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Geospatial analyses of alcohol and drug problems: empirical needs and theoretical foundations

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Abstract Over the past four decades geospatial analyses of alcohol and drug problems have moved to the forefront of ecological studies of the correlates and determinants of drug addictions in community health. These advances have been predicated upon the expanding computational capabilities of geographic information systems, advancement of statistical tools for the analysis of spatial data, and the formulation of suitable social ecological theory. This paper provides an introduction to the study of drug markets in the US as a model social problem for geospatial research and analysis. Market and epidemic models of the growth of the methamphetamine abuse and dependence in California are used as examples of two fruitful approaches to understanding the social processes that underlie use of this dangerous substance. Data on the growth of the epidemic are described and used to motivate theoretical and empirical concerns regarding further analyses of the development of drug markets over space and time. These concerns, in turn, begin to be addressed by the remaining four papers in this series, each providing some examples and insights into avenues of geospatial research which can be profitably explored in the future.

Keywords Meethamphetamine · Illegal drugs · Epidemic · Economics · Markets

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The harmful use of alcohol and other drugs in the United States accounts for about $366 billion per year in health care costs, lost worker productivity, and criminal justice activities. Alcohol use accounts for about $185 billion (Harwood 2000). Illegal drug use accounts for about $181 billion, with most costs due to premature deaths and lost productivity ($129 billion; Office of National Drug Control Policy, ONDCP 2004). The very large bill related to premature deaths and lost productivity is due in greatest measure to crime related costs ($108 billion). Police and corrections expenditures and productivity losses related to crime are substantial. Although considerable costs arise from drug abuse dependence and treatment, much larger costs arise from other so-called "acute" harms, problems that are associated with a single occasion of use. These include problems ranging from disruptions in judgment and motor performance that lead to accidents and injuries (e.g., drunken and drugged driving), to cognitive impairments that affect judgment in social contexts which can place the user and others at risk (e.g., interpersonal violence, child abuse and neglect), to crimes committed in the act of marketing or obtaining drugs (i.e., systemic violence), to drug overdoses that appear in emergency departments. Acute problems are particularly troublesome to public health advocates because they are not restricted to heavy users, often occur among more casual and light users, and involve the victimization of non-users as well. In this sense, alcohol and drug problems are global and affect all sectors of societies the world over.

Since alcohol use is legal in most countries, alcohol abuse, dependence and related problems are often endemic in most societies. In the US a relatively constant proportion of the population are drinkers, about 64% having drunk at some point in the past year, and this figure has varied but little from-year-to-year for many decades. A much smaller proportion of drinkers report serious problems related to use and may be labeled as alcohol dependent or addicted–about 7% (National Institute on Alcohol Abuse and Alcoholism, NIAAA 2009). Again these figures vary relatively little from 1 year to the next. So-called illegal drugs are, of course, banned in most countries and, while their use may also be considered endemic (e.g., cocaine use in the US), sales and distribution of these drugs are constrained by drug policies and enforcement activities. In the US levels of illegal drug use have remained relatively stable over many decades. For example, the proportion of the population having used cocaine in the past year has remained at about 5% and varies little from-year-to-year (Substance Abuse and Mental Health Administration, SAMSHA 2004). Policy and enforcement efforts have not eliminated the use of any illegal drug in the US, but rather have shaped an alternative illegal market that maintains distribution systems across the country. These markets can be the source of drug epidemics that grow in response to the adoption of new illegal substances by former users or the recruitment of new users. Any lapse on the part of enforcement agents or any innovation on the part of the illegal drug market can lead to sudden up-ticks in the level of illegal drug use.

Geospatial analysis and drug epidemics

As an endemic health problem, rates of alcohol use and abuse have remained quite stable in most countries for many years, although occasional exceptions do exist (e.g., the increase in Russian alcohol abuse in response to liberalized availability in the later twentieth century, Babor et al. 2003). Within the US, stable patterns of use extend from the national level down to states which exhibit small differences in regional patterns of use. Within states, counties exhibit somewhat larger differences in drinking levels, but substantive variability only appears at the zip code level and below. Thus, as for many spatial ecological processes, greater geographic resolution leads to a clarification of patterns of behavior related to the spatial distributions of different populations and environments. For example, Gruenewald et al. (2006) showed that measures of the population and physical characteristics measured at the zip code level in California could be statistically related to the incidence of violent injuries. With yet further geographic and temporal resolution, patterns of harm related to changes in populations and environments over space and time become visible. Consequently, Banerjee et al. (2009) used data at the Census block group level to show that the geographic distribution of violent injuries varied in relation to the relatively stable locations of alcohol markets and the often changing locations of drug markets in a single city.

For obvious reasons there are no national markets for illegal drugs and as a consequence the observed spatial distributions of drug use and related problems exhibit very different geographic patterns across states and communities in the US (e.g., Stockwell et al. 2005). Hampered by legal restrictions and enforcement efforts, illegal drug markets have far fewer distributors and sellers than could be sustained by demand. One result of this situation is that any shift in supply that accompanies changes in enforcement efforts or market innovation can have dramatic spatial and temporal effects at the local, state, and national levels. At a national level the most dramatic of such events was the rapid increase in heroin use across the US observed between 1965 and 1975 (Hunt and Chambers 1976). Similar dramatic changes have been noted in England and Wales (Parker 1998), and most recently in Australia (Dray et al. 2008). The most recent large-scale drug epidemic in the US is the ongoing methamphetamine epidemic which originated on the West Coast of the US and has grown substantially over the past 30 years. This epidemic is particularly interesting because of the addictive potential of methamphetamine; the substantial health risks associated with use and abuse, and, from a social geographer's perspective, the availability of data systems by which to characterize its spatial development.

This paper focuses upon the emerging methamphetamine market to provide examples of the advantages and challenges of applying "geospatial analysis methods", construed to include geographic information systems (GIS) and descriptive and inferential

spatial statistics, to studies of drug markets in the US. The goals are to provide an outline of the urgent need for this research, identify specific geographic and geostatistical problems that must be solved for these studies to move forward, and introduce the remaining papers in this series that begin to address a number of these issues.

The methamphetamine story

Since the advent of the "War on Drugs" in the 1980's, much attention has been focused on policing drug sales and trafficking in an effort to reduce the escalation of drug problems in US communities (Harrison and Backenheimer 1998). However, illegal drug markets respond efficiently to changes in patterns of enforcement, tending to rebound or displace to nearby communities following heightened enforcement efforts (Caulkins 2000). The limited effects of drug enforcement are due to two main factors: (1) a persistent demand for drugs and (2) the existence of private and relatively closed markets for drug sales that enable the rebound of public markets upon the relaxation or cessation of enforcement activities (Hunt et al. 2008). While researchers are able to document the demand for illegal drugs using surveys administered at national and more local levels (National Institute on Drug Abuse 2002; Kadushin et al. 1998), work that illuminates the development of drug markets is limited by the lack of direct market data.

Drug markets, whether legal or illegal, are driven by the same supply–demand relationships common to any economic market (see Fig. 1). In legal drug markets most aspects of supply and demand are clearly visible. For example, it is easy to identify drinkers, obtain self reported measures of the demand for alcohol, and collect indices of alcohol sales, prices, production and distribution through survey and secondary data sources (Babor et al. 2003). In illegal drug markets, however, most aspects of the market are hidden and operate through social networks with informal contracts enforced through informal and sometimes violent means (Eck 1995; LaScala et al. 2005). Sometimes illegal drug markets become visible, characterized by drug exchanges that occur in areas where individuals naturally congregate and where the threat of detection by enforcement

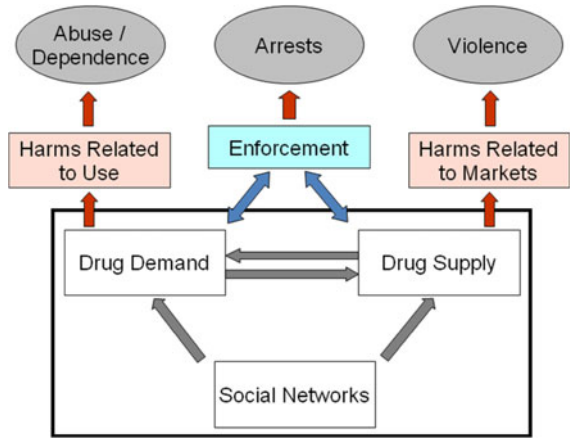

Fig. 1 Indicators of AOD supply and demand

agents is low (for example, around shopping malls, public schools, rapid transit hubs, and liquor and convenience stores; Wittman 2007). Not surprisingly, these markets are based upon exchanges between relative strangers and are the markets most easily uncovered by enforcement agents. But most often illegal drug markets are invisible. They are private markets in which social contacts between consumers and sellers facilitate the development of new clientele through social exchanges with members of drug users' social networks. These private markets are more closed to public scrutiny, less likely to be identified by enforcement agents, and persist when public markets are disrupted. Although distinctions between public and private markets are a matter of degree, privacy is central to the maintenance of illegal drug markets. This privacy also precludes direct empirical investigation (Babor et al. 2010). Instead, what we see when we try to observe these markets are the enforcement efforts of police, both responding to and affecting drug market activities, and problems associated with drug use (e.g., abuse and dependence) or the maintenance of drug markets (e.g., violence).

If one stands back from the very difficult problems of studying drug markets, it is possible to take an alternative epidemiological approach and ask a somewhat different question: "To what extent do we see patterns in available data that indicate the growth and spread of a drug market?" Treating a measurable outcome related to drug use as if it were a contagious disease, like the flu, we could look for patterns in the data which suggest contagious spread,

identify population characteristics associated with the disease, or indicate vectors which rapidly accelerate progress of the disease. We may not understand all the mechanisms involved, as, in fact, we do not with respect to any emerging virus. Yet the economic bases of drug markets and their relationships to problems are reasonably well understood, and sufficiently understood to use problems associated with these markets as markers for market locations (Caulkins and Nicosia 2010). The major difference is that the time course of a flu epidemic is on the order of weeks and months and that for a drug epidemic is years and decades. In either case we are measuring only the end-state of an infection, either flu symptoms or abuse outcomes. This epidemiological approach is particularly compelling when one considers the methamphetamine epidemic of the past 30 years. Cases of hospital admissions for methamphetamine abuse or dependence increased dramatically over this time, exhibiting exponential growth (Fig. 2) and substantial spatial heterogeneity (Fig. 3).

As shown in Fig. 2, the number of methamphetamine hospital admissions per 10,000 persons in California grew from 0.34 in 1983 to 9.38 in 2005, a 28-fold increase. This growth continued in most years, transiently interrupted by a series of precursor laws which restricted access to ephedrine and pseudoephedrine, essential materials for the production of this synthetic drug. Each precursor law had the effect of halting or reversing growth in admissions (Cunningham and Liu 2003), but in each instance growth continued after several years. Greatest effects of the precursor laws arose during a period from 1995 through 1998 when three successive laws went into effect. Before this time, from 1983 to 1995, exponential growth of 18.0% per year was observed. After this time, from 1999 through 2005, exponential growth resumed at a rate of 18.5% per year. While an average growth rate of 12.7% per year was observed from 1983 to 2005 across the state, as shown in Fig. 3 this growth was not consistently reflected in every area of the state. There was substantial spatial heterogeneity in the distribution of methamphetamine hospital admissions across zip code areas over time. The figure shows maps of the epidemic for the state of California and three regional areas, the San Francisco Bay, Sacramento, and greater Los Angeles. In every region some zip code areas showed substantial increases in admissions while others showed little or none.

Substantial differences in the temporal patterning of drug arrests related to methamphetamine production and use were also seen across the state since the 1980s. As shown in Fig. 4, arrests for dangerous drugs, a category strongly dominated by methamphetamine for the last

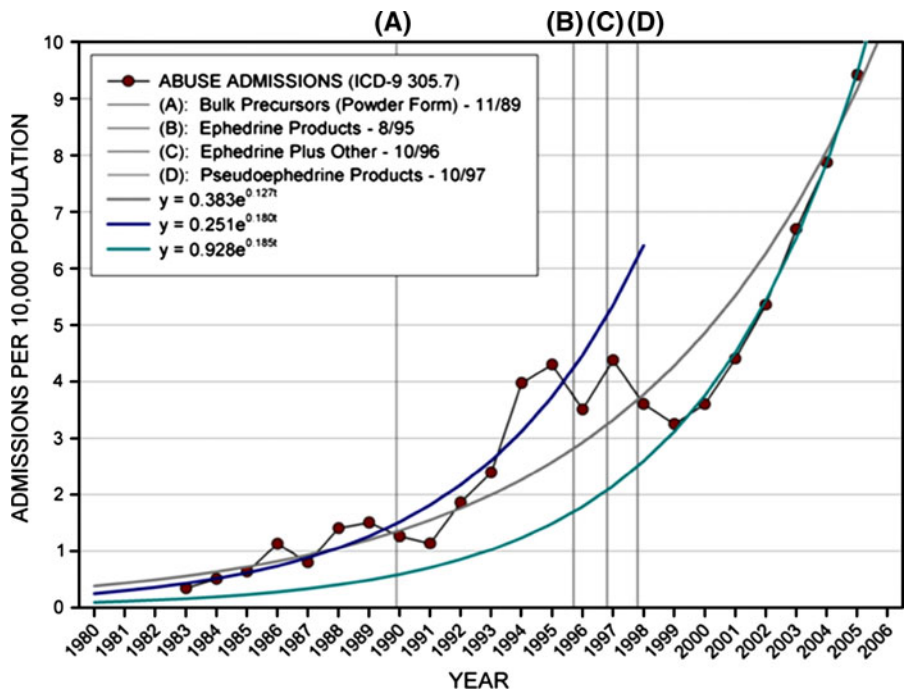

Fig. 2 Methamphetamine Hospital admissions

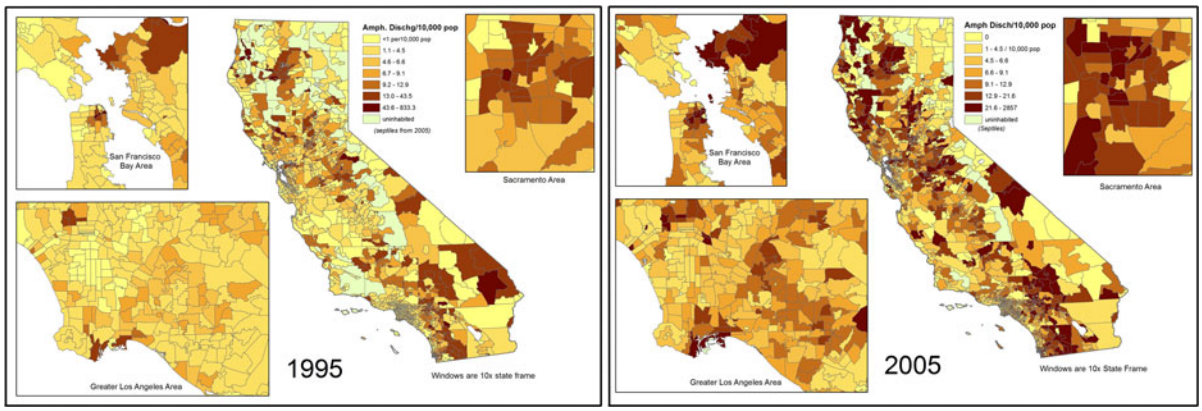

Fig. 3 Growth of Methamphetamine Hospital admissions in California 1995–2005

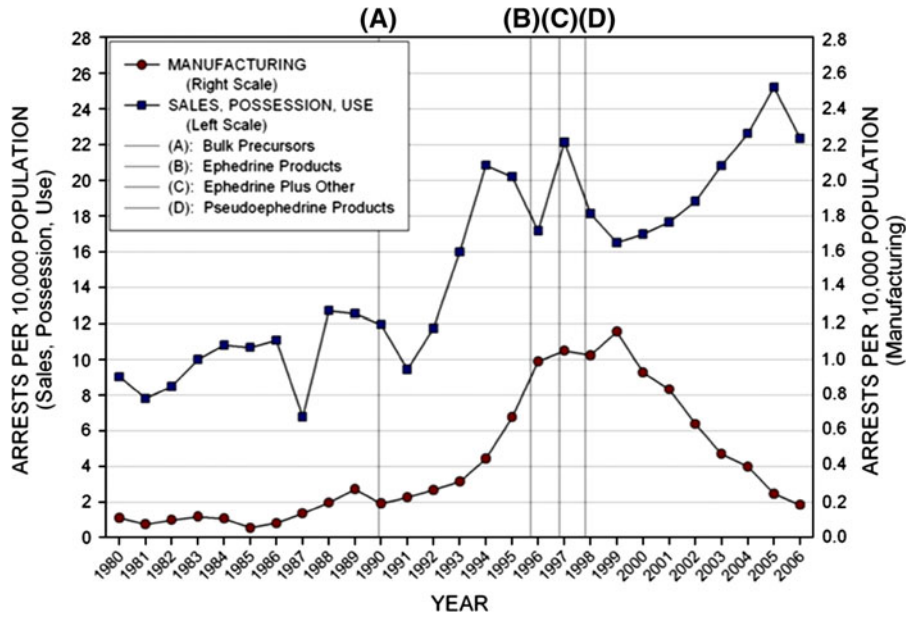

Fig. 4 Methamphetamine related arrests

two decades, has increased since the 1980s with occasional interruptions due to precursor laws (Cunningham and Liu 2005). Numbers of arrests for drug manufacturing on the other hand, a figure dominated by enforcement activities directed at domestic methamphetamine laboratories in California, peaked in the 1990s and have declined ever since. The recent reductions in methamphetamine lab seizures in the state have been attributed to constraints placed on the market by the precursor laws of the 1990s and a shift in production and distribution to international drug cartels. Local variations in numbers of arrests over time were also substantial (Fig. 5). Some cities in the state experienced a rapid rise in methamphetamine arrests at an early point in the epidemic (e.g., Hayward and Hercules). Others saw increases and subsequent declines later in the epidemic (e.g., Fountain Valley). Yet others, the majority, witnessed continued increases throughout this time (e.g., Sunnyvale, Ojai, San Fernando).

Theory and methods in the study of drug epidemics

Whether the use of drugs is endemic, like alcohol, sporadically epidemic, as the case with cocaine and

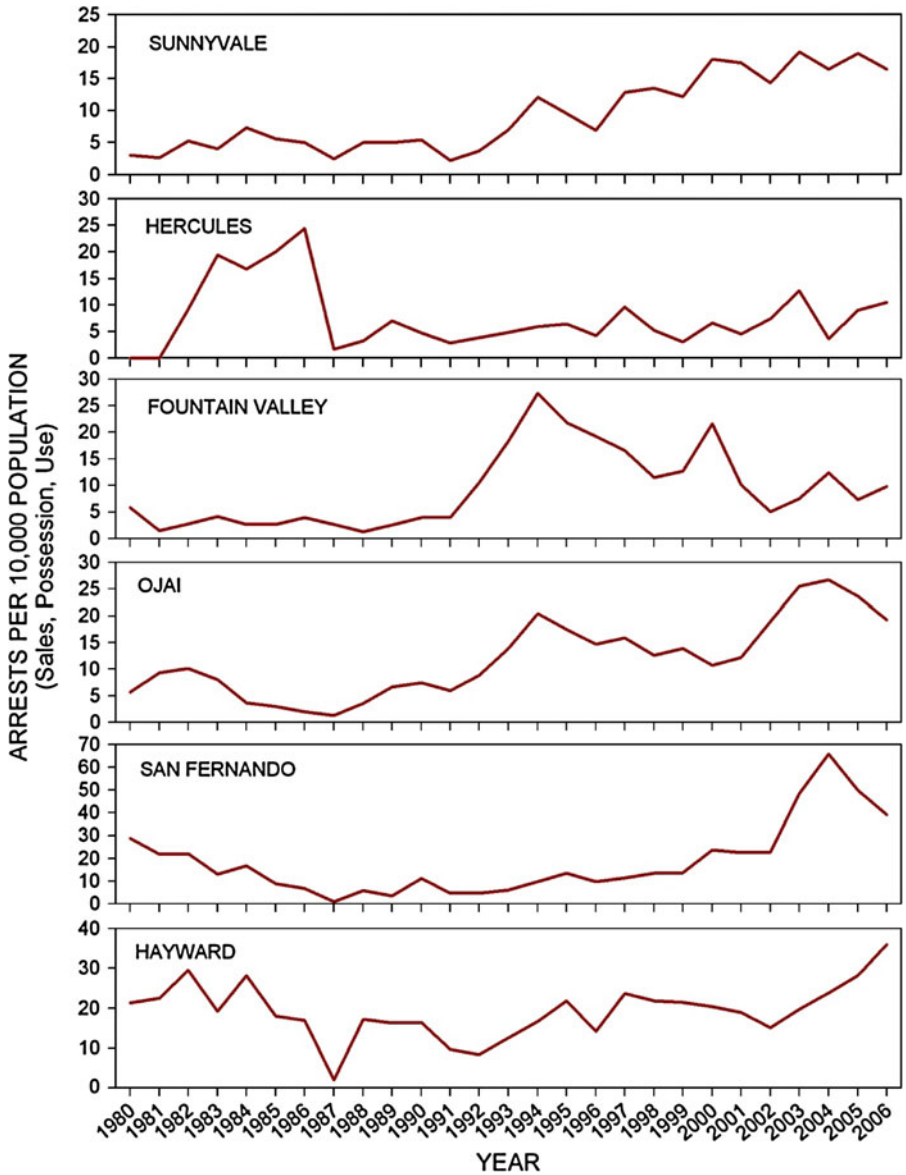

Fig. 5 Methamphetamine arrests in individual cities

heroin, or currently epidemic, like the emerging market for methamphetamine, the use and abuse of these substances bear substantial health and social costs. As an examination of the emerging methamphetamine market shows, drug epidemics can grow rapidly and different regions of a state may exhibit different levels of use and related problems at different times and to varying extents. The sources of these variations in patterns of growth are the subject of both theoretical interest among public health researchers and empirical interest among geographers and spatial statisticians. Among theorists the central problems are (1) how to conceptualize the behavioral and social forces that shape drug epidemics and (2) how to formulate suitable social theory in spatial terms. In particular, the formulation of spatially adequate theory, theoretical formulations that explain emergent patterns of spatial growth in spatial terms, is not familiar territory to social or public health scientists. It is difficult to conceptualize the spatial processes that promote epidemic growth, such as those processes which explain patterns of

contact between drug markets and drug users. It is equally difficult to assess spatial impacts of available treatment and prevention services. Among empiricists the central problems are (1) how to model these varying relationships over time and space and (2) how to do so while constrained by available and often highly limited spatial data. In particular, the use of "received" spatial units, those units somewhat casually defined by geopolitical or commercial interests, like zip codes, is particularly problematic for spatial analysts seeking to empirically test different social theories of epidemic growth. Not only are these and similar geopolitical units defined for other purposes, with shapes that conform to the needs of political and economic interests, but the shapes of these units can change arbitrarily over time. For example, in a recent panel study of rates of methamphetamine abuse in California, we found that only 35% of zip code areas were "consistently" defined over a 6 year period (Gruenewald et al. 2010). Consistent zip code areas were defined as those having 90% or better overlap in population coverage from 1 year to the next.

The research presented in the following series of four papers addresses both theoretical and empirical concerns in geographic studies of drug markets and drug epidemics. Gorman et al. provide an introduction to spatial theoretical models suitable for the analysis of relationships between neighborhood characteristics, alcohol and crime. They make the particular point that many social theories about crime, drugs and related problem behaviors are not spatial in any intrinsic sense, making no specific predictions about geographic relationships to be expected between theoretical constructs. Rather, these theories defer spatial explanations of social phenomena to other work. Many practical studies of the addictions, on the other hand, confront researchers directly with problems in spatial analysis. As one example, Friesthler shows that drug and alcohol services that address treatment need must also address the spatial availability of treatment and prevention resources. Ponicki et al. move on to empirical issues by introducing Bayesian space time varying parameter models which can be used to assess the impacts of drug prevention policies on drug epidemics, in this case specifically the methamphetamine epidemic in California. These models are unique in that they are capable of identifying the geographically varying impacts of preventive and enforcement interventions on outcomes. And, finally, Zhu et al. introduce a Bayesian misalignment model which enables analyses of data from misaligned geographic units over time, such as zip codes. These models offer to researchers the opportunity to assess the biasing forces of misalignment and correct for such biases in analyses of temporal data using data from spatially misaligned geopolitical units.

It is the hope of the authors that their efforts will inform and inspire geographers and geostatisticians to focus on societal studies of drug epidemics as model problems for future research. Geographic studies of social problems are at a nascent and essential stage of development. The geographic models and methods by which we can map drug epidemics and theoretically analyze and statistically assess the social and ecological correlates of epidemic growth, are active areas of research. Model problems in the behavioral and social sciences, such as those examined in this series of papers focus attention upon the key elements of geographic research and analysis that will best aide efforts to prevent and treat these important public health problems.

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