Chapter 3
Integrating GIS into the Study of Contextual Factors Affecting Injection Drug Use Along the Mexico/US Border

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"When [drugs] wreak their devastation, they respect no boundaries of income, race, occupation or geography" – Kofi Annan, Secretary General (United Nations 2006)

Abstract While the relationship between individual-level factors and drug use or associated risk behaviors has been investigated in-depth, comparatively little is known about the influence of contextual determinants. Geographic information systems (GIS) enable users to simultaneously display a number of environmental data layers and use spatial statistics to explore the relationships between contextual and individual-level variables. This makes GIS a potentially powerful tool in substance use research. One area where geography has a striking influence on health is at the US/Mexico border, where the confluence of drug trafficking routes, migration, and income inequalities form unique environmental influences on drug use scenes. In this chapter, we describe some of the spatial and environmental issues, such as migration, neighborhood characteristics, and proximity to services, which may affect drug use behaviors and risks. A number of practical methods to measure geographical indicators are also described, focusing on a case study of injection drug use in the Mexico/US border city of Tijuana, Mexico.

Introduction

While much research has been done to characterize individual-level risk factors for drug use and risk behaviors, comparatively little is known about contextual determinants. In recent years, public health and substance use researchers have come to appreciate how macro-level or structural factors may contribute to the

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"risk environment" (Diez Roux 2001; Rhodes, Singer, Bourgois, Friedman, and Strathdee 2005; Rhodes et al. 1999), especially in regards to transmission of the human immunodeficiency virus (HIV) and other infectious diseases (Gleghorn, Jones, Doherty, Celentano, and Vlahov 1995; Harrison, Vlahov, Jones, Charron, and Clements 1995; Holmberg et al. 1995; Latkin, Mandell, Vlahov, Oziemkowska, and Celentano 1996; Manoff et al. 1996). These determinants include social, geographic, economic, and political factors, encompassed in an ecosocial approach where multiple categories of determinants are simultaneously considered (Poundstone, Strathdee, and Celentano 2004). Social determinants of health present in day-to-day life can exert influence on health above and beyond individual characteristics. A compilation of data from studies of injection drug users (IDUs) globally showed that HIV prevention interventions that focus solely on individual behavior change result in only partial reduction of risk of transmission, ranging from 25% to 40% (Rhodes et al. 2005). Developing "structural" interventions which act on the social and physical environment represents an avenue for addressing risk not affected by individual-level interventions and may eventually help to reduce health disparities (Burris et al. 2004; Diez Roux et al. 2001).

Most studies of injection drug use have largely described the geographic boundaries and characteristics of environments without analyzing what constitutes a risk environment. Geographic information system (GIS) models and the application of spatial statistics within a GIS provide a palette of tools that can help to improve understanding of the relationship between the environment and individual-level characteristics. The ability to simultaneously present a number of environmental data layers and explore their relationship with drug use variables through spatial statistics makes GIS a powerful tool in substance use research.

The illegality of drug use and the often mobile nature of illicit drug users makes mapping in substance use studies more complicated than in a typical health study. A further complication comes when working in countries where the digital mapping infrastructure tends to be underdeveloped. Both complications mean that researchers are generally required to create their own digital boundary files, or at least adapt those produced by others. For these reasons, this chapter will primarily draw upon examples from an ongoing bilateral study (Project *El Cuete*) of injection drug use in the Mexico/US border city of Tijuana, Mexico.

Tijuana is the northwestern-most border city in Mexico, with the highest prevalence of drug use in Mexico (SSA 1998). The US/Mexico border area is unique in that geography has a striking effect on health. Prevalence of infectious diseases in the 100 km area directly north and south of the international border are unusually high for both Mexico and the United States (Brouwer et al. 2006; Doyle and Bryan 2000; United States–Mexico Border Health Commission 2005). A number of cities along the border also lie along the major drug trafficking routes, further complicating the health situation. This chapter will briefly describe some of the spatial/environmental issues, such as migration, neighborhood characteristics, and proximity to services, which may have an influence on injection drug use behaviors and risks. Some practical issues involved in measuring geographical indicators are also covered, focusing on the case study of our Mexico/US border field project.

GIS As a Tool for Studying Drug Use

In moving the field of drug addiction research forward, innovative methods are needed to measure macro-level risk factors in an effort to characterize the complex interactions between factors operating at the level of the individual, network, and environment, thereby setting the stage for the development of structural interventions. Since epidemiology is an inherently spatial science, GIS applications have taken off rapidly in public health as new geospatial techniques have become available (Cromley and McLafferty 2002; Jenks and Malecki 2004; Mullner, Chung, Croke, and Mensah 2004).

There are as yet, however, few published reports of the application of GIS to the study of injection drug use, let alone substance use in general. Ecologic associations have been shown to be important in a number of studies of alcohol abuse, where, for example, it was found that higher density of alcohol outlets in Los Angeles was associated with higher rates of assault, independent of unemployment, age, income, female-headed households, or household size. In fact, alcohol outlet density explained 7% of the variance in the rate of assault (Scribner, MacKinnon, and Dwyer 1995). In the US city of Baltimore, Maryland, GIS was used to assess patterns of drug use. Type and frequency of drug use were associated with specific geographic areas, independent of neighborhood characteristics (Latkin, Glass, and Duncan 1998). Recently, Trooskin et al. used a GIS model to explore clustering of hepatitis C virus cases in the US state of Connecticut (Trooskin, Hadler, St Louis, and Navarro 2005). Most clusters occurred in known injection drug using areas, where the state was already providing limited needle exchange services; however, a new cluster in an area without such services was also identified, suggesting the need to rethink the distribution of service areas. GIS has also been used to model social networks of urban youth who were or were not substance users (Mason, Cheung, and Walker 2004). This analysis compared distances of homes to risky or safe places identified by young people. The above studies begin to illustrate the power of GIS to inform formation and optimization of public health interventions and increase understanding of at-risk drug using populations.

Background of Tijuana, Mexico and Project *El Cuete*

The more than 2,000 mile border separating Mexico and the United States forms a unique environment encompassing over 12 million inhabitants in the 100 km area directly north and south of the international boundary (United States–Mexico Border Health Commission 2005). It is the most extensive land frontier separating a developed and developing country, and the income gap is the largest between any two contiguous countries (INEGI 2000b). Located on the far northwestern edge of the border region, Tijuana, Mexico, a city of 1.3 million, sits just south of twin-city San Diego (INEGI 2000b).

Situated along the Tijuana/San Diego border area is a major drug trafficking route through which heroin, cocaine, and methamphetamine are smuggled to the United States (Bucardo et al. 2005). "Spillover" from these shipments has created a robust local drug consumption market (Bellis 2003; Magis-Rodríguez, Marques, and Touze 2002; Medina-Mora et al. 2003; SSA 1998). In fact, Tijuana has one of the fastest growing IDU populations in Mexico and the highest prevalence of consumption of illicit drugs in the country (Magis-Rodríguez, Marques et al. 2002; SSA 1998). There are estimated to be 10,000 IDUs and more than 200 shooting galleries in Tijuana (Morales, Lozada, Magis, and Saavedra 2004), where *people who do not necessarily know each other get together to inject drugs*.

HIV prevalence among IDUs and other high risk populations in Mexico has thus far remained low (Bastos, Strathdee, Derrico, and Pina 1999; Güereña-Burgueño, Benenson, and Sepulveda-Amor 1991; Magis-Rodríguez, Marques et al. 2002). Of the estimated 160,000 people living with HIV, approximately 2–6% are believed to be IDUs (Magis-Rodríguez, Rivera Reyes, and Bravo-García 2002; Noriega-Minichiello, Magis, Uribe, Anaya, and Bertozzi 2002; UNAIDS 2004). However, recent research by Strathdee and her associates in Tijuana has indicated that risky injection behaviors are rampant (Strathdee et al. 2005). Further, studies suggest that HIV prevalence is increasing dramatically in sentinel populations in Tijuana, such as pregnant women who have used drugs (Viani et al. 2006). A recent modeling exercise estimated that 2–7% of Tijuana IDUs were HIV-infected and comprised the at-risk group with the second largest number of infected persons (just behind men who have sex with men) (Brouwer et al. 2006). Although Mexico is considered a country of low HIV/AIDS prevalence with a concentrated epidemic, the window of opportunity for prevention may be closing rapidly since IDU-associated HIV epidemics are often explosive and can quickly become generalized (Rhodes et al. 2002; UNAIDS/WHO 2003). Studying the environment in which drug use occurs may help to identify risks associated with transmission of blood-borne viruses in this city and aid in the development of effective intervention strategies.

To illustrate some of the key subjects and practical issues that can be explored using GIS to study IDUs and expand upon unique aspects of border areas, we present here a description of Project *El Cuete*, an ongoing collaborative research study to assess infection prevalence, risk behaviors, and possible interventions in injection drug using populations along the Mexico/US border (*El Cuete* is a slang term commonly used among border IDUs to refer to a syringe). Project *El Cuete* is a three-phase research project funded primarily by the National Institute on Drug Abuse that is being undertaken by the University of California San Diego along with governmental agencies in Mexico [Centro Nacional para la Prevención y el Control del VIH/SIDA (CENSIDA), Instituto Nacional de Salud Pública] and several Mexican non-governmental organizations (Patronato ProCOMUSIDA, A.C., CIRAD, A.C., and Programa Compañeros, A.C.). Institutional review boards of the Tijuana General Hospital and University of California, San Diego approved the study's protocols.

Phase I of Project *El Cuete*, conducted in 2004, consisted of in-depth qualitative interviews administered to 20 IDUs in Tijuana and 24 in Ciudad Juarez (just

south of El Paso, Texas, USA) to gather exploratory information on drug use and injection, and sexual behaviors. From February–April 2005, Phase II consisted of a cross-sectional study using respondent-driven sampling (RDS) methods to collect quantitative information on HIV risk behaviors among 222 IDUs in Tijuana and 206 in Ciudad Juarez and conduct antibody testing for HIV, hepatitis C, and syphilis. RDS is a chain referral method whereby a group of "seeds" were selected based on diversity of gender, location, and drug preferences, and given three uniquely coded coupons to refer IDUs in their social network. It is increasingly being used to recruit subjects from "hidden populations," such as IDUs (Heckathorn 1997, 2002). Referral chains continued until approximately 200 were recruited at each site. IDUs who tested positive for any of these infections received counseling and referral to treatment. Phase III, a longitudinal cohort study of infection incidence, will follow 1,000 IDUs recruited through RDS in Tijuana. Eligibility criteria for project *El Cuete* include: having injected illicit drugs within the past month, aged 18 years or older, able to understand and speak Spanish or English, and willing and able to provide informed consent. Examples presented here will focus primarily on phase II results from Tijuana. The main reasons for incorporating GIS into Project *El Cuete* were to determine social and environmental factors potentially affecting the drug use scene and any barriers to accessing public health resources.

Practical Mapping Issues in Tijuana

The city of Tijuana is approximately 24 kilometers wide (from the Pacific Ocean on the west to the city's eastern edge) and covers a total area of 1,727 square kilometers. As is the case with all urban areas, Tijuana is divided into a large number of neighborhoods (more than 600), which are known in Mexico as colonias. Whereas new, sparsely populated colonias are largely created by administrative or commercial boundaries, colonias in the most populated areas of the city stem from neighborhoods with distinct historical traditions and characters, often informal in their origins. Tijuana colonias have an average of approximately 1,900 residents and are one of the smallest units for which public census data is available, which is an appropriate unit for analyses of neighborhood effects (Diez Roux, 2001).

Obtaining Base Maps

Working in countries without a long tradition of digital mapping often means constructing digital maps from scratch, by venturing out on foot to map with global positioning system (GPS) machines or by digitizing paper maps, satellite, or aerial photos. We were fortunate to be able to obtain from the Instituto Nacional de Estadística, Geografía e Informática (INEGI) – National Institute of Statistics, Geography, and Informatics – of Mexico computer aided design files of the Tijuana municipal area demarcating colonias and city streets. These were then geo-referenced

by the researchers using ArcGIS 9.0 (ESRI corp., Redlands, CA, USA). Additional geographic layers were obtained from local sources, such as the Tijuana Instituto Municipal de Planeación (Municipal Planning Agency). Even with these resources, the rapid growth rate of the city (roughly 5% per year) (INEGI 2000b) presents a challenge in obtaining digital boundary and street data for new neighborhoods.

Mapping Individuals

Perhaps one of the most challenging aspects of mapping in any substance-use study is obtaining individual-level positional data. Over half of the *El Cuete* phase II sample population (55%) was homeless. Even for those with a fixed address, there is no regular system of addresses/street names. For example, houses on a given street may not be numbered sequentially. For this reason, creating a digital street address database, such as Streetmap USA (ESRI corp., Redlands, CA, USA), and performing computerized geocoding for Tijuana is infeasible.

Our strategy in responding to these challenges initially began with asking participants for the name of the neighborhoods where they live or inject drugs. While colonia names are not standard and personal concepts of colonia boundaries may vary from official demarcations, these data have allowed us to generally assign participants to one or another section of the city. A weakness of such data is that it is not very powerful in comparing trends between colonias if the number of participants assessed per colonia differs greatly, which is usually the case with respondent-driven sampling and the nature of the drug use scene in Tijuana. A strategy to obtain more precise data was to ask for the cross-streets nearest to where participants spend most of their time. However, in phase II, only 34% listed more than one nearby street. Further, except for a small percentage of cases, obtaining GPS waypoints of where participants live or inject was largely ruled out due to concerns for the safety of the researchers trying to obtain those data.

Most of the participants in our study travel around the city on foot and have very good mental maps of their immediate neighborhoods. In Phase III, we have begun to tap into this knowledge by asking participants to identify the areas they live, use drugs, earn money, or buy drugs by pointing to specific locations on paper maps of each colonia of the city. This strategy is quite successful after a few landmarks or main roads are pointed out. As many of our field staff are former IDUs or work as health promotoras (health promotion field workers) in neighborhoods where drug use is common, they are comfortable in assisting with mapping. We have obtained data using similar methods in other settings, such as showing aerial photos of neighborhoods to study participants.

Many of the homeless in Tijuana live in one of the few parts of the city where they are able to find shelter – the Tijuana river bed. For participants living in the canal, we have taken advantage of the numbering system of portals (pipe drains) along the canal's length (Fig. 3.1A). Participants usually know the portal number closest to where they live, which enables us to link this information to GPS waypoints for these portals.

Fig. 3.1 Images portraying aspects of the urban environment in Tijuana. The numbering system of portals (pipe drains) along the Tijuana River canal facilitates mapping of homeless project *El Cuete* participants who live in the canal (Panel A). In colonia Zona Norte, it is common to observe injection drug users openly injecting near by the fence that separates Mexico from the United States (Panel B).

A number of ethical issues arise when collecting detailed location data on marginalized populations for whom we are also collecting sensitive health and behavior data. Although participants provide information willingly and risk of accidental release of data is fully explained in the informed consent process, to safeguard such information, no personal identifiers are used on paper nor digitized maps. All mapping results are aggregated or the scale decreased so that individual positions can not be determined, electronic files are password protected, and results of our study are shared with healthcare personnel, non-governmental organizations, and other health researchers only for the purpose of improving healthcare access and increasing understanding the risk environments faced by participants.

Characteristics of Neighborhoods

Neighborhoods are potentially important determinants of health for reasons that have to do both with their demographic composition and with the specific environmental context (Diez Roux 2001; Mitchell, Dorling, and Shaw 2002; Oakes 2004; Sampson 2003). Composition refers to the characteristics of people inhabiting a

neighborhood. To the extent that neighborhood residents are poor and have poor health, for example, their behavior may negatively affect the health behavior of other residents, even beyond their own characteristics. Context refers to environmental characteristics that are exogenous to the demographics of residents. Proximity to polluted water or polluted air and inadequate health infrastructure would be examples of this. In Tijuana, we can note that living in a drainage canal represents the kind of environmental context that is conducive to poor health outcomes. Strategies for obtaining neighborhood-level data are discussed in the following sections.

Neighborhood Disadvantage

Neighborhood disadvantage is a demographic compositional measure of social disadvantage within the confines of a traditional neighborhood or amongst residents within a defined census tract; it is usually designed to reflect the constructs of area income and wealth, education, occupation and employment, and socioenvironmental characteristics related to area crowding, stability, and housing (Diez Roux 2001, 2004; Diez-Roux et al. 2001; Mitchell et al. 2002). A study by Galea et al. found neighborhood disadvantage to be a significant predictor of frequency of injection drug use, even after controlling for individual-level risk factors (Galea, Ahern, and Vlahov 2003). Although Galea's study did not explore causation, it is believed that injection drug use may be a way of coping with the psychosocial stress of living in highly disadvantaged neighborhoods. Conversely, it is theorized that concentration of IDUs may be higher in disadvantaged neighborhoods due to migration into the area by IDUs from wealthier neighborhoods in order to escape from social controls (Galea et al. 2003).

A recent study comparing IDUs from economically advantaged and disadvantaged neighborhoods found that the former were more likely to get syringes from a single source and also more likely to inject at home, rather than in a social setting, such as a shooting gallery (Buchanan, Shaw, Teng, Hiser, and Singer 2003). Interestingly, the same study showed a disadvantage for residents in wealthier neighborhoods in that they were much less likely to come into contact with outreach workers (Buchanan et al. 2003).

In beginning to build a GIS model of the risk environment for Project *El Cuete*, census data were obtained from INEGI that provide information on a number of colonia-level economic and social indicators. A full census is conducted every 10 years in Mexico so characteristics of colonias undergoing rapid migration or changes in infrastructure may not fully reflect current conditions. However, certain census variables, such as data on available health services, are updated annually and Mexico also conducts a mid-decade mini-census. INEGI census data have been previously used to calculate a "social well-being index," similar to neighborhood disadvantage but at the municipal (county) level, which was subsequently compared to morbidity levels for certain diseases (Ochoa-Diaz Lopez, Sanchez-Perez, and Martinez-Guzman 1996). The latest colonia-level Tijuana census in 2000

collected 227 variables on neighborhood characteristics such as percent unemployed or underemployed, average number of occupants per room, education level, percent receiving less than minimum wage, and number of houses with electricity or indoor plumbing. We are defining neighborhood social disadvantage based on a combination of these census-derived variables, referencing recent work by Diez-Roux (Diez Roux 2001; Diez-Roux et al. 2001). Additional data [e.g., road conditions, "broken window" index etc. (Cohen et al. 2000; Cohen, Farley, and Mason 2003)] are being garnered by taking a number of field measurements in the colonias in which most of our participants are clustered, and by comparing remotely sensed imagery of these neighborhoods. One of the coauthors has performed similar analyses of remotely sensed imagery of Accra, Ghana in order to characterize the built environment by developing a "slum index" for that city (Weeks, Hill, Getis, and Stow 2006).

Mobility and Injection Drug Use

A major challenge to the study of drug using populations is their mobility. When it comes to applying GIS tools to such a population, the difficulties of assigning a fixed "place" become even more evident. Exploring and understanding mobility, however, can lead to a better understanding of the dynamics of drug use trends and spread of disease, and guide the targeting of public health measures.

Local Mobility and Social Networks

Social networks and cultural factors, including knowledge, beliefs, and customs, may affect acceptability of drug use, injection practices, chance of encountering HIV-positive persons, and utilization of drug abuse treatment (Kottiri, Friedman, Neaigus, Curtis, and Des Jarlais 2002). By using data regarding who recruited whom, garnered from our respondent-driven sampling technique, we are able to use GIS to compare the spatial distribution of "seeds" and their referrals. One hypothesis to be tested is whether those who recruit a greater distance from their neighborhood will have a higher prevalence and incidence of blood-borne infections, based on their likely role as a bridge between social networks.

Only 53% of the *El Cuete* Phase II participants lived and injected in the same neighborhood. This is an important consideration in the study of the risk environment of an individual since, while one may live in a relatively safe area close to services, a subject may be spending most of his/her time in a riskier area. Homelessness and local mobility also means that participants will likely move during the course of longitudinal studies. For this reason, in Phase III of the study, we are collecting locator information every 3 months during the 18 months of follow-up. Not only does this assist in tracking down participants due for follow-up visits but it also enables us to explore temporal changes in the risk environment.

National Mobility

Mobility is not just local. In the United States, at-risk youth are known to travel throughout the country and IDUs, in particular, are known for their migratory nature (Jones, Davidson, Bisset, and Brettle 1988; Perlis, Torrico, and Settembrino 2002). The case is no different here. In fact, Tijuana, as a rapidly growing border town, attracts migrants from all parts of Mexico and Latin America. Proximity to the United States has created economic opportunities that attract migrants from other areas of Mexico, as reflected in the fact that over half of Tijuana's population in 2000 was born outside of the state of Baja California (where Tijuana is located) (INEGI 2000b). In a survey of homosexuals/bisexuals, prostitutes, and prisoners in Tijuana in 1991, only 22%, 5%, and 21%, respectively, originated in the Baja California region (Güereña-Burgueño, Benenson, Bucardo Amaya, Caudillo Carreno, and Curiel Figueroa 1992). In the case of *El Cuete* participants, although 76% had resided in Tijuana for at least 5 years, 70% were born outside of Baja California. Of these, 18% had come to Tijuana intending to cross to the United States and 20% ended up in Tijuana after deportation from the United States. This has important implications for health as Mexican migrants who have tried unsuccessfully to cross the border into the United States often feel of a lack of identity or attachment; many harbor a distrust of local officials, thus discouraging healthcare or treatment-seeking (Montiel-Hernandez, Muniz, Baez-Villasenor, and del Rio 1996).

In characterizing drug use trends in Mexico in general, spatial relationships to drug trafficking routes may also put certain neighborhoods and cities more at risk than others. This phenomenon has been documented in Brazil along major highways used for drug trafficking (Bastos et al. 1999), in overland heroin routes in Southeast (Beyrer et al. 2000) and Central Asia (Parfitt 2003), and in parts of Nigeria which have become transit points for heroin trafficked by air (Adelekan and Stimson 1997; Stimson, Des Jarlais, Ball, and Organization 1998). Similar patterns are seen in Mexico, where, for instance, drug use prevalence is two to three times the national average in border cities located along drug trafficking routes to the United States (SSA 1998). The state of Baja California also has the highest cumulative national AIDS incidence, following only Mexico City (CONASIDA 2004). Figure 3.2 shows the relationship between drug of primary impact for drug treatment admission and major methamphetamine producing states. The concentration of methamphetamine production in western Mexico is reflected in higher methamphetamine use in the West.

Cross-Border Mobility

International mobility and living in a border region between nations with disparate laws, customs, and healthcare should also be considered when mapping "place" in drug use studies. Migration has been linked to lower socioeconomic status, power inequalities, social and cultural alienation, a breakdown of family units and fear of deportation and violence (Brockerhoff and Biddlecom 1999; Massey, Arango,

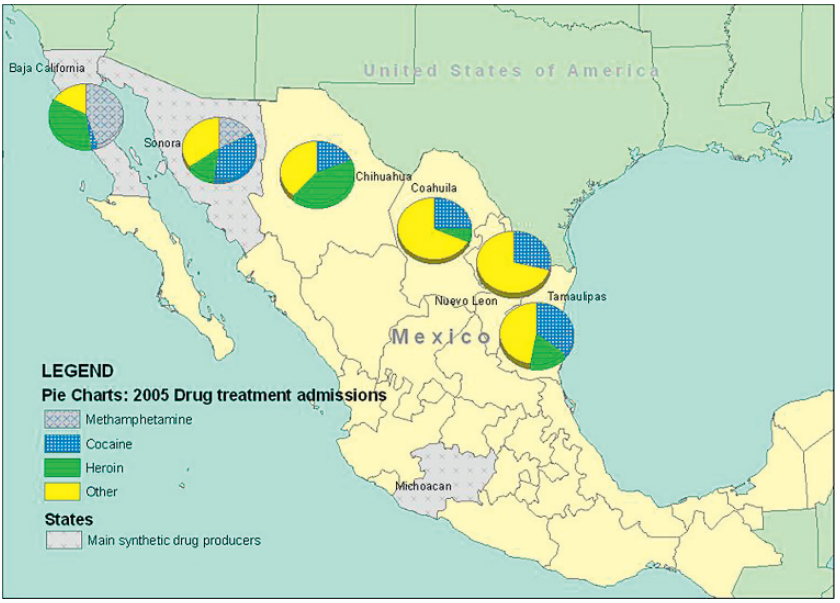

Fig. 3.2 Map of 2005 drug treatment admissions in Mexican states bordering the United States. Pie charts above each of the six Mexican states bordering the United States show the percentage of drug treatment admissions by primary drug used. The "Other" category includes marijuana, inhalants, alcohol, tobacco, and a variety of veterinary products. Major synthetic drug producing states are shaded

Source: Treatment data were compiled from the Mexican Addiction Epidemiologic Surveillance System or SISVEA (Maxwell, Cravioto, Galvan, & Cortes, 2005; SSA, 2002). Data on main synthetic drug producing states were derived from the Sistema Estadistico Uniforme para el Control de Drogas (SEUDC) (PGR, 2000). (See also Plate 1 in the Colour Plate Section)

Hugo, Kouaouci, and Pellegrino 1994; Peterson 1958; Rachlis et al. 2007). Often, drug trafficking takes place in regions where there are porous borders and previous research suggests that border regions can be magnets that heighten HIV susceptibility through social disruption and the coming together of vulnerable populations including IDUs and commercial sex workers (Lyttleton 2002; Organista 2004; Rhodes 2005).

The San Ysidro border station between Tijuana and San Diego is the busiest point of entry along the US/Mexico border (indeed, in the world) with up to 50,000 vehicles and 25,000 pedestrians crossing the border at this point each day (INEGI 2000b; US General Services Administration 2006). In effect, the border is an ambiguous line, failing to fully separate populations that have so many social, economic, and cultural ties. IDUs are known to congregate in the neighborhoods near the international boundary, which are more difficult for police to patrol due to structural barriers such as high walls and busy roadways (Brouwer, Firestone, Lozada, Magis-Rodríguez, and Strathdee 2005) (Fig. 3.1B).

In applying GIS to this unique drug scene, we are exploring whether frequency of border crossings and the distance between a drug user's residence and the

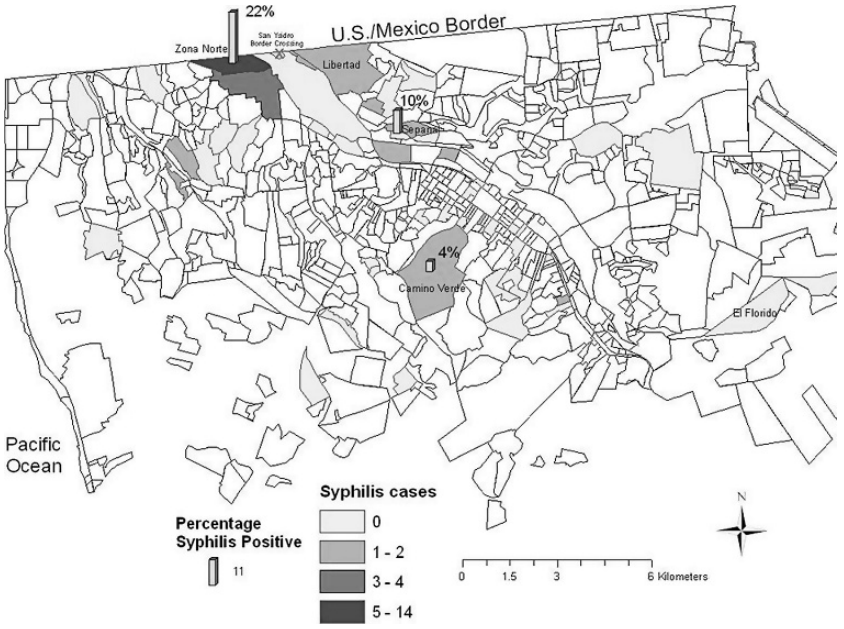

Fig. 3.3 Distribution of syphilis-positive project *El Cuete* participants, 2005 ($n = 220$). Colonias of residence of syphilis-positive project *El Cuete* participants are shaded according to how many cases live in that colonia (Note: values are not normalized by number interviewed per colonia). Height of bars represents percentage of participants positive for syphilis at each of three interview sites. Syphilis was higher nearer the border (χ^2 for trend, $P = 0.002$) even when adjusting for age, gender, and prevalence of commercial sex work (Frost et al., 2006)

Mexico/US border is related to type of drug used and prevalence of blood-borne infections. In preliminary analyses, we have already seen an increased prevalence of syphilis in our interview site closest to the border, while it was lowest furthest from the border (Fig. 3.3). However, it is not possible to fully distinguish between spatial distances and neighborhood effects. The border area is the oldest part of Tijuana and one of the most run down; it also has a lot of dead-end streets and a busy highway which may be among the reasons why it is not developed and is a haven for shooting galleries. Therefore, any findings based on spatial distance from the border will have to be considered in light of the characteristics of neighborhoods near and far from the border.

Mapping Infection Distribution and Proximity to Safe/Risky Places

Proximity to risky or protective areas has been shown in a number of studies to be related to risk behaviors and treatment seeking (Mason et al. 2004; Scribner et al. 1995). We detail below a few environmental factors whose distribution can be mapped and compared with IDU behaviors and infection prevalence.

Distribution of Shooting Galleries

The IDU social environment in Tijuana is highly influenced by attendance at shooting galleries [picaderos], where injection norms, such as renting and/or buying used needles and injecting on the premises, are often determined. The Mexican government reportedly closed 1,400 picaderos in Tijuana in 2002 (Oficina de la presidencia de la republica 2002), but over 200 are believed to currently exist in the city. During phase II of project *El Cuete*, we found that 69% of participants had injected in a shooting gallery in the past 6 months, and 57% claimed it was the place they most often injected (n = 222). Shooting galleries are uncommon in western US cities, but are widespread in the eastern US and in Puerto Rico, which have experienced severe IDU-associated HIV epidemics (Latkin et al. 1996; Noriega-Minichiello et al. 2002; UNAIDS 2004).

By virtue of their clandestine nature and territorial issues in drug trafficking, mapping of shooting galleries or "picaderos" can be dangerous. However, participatory mapping method with IDUs, especially those who frequent or manage picaderos, is one strategy by which to gain information on the density of these venues in neighborhoods. Inquiring through interviews about the estimated number of picaderos in the neighborhood where a participant injects can provide estimates of picadero distribution. This information will allow us to explore whether colonia shooting gallery density is related to the risk of acquiring a blood-borne disease.

Harm Reduction Resources

Risky injection behaviors, such as needle and syringe sharing, are likely enhanced when supportive services, such as needle exchange programs (NEPs) or pharmacies, are lacking (Rhodes et al. 2003). To reduce drug-related harm, services must not only be available, but also be accessible. Studies in Vancouver and New York City found that IDUs who lived further from NEPs were less likely to use them or properly dispose of syringes (Rockwell, Des Jarlais, Friedman, Perlis, and Paone 1999; Wood et al. 2004). In a similar situation, IDUs in Baltimore who had to travel longer distances were less likely to enter drug treatment programs (Strathdee et al. 2006).

As in most Latin American countries, few non-governmental organizations in Mexico appear to be involved in prevention activities aimed at drug users (Magis-Rodríguez, Marques et al. 2002). Harm reduction programs, especially NEPs, have often been met with opposition within the Mexican government. To our knowledge, there is only one documented NEP in all of Mexico, which is operated in Ciudad Juárez (Ramos 2000). Although no formal NEPs currently operate in Tijuana, there are more than 1,600 registered pharmacies where IDUs can theoretically purchase syringes legally over the counter. The purchase of needles and syringes in Mexico does not require a prescription. However, in areas of high drug activity some pharmacists limit sales of needles and syringes to those who appear to be drug users, by either saying that they have "run out" of the type of needles popular with drug

users or by artificially raising prices (Strathdee et al. 2005). Qualitative studies in other settings have identified pharmacists' lack of knowledge regarding the laws and regulations governing syringe sales as a barrier (Blumenthal, Springer, Jones, and Sterk 2002; Wolfe, Amelunxen, Torres, Jenison, and Churchill 2002). Store policies or commercial considerations may also be at play. Using the Tijuana municipal pharmacy registry, which is updated annually, we are able to map pharmacy density per colonia and explore whether it affects direct or indirect syringe sharing by IDUs.

Legal Controls

While legal controls do have their place in society, enforcement of laws restricting drug use can have unintended consequences and even worsen the risk environment for disease transmission. Studies in Hong Kong and Thailand found that increased enforcement of laws prohibiting the opium trade and prosecution of users in urban areas led to increased prices for opium, and subsequent transition from opium smoking to injection of heroin (Westermeyer 1976). Thus, a problem that was primarily composed of drug use itself was compounded with all the health threats of blood-borne pathogens through higher rates of parenteral drug use.

A recent study in Togliatti, Russia, which has seen an explosion of HIV among IDUs, found fear of police detainment to be associated with needle and syringe sharing (Rhodes et al. 2003). In various contexts, fear of police detainment or arrest can discourage IDUs from carrying needles, leading them to share needles at the point of sale or inject with rented needles in shooting galleries (Harvey et al. 1998; Koester 1994; Rhodes et al. 2003; Strathdee, Zafar, Brahmbhatt, Baksh, and ul Hassan 2003). This practice can promote disassortative mixing, which in turn can increase the risk of transmission of blood-borne infections. Prescription laws, such as those limiting access to clean needles, can also increase risk of blood-borne infections. Freidman et al. have shown HIV prevalence in the United States to be related to local prescription laws (Friedman, Perlis, and Des Jarlais 2001). Both internal and external legal controls have helped to shape the drug scene in Tijuana. Efforts to crack down on drug trafficking across the Mexico/US border following September 11, 2001 led to reported increases in heroin availability and decreases in prices in Mexican border towns (Chavira 2003; Medina-Mora and Rojas Guiot 2003). In-depth interviews from phase I of Project *El Cuete* revealed that policing practices negatively affected accessibility to sterile syringes and promoted use of shooting galleries as it was common for IDUs to be arrested for carrying used or sterile syringes (Miller et al., 2008).

Tijuana is divided into seven administrative delegations, with policing areas based on sub-delegations (INEGI 2000a). Using municipal data, we will map locations of police delegations and stations and overlay neighborhood crime statistics in order to examine the impact of these influences on injection behaviors and risk of blood-borne infection. With the aid our study partner, COMUSIDA, and data from the Centro de Integracion Juvenil [juvenile hall], we are able to map "high risk"

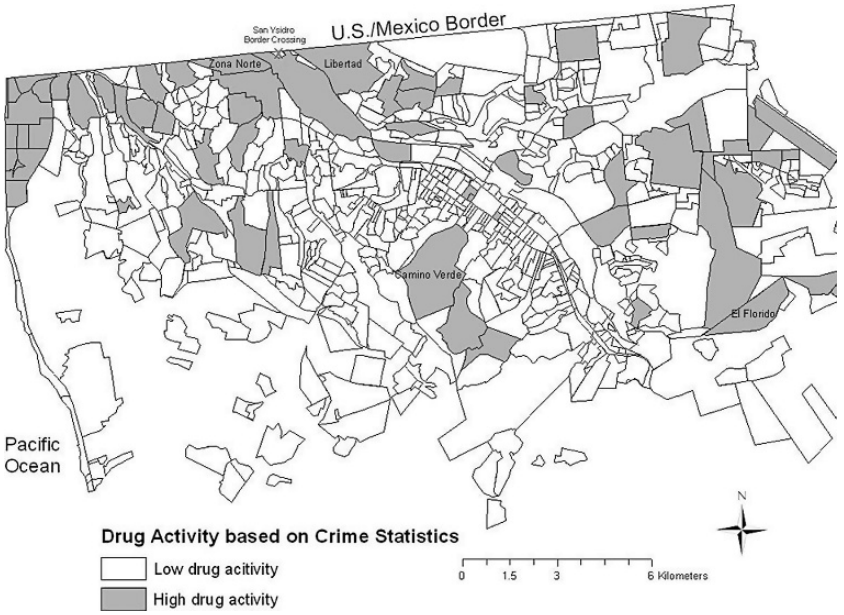

Fig. 3.4 Colonias with high drug activity, Tijuana, Mexico, 2005. Colonias identified as areas of high drug activity based on year 2005 local crime statistics for sale and consumption of illicit drugs Source: Mexican Department of Justice and COMUSIDA, A.C. Tijuana, Mexico

zones of the city according to neighborhood crime statistics for assaults, burglaries, vehicle thefts, and sale and consumption of drugs. Figure 3.4 shows a map containing estimated locations of high- and low-density injection drug use colonias based on these crime statistics.

Distribution of Drug Treatment Programs and Health Services

Lack of health and supportive resources has been repeatedly cited as a primary reason for not seeking drug treatment. For instance, an assessment of barriers to drug abuse treatment in Mexico and the United States found the principal obstacles to include lack of treatment "slots" and ignorance regarding facilities (Appel, Ellison, Jansky, and Oldak 2004).

Drug use in most areas of Tijuana occurs in an atmosphere of limited access to support services (Magis-Rodríguez, Marques et al. 2002). There are an estimated 20 residential drug treatment programs in Tijuana with a capacity to treat 3,500 persons per year (Trillo 2002). Taking into account estimates of the number of substance users in the city, however, the coverage of these programs is believed to be less than 20%. In light of this deficiency, some drug users report traveling to the United States to seek drug treatment that is considered unavailable in Mexico (Ferreira-Pinto and Ramos 1997; Ramos 1990).

The Mexican government is committed to providing treatment for all those with HIV/AIDS and has increasingly taken efforts to provide services to drug users, yet treatment often does not reach targeted populations. In applying GIS to Project *El Cuete*, we will use handheld GPS devices to map the locations of drug treatment programs, health centers, and IDUs' residences and injection neighborhoods. At the same time, we will collect other attributes associated with each location, and evaluate whether proximity to treatment centers is related to past drug treatment seeking and participation as well as prevalence of blood-borne pathogens.

Implications/Future Directions

In this chapter, we have endeavored to demonstrate the feasibility of applying GIS to the study of the IDU risk environment. A goal of our work in Tijuana, similar to health projects in other areas, is to eventually convert our GIS database into an internet-based tool to be available to those seeking drug abuse treatment and to facilitate decision making by policy makers and service providers trying to find the best way to allocate sparse resources. GIS mapping has already helped guide us to the neighborhoods which our mobile study clinic, the *Prevemovihl*, should visit. A limitation of ecological studies is that it is difficult to distinguish between the effects of the social/spatial context itself versus the characteristics of individuals making up the area under study. However, new techniques in multi-level analysis allow one to distinguish between the relative contribution of within- and between neighborhood effects, as well as estimating how much variability at the contextual level is due to individual factors (Diez Roux 2001, 2004; Oakes 2004). Although there are many limitations in trying to obtain accurate positional data in drug use studies, applying GIS to this field will substantially improve understanding of interactions between drug users and the risk environment over what is currently known.

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