los Angeles	

metropolitan areas, census tracts, and population (by race/ethnicity)
by racial/ethnic segregation (multi-group dissimilarity index, Dm)




estimated cancer risk by pollutant, all sources,
California metropolitan areas
diesel particulate matter
chromium
formaldehyde
polycyclics
(1,3) butadiene
carbon tetrachloride
benzene
acetaldehyde
chloroform
vinyl chloride
ethylene dibromide
ethylene dichloride
acrylonitrile
dichloropropene
methyl tertiary butly ether (MTBE)
nickel
tetrachloroethane
arsenic
ethylene oxide
beryllium
methylene chloride
perchloroethylene
trichloroethylene
cadmium
lead
hydrazine
propylene dichloride
quinoline

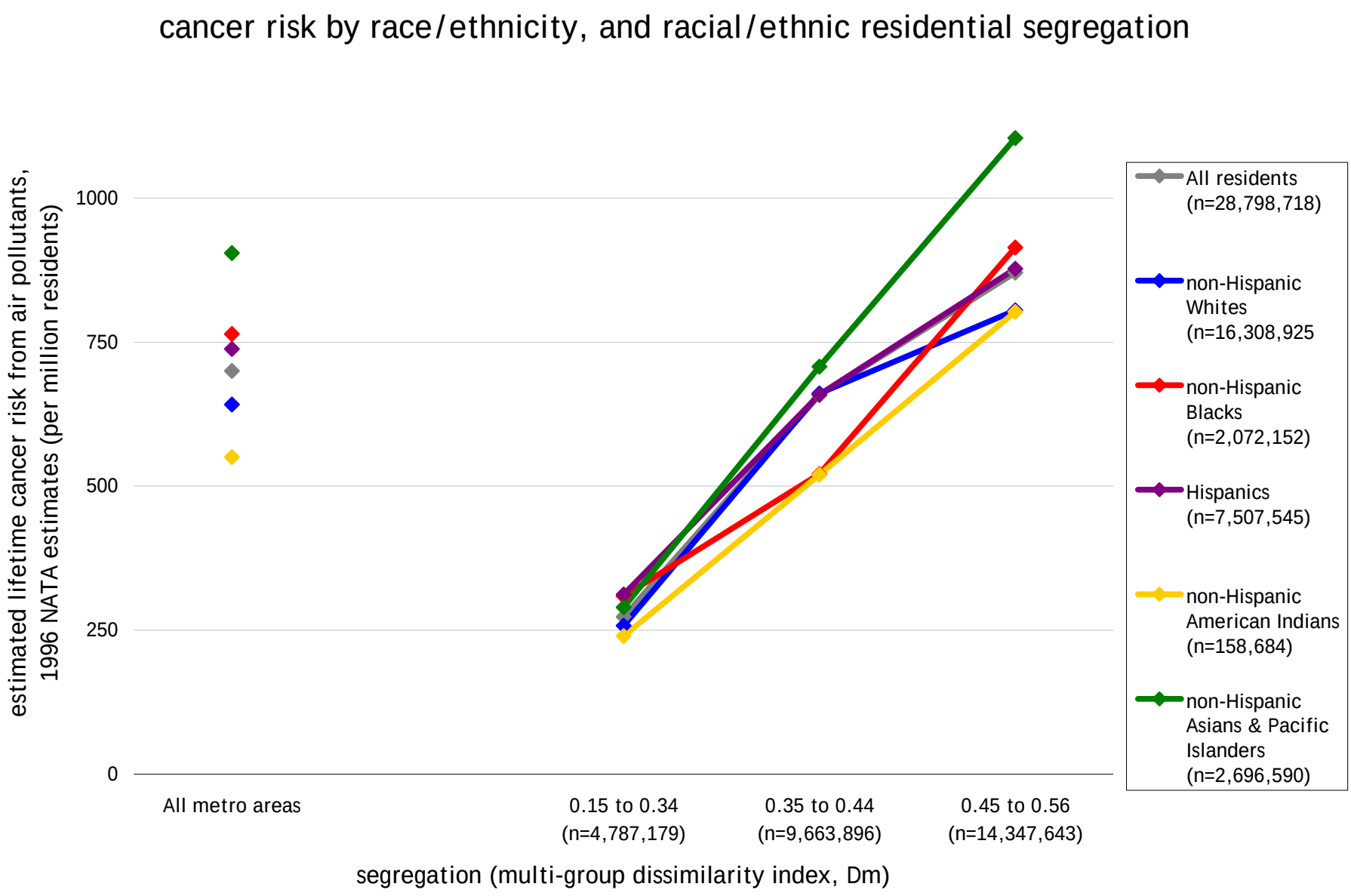

estimated cancer risk by source,
and by racial/ethnic residential segregation
estimated lifetime cancer risk from air pollution,
1996 NATA estimates (per million inhabitants)
1000
750
500
250
0
All metro areas
0.15 to 0.34
(n=4,787,179)
0.35 to 0.44
(n=9,663,896)
0.45 to 0.56
(n=14,347,643)
segregation (multi-group dissimilarity index, Dm)
non-road mobile sources
on road mobile sources
area sources
point sources
background

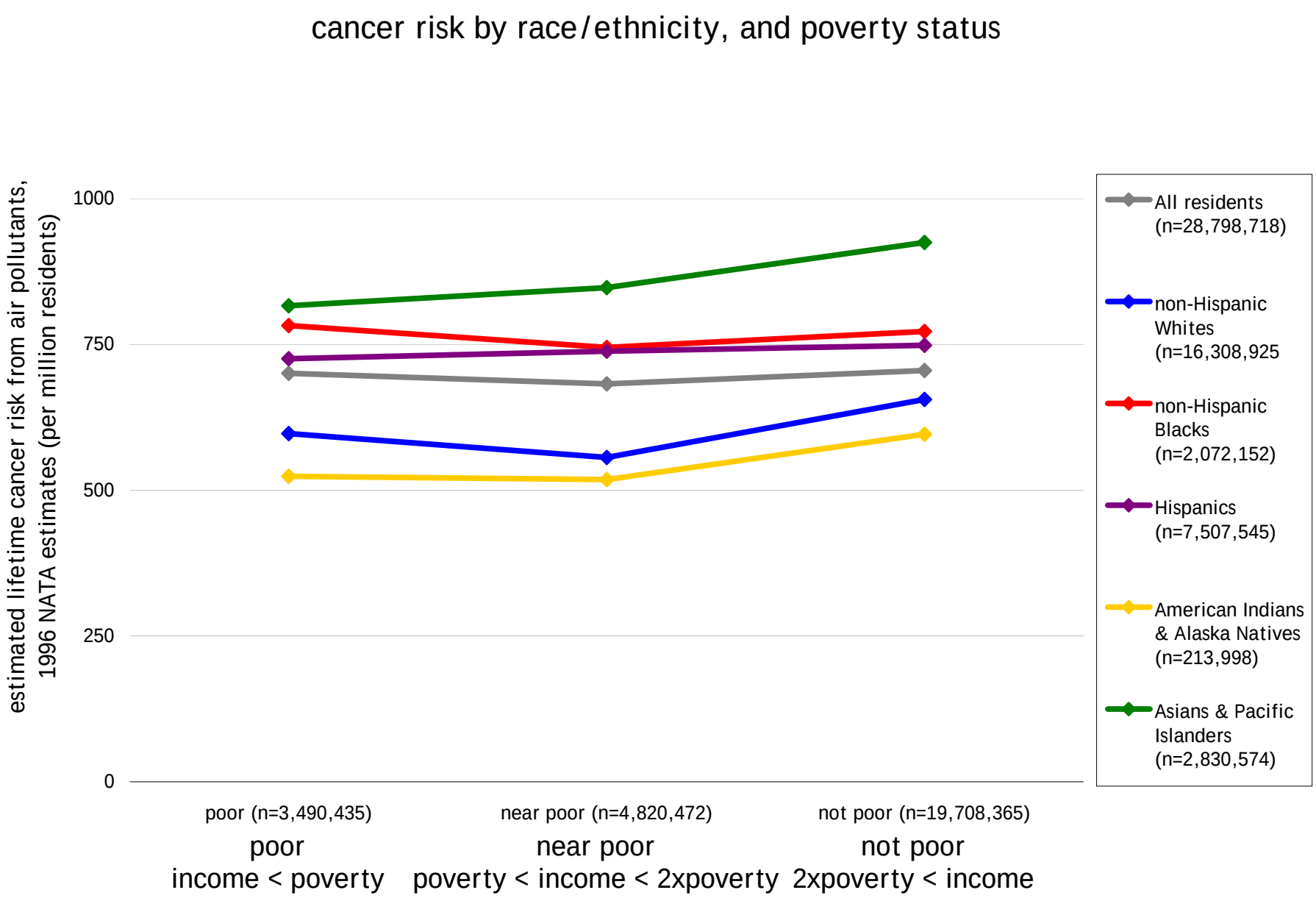
Population Risk Index

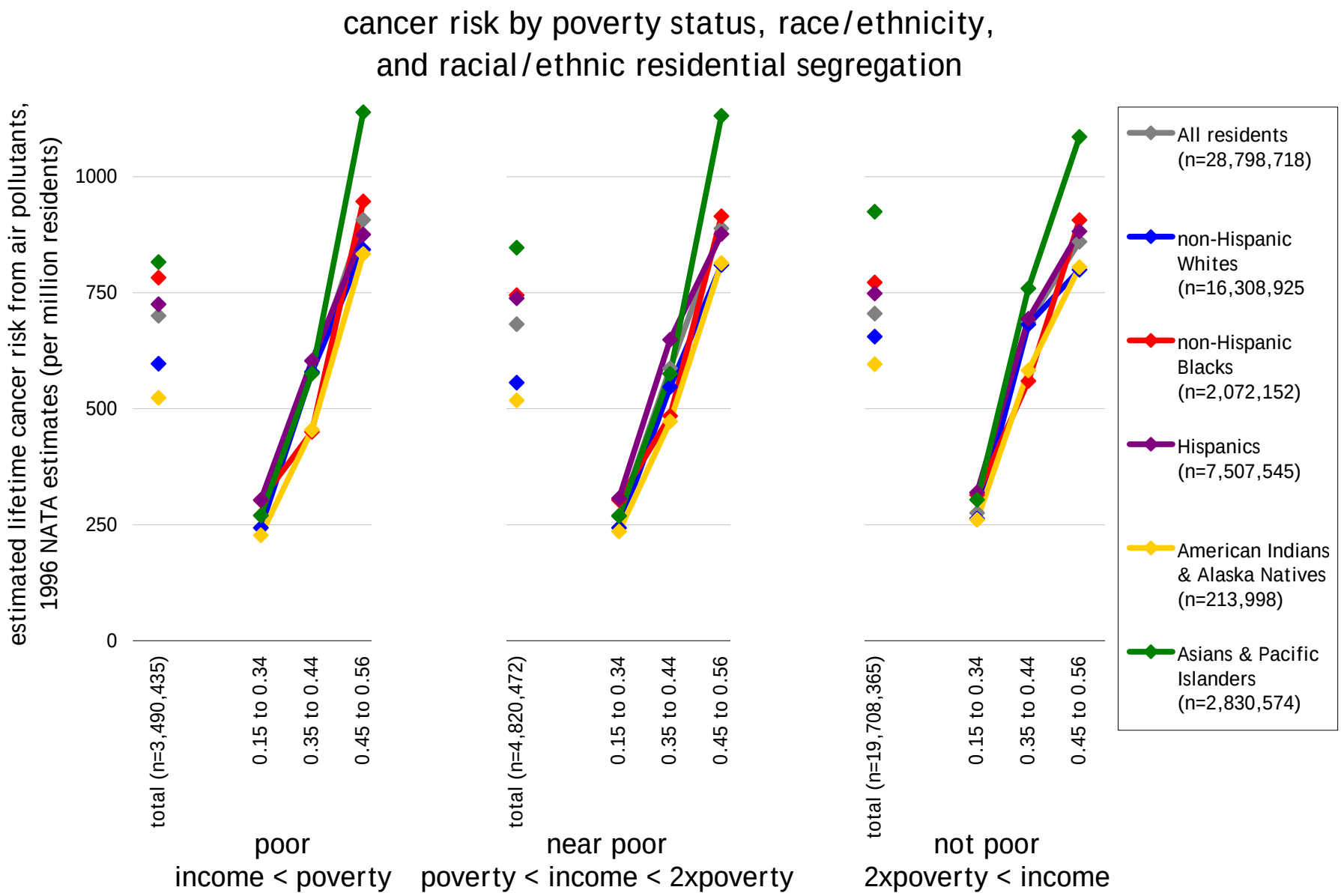
- PRI displays inequities in estimated cancer risks associated with air toxics across income and racial/ethnic categories.
- Weighted average of census level individual lifetime cancer risks:

$$PRI_S = \Sigma R_c n_{cS} / N_{CS}$$

- R_c = individual lifetime cancer risk estimate in census tract c
- n_{cS} = number of people in sub-population S in census tract c
- C = set of all census tracts considered in the analysis ($C = \Sigma c$)
- N_{CS} = total number of people in sub-population S who reside in all tracts C


cancer risk by race/ethnicity, and racial/ethnic residential segregation
estimated lifetime cancer risk from air pollutants, 1996 NATA estimates (per million residents)
1000
750
500
250
0
All metro areas
0.15 to 0.34 (n=4,787,179)
0.35 to 0.44 (n=9,663,896)
0.45 to 0.56 (n=14,347,643)
segregation (multi-group dissimilarity index, Dm)
All residents (n=28,798,718)
non-Hispanic Whites (n=16,308,925
non-Hispanic Blacks (n=2,072,152)
Hispanics (n=7,507,545)
non-Hispanic American Indians (n=158,684)
non-Hispanic Asians & Pacific Islanders (n=2,696,590)


cancer risk by race/ethnicity, and poverty status
estimated lifetime cancer risk from air pollutants, 1996 NATA estimates (per million residents)
1000
750
500
250
0
poor (n=3,490,435)
near poor (n=4,820,472)
not poor (n=19,708,365)
poor
income < poverty
near poor
poverty < income < 2xpoverty
not poor
2xpoverty < income
All residents (n=28,798,718)
non-Hispanic Whites (n=16,308,925
non-Hispanic Blacks (n=2,072,152)
Hispanics (n=7,507,545)
American Indians & Alaska Natives (n=213,998)
Asians & Pacific Islanders (n=2,830,574)

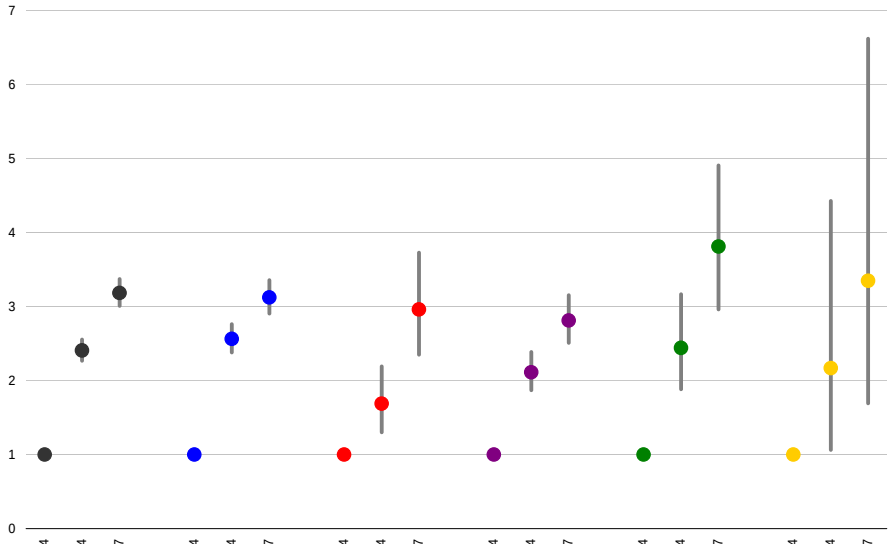

cancer risk by poverty status, race/ethnicity,
and racial/ethnic residential segregation
estimated lifetime cancer risk from air pollutants,
1996 NATA estimates (per million residents)
1000
750
500
250
0
total (n=3,490,435)
0.15 to 0.34
0.35 to 0.44
0.45 to 0.56
poor
income < poverty
total (n=4,820,472)
0.15 to 0.34
0.35 to 0.44
0.45 to 0.56
near poor
poverty < income < 2xpoverty
total (n=19,708,365)
0.15 to 0.34
0.35 to 0.44
0.45 to 0.56
not poor
2xpoverty < income
All residents (n=28,798,718)
non-Hispanic Whites (n=16,308,925
non-Hispanic Blacks (n=2,072,152)
Hispanics (n=7,507,545)
American Indians & Alaska Natives (n=213,998)
Asians & Pacific Islanders (n=2,830,574)

Covariates

- Segregation (MSA):
  - low (17 to 30%)
  - moderate (30 to 45%)
  - high (45 to 60%)
  - extreme (60 to 80%)
- Population Density (Tract)
- Townsend Index (Tract): sum of four z-scores /4:
  - crowding
  - unemployment
  - home ownership
  - car ownership
- Sprawl (MSA):
  - mixed use index
  - street connectivity index
- Eligible Voters (Tract)
- Average commute time (County)

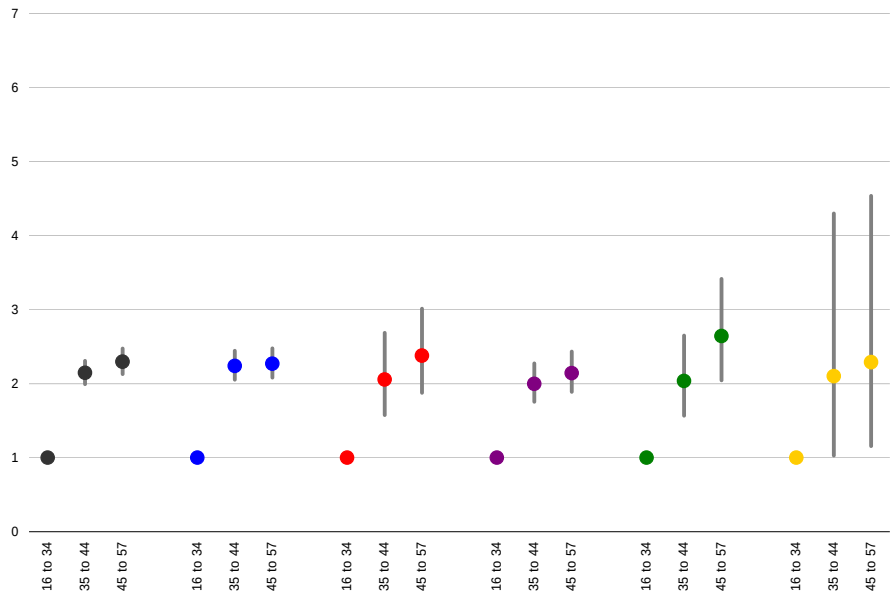
estimated cancer risk ratios relative to lower segregation levels (0.16 to 0.34)
by race/ethnicity, California metropolitan areas (n=25)
crude, R^2=15%

	(0.45 <=Dm< 0.57)			(0.35 <=Dm< 0.45)		
	hazard ratio	95% conf. interval		hazard ratio	95% conf. interval	
Total	2.41 (	2.27 -	2.55)	3.18 (	3.01 -	3.37)
non-Hispanic White	2.56 (	2.38 -	2.76)	3.12 (	2.90 -	3.36)
non-Hispanic Blacks	1.69 (	1.30 -	2.19)	2.96 (	2.35 -	3.73)
Hispanics	2.11 (	1.87 -	2.38)	2.81 (	2.51 -	3.15)
non-Hispanic Asians & Pacific Islanders	2.44 (	1.88 -	3.17)	3.81 (	2.96 -	4.91)
non-Hispanic American Indians & Alaska Natives	2.17 (	1.06 -	4.43)	3.35 (	1.69 -	6.62)



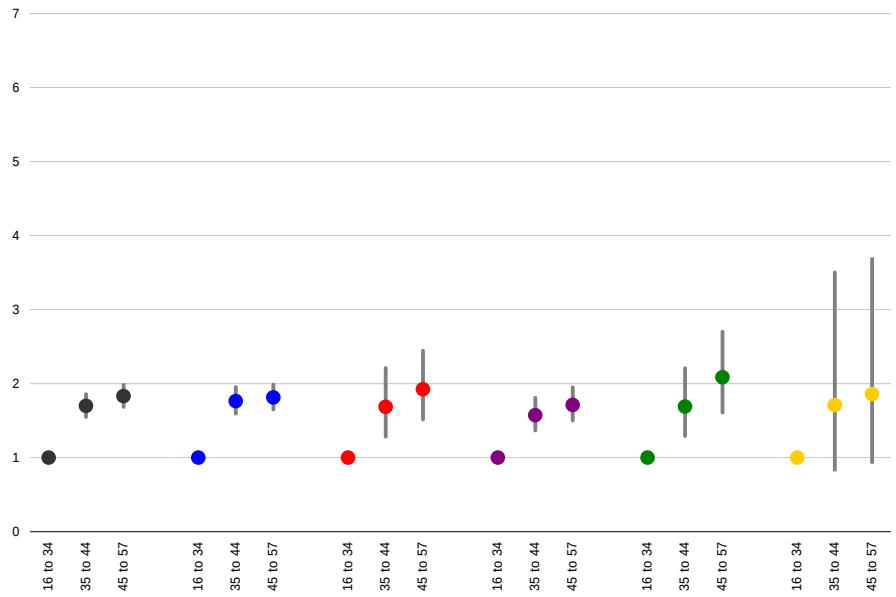
estimated cancer risk ratios relative to lower segregation levels (0.16 to 0.34)
by race/ethnicity, California metropolitan areas (n=25)
adjusted for tract population density , poverty rate, and material deprivation (Townsend index);
county voter turnout;
and metropolitan area population size, R^2=38%

Total	2.15 (1.99 - 2.31)	2.29 (2.13 - 2.47)
non-Hispanic White	2.24 (2.05 - 2.44)	2.27 (2.08 - 2.47)
non-Hispanic Blacks	2.06 (1.57 - 2.68)	2.38 (1.88 - 3.01)
Hispanics	2.00 (1.76 - 2.27)	2.14 (1.89 - 2.43)
non-Hispanic Asians & Pacific Islanders	2.04 (1.57 - 2.65)	2.64 (2.04 - 3.41)
non-Hispanic American Indians & Alaska Natives	2.10 (1.03 - 4.30)	2.29 (1.15 - 4.53)



estimated cancer risk ratios relative to lower segregation levels (0.16 to 0.34)
by race/ethnicity, California metropolitan areas (n=25)
adjusted for tract population density , poverty rate, and material deprivation (Townsend index);
county voter turnout;
and metropolitan area average commuting time, population size, R^2=42%

Total	1.70 (1.55 - 1.86)	1.83 (1.69 - 1.99)
non-Hispanic White	1.76 (1.59 - 1.95)	1.81 (1.65 - 1.99)
non-Hispanic Blacks	1.68 (1.28 - 2.21)	1.92 (1.51 - 2.44)
Hispanics	1.57 (1.37 - 1.81)	1.71 (1.50 - 1.95)
non-Hispanic Asians & Pacific Islanders	1.69 (1.29 - 2.21)	2.09 (1.61 - 2.70)
non-Hispanic American Indians & Alaska Natives	1.71 (0.83 - 3.50)	1.86 (0.94 - 3.69)



Segregation & Environmental Health

❖Racial segregation can play an important role in the differential distribution of air pollution exposures across demographic groups.

❖ Stratifying by segregation shows air pollution burdens are higher for all demographic groups within the most segregated areas.

❖ Demographic disparities are higher in the more segregated areas.

❖ Multivariate models show these relationships persist even after controlling for population density, material deprivation (Townsend Index), political empowerment, and commuting time.

Limitations

- Ambient air concentrations are not reflective of personal exposures and do not include indoor exposures.
- Concentration estimates from 1996 that may have changed significantly over time.
- Several pollutants could not be included in this analysis due to limited cancer toxicity data.
- Dispersion model underestimates concentrations of certain pollutants.
- Potential for mis-interpretation of ecological risk as individual risk

Methodological Challenges

- Measuring multiple exposures, cumulative risks and health impacts across segregation levels and between demographic groups over varying geographic scales
- How segregation interacts with:
  - community social factors (e.g. area level poverty)
  - and individual factors (e.g. genetics, age, stress)

  that could enhance vulnerability to the health effects of environmental hazards.