HIV, SEXUALLY TRANSMITTED INFECTIONS, AND INDOOR COMMERCIAL SEX WORKERS: APPLICATION OF SOCIAL NETWORK ANALYSIS TO ASSESS THE POTENTIAL FOR DISEASE PROPAGATION

by

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ABSTRACT

Keywords: Social network analysis, HIV/AIDS, sexually transmitted infections, commercial sex workers

Objectives: The study objectives were: (a) to determine the structure and characteristics of the sexual networks of the indoor commercial sex industry and (b) to determine the potential for sexually transmitted infection (STI) transmission to the general population.

Methods: In-person, structured interviews were conducted with 49 indoor female sex workers (FSW) from seven indoor sex establishments in the Greater Vancouver Regional District. Interviews elicited demographic, sexual behaviour, and sexual health information from respondents (egocentric data), information about respondents’ sexual relationships (dyadic data), and proxy demographic and sexual behaviour information about respondents’ most recent 5-10 sex partners (network data). Social network analysis (SNA) was used to examine the network structures and characteristics.

Results: FSW respondents provided data on 234 sexual partners, 205 (88%) of whom were commercial clients. There was a single, connected sexual network of 553 individuals with a high frequency of dense, cyclic microstructures. There was a high degree of sexual bridging between sex establishments, between age and ethnic groups, and between the commercial sex core and the general population. Two types of clients could be categorized as high-risk from the network perspective, including those who bridged between sex establishments and those who were house regulars (clients who had sex with all the workers at an establishment). All known HIV and STI infection in sexual partners was in high-risk clients.

Conclusions: SNA is a valuable tool with which to examine STI risk at the individual, dyadic, and network levels. The indoor commercial sex industry likely comprises a fully connected sexual network. The structural properties of the network suggest that if STI were introduced, even a small decrease in the amount of condom use or an increase in the number of infected individuals could support the transmission of these pathogens within the commercial sex network and to the general population. SNA also provides the tools with which to plan STI
control programs, including the identification of prominent network members who may be important targets for STI control strategies.
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CHAPTER 1
BACKGROUND AND LITERATURE REVIEW

1.1 Introduction

The indoor commercial sex industry operates clandestinely in Canada and employs female sex workers (FSW) under the guise of legitimate businesses, such as massage parlours, body rubs, and escort services (1;2). FSW have long been viewed as a community at high risk for acquiring sexually transmitted infections (STI) and the human immunodeficiency virus (HIV) and as a reservoir for transmitting infection to the general population (3-8). However, STI do not originate in FSW, nor do they transmit infection among themselves.

Studies that identify risk factors for STI transmission are guided by knowledge of the transmission dynamics of infectious disease. Transmission dynamics refers to the factors and the interplay between them that determines pathogen spread. Most empiric studies take the standard approach of collecting data on individual-level demographic and behavioural factors, such as age, number of sex partners, commercial sex work, concurrent sex partners, socioeconomic status, prior STI infection, condom use, and drug-using behaviours (9-12). They generally apply analytic models to determine the independent predictors of outcomes such as STI prevalence, incidence, morbidity, and mortality. These data are also used to parameterize population components of deterministic or stochastic mathematical models to forecast epidemic spread through populations and the impact of various prevention and control strategies (9;13). Findings from these types of studies are used to develop prevention strategies targeted at individuals or groups who possess these high-risk attributes or behaviours, such as FSW (14-16).

Over the past two decades there has been a shift in the paradigm of how STI transmission is studied. Epidemiologists looked towards the social sciences and started applying the theoretical and empirical frameworks of social network analysis (SNA). SNA theory posits that risk cannot be adequately explained by individual-level risk behaviours and demographic characteristics alone. Rather, risk is dependent on relationships among people and the topology of how

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1 Throughout this thesis, the term STI will be used to imply inclusion of sexually transmitted HIV, unless stated otherwise.
individuals are connected within a group. Network parameters are also added to mathematical simulation models (17-19).

Although the literature suggests that indoor FSW in developed countries may have low levels of HIV, they may still be at high risk for acquiring and transmitting other STI due to the structure and attributes of their sexual networks. However, most FSW research does not include indoor workers, despite comprising an estimated 80% of the Canadian commercial sex industry (20). Therefore, the overall goal of this thesis was to apply SNA to explore the sexual networks that form within the indoor commercial sex industry and to examine the implications for disease propagation.

1.2 Thesis Organization

This thesis is organized into five chapters. Chapter 1 includes the introduction, literature review, objectives, and hypotheses. Chapter 2 is a version of a manuscript that describes the operational methods used to gain access to the study population for the purposes of data collection. Chapters 3 and 4 are versions of manuscripts that present the main analytic findings of the research. Finally, Chapter 5 is a summary and discussion of the main findings, the limitations, the recommendations, and future research directions.

1.3 Literature Review

The literature review is organized around three main topics. The first section provides the background of the study of STI transmission in terms of transmission dynamics. Although this thesis does not strictly apply the more traditional approaches to STI epidemiological inquiry, this background forms the foundation upon which SNA builds to enrich our understanding of the forces at play in STI epidemiology.

The second section deals with SNA and provides a description of the conceptual framework, the network-related consequences to infection transmission, and the application of SNA to the field of STI epidemiology. More attention is paid to describing the conceptual framework and historical development of the field because it is a relative newcomer to the field of epidemiology and it is not widely understood. Furthermore, although the contribution of SNA to the
understanding of transmission dynamics is becoming well recognized, its mainstream application
to epidemiology remains under development.

The final section provides a brief review of the literature on the STI risk environment of FSW in
general and of the indoor sex work environment in particular. The role of prostitution in the
transmission of STI and issues surrounding risk for the population are reviewed.

1.3.1 Transmission Dynamics

In order to develop STI prevention programs and to design and interpret research studies on
determinants of transmission, an understanding of transmission dynamics is required. This
section provides an overview of the literature related to transmission dynamics. Specific
attention is paid to determinants of the transmission rate within the framework of the
reproductive number model, the core group hypothesis, and the contributions of the concepts of
bridging, sexual mixing, and concurrency.

1.3.1.1 Determinants of Transmission: The R₀ Model

Anderson and May (21;22) summarized several key characteristics of STI epidemiology that
distinguishes it from most other infectious diseases. First, unlike infections such as influenza
and tuberculosis, only sexually active individuals are at risk for STI acquisition. Second,
increasing the population density will not necessarily impact the rate of new infections, unless
the increase in density in some way increases the level of sexual contact within the population.
Third, many STI possess a carrier phenomenon whereby many infected individuals may be
asymptomatic, do not seek treatment, and remain infectious for extended periods of time.
Fourth, most STI impart little or no immunity, resulting in recovered individuals returning to the
susceptible pool. The exceptions are those infections that impart acquired immunity, such as
hepatitis B, or where remission of infection does not occur, such as HIV and genital herpes.
Fifth, there is great variability in the incubation period within groups of infected persons that is
influenced by genetic variability in the host and agent. Sixth and finally, heterogeneity in sexual
behaviour directly influences variability in STI infection patterns and transmission rates both
within and between different populations.
Mathematical models are commonly used to develop an understanding of STI transmission dynamics and to facilitate the interpretation of observed data. Cooke and Yorke (23) developed the first model of gonorrhoea transmission dynamics that considered some of the unique epidemiologic features of STI. Like many other STI, because gonorrhoea does not impart acquired immunity, prevalence saturation is not limited by rising levels of immunity within the population, but rather by increasing the density of infected individuals, termed preemptive saturation by Yorke et al. (24). That is, sexual contact between an infected individual and a sexual partner cannot result in transmission if the partner is already infected. Yorke et al. (24) postulated that, because in the United States at any given time only two percent of an average infected person’s sexual contacts are already infected, preemptive saturation can not be a significant factor if the population is viewed as a single, homogeneously mixing group. This gave rise to the notion of heterogeneity in sexual activity within populations, in that there are many distinct subgroups that differ on important characteristics, such as average number of sex partners, sexual practices, age, ethnicity, socioeconomic status, and other factors. They demonstrated that a core group of about 500,000 highly sexually active individuals with a high prevalence would have preemptive effects that could explain the observed prevalence data in the United States. If each core group member infected on average more than one susceptible individual over the course of the infection, and each non-core group member infected on average less than one, then at equilibrium, the two combined rates produced one new infection for each current infection, thereby maintaining endemicity.

The concept of a basic reproduction number, or \( R_0 \), refers to the number of secondary infections that one case can reproduce during the period of infectivity in a completely susceptible population (25). Originally used to refer to birth rates (26;27), the notion of a reproduction number in infectious disease epidemiology was first introduced in 1952 by Macdonald who studied malaria (28). It was subsequently made popular through the Dahlem Workshop organized by Anderson and May in 1982 (29), and its mathematical framework was published by Diekmann et al. (30). May and Anderson’s basic version of the equation is most commonly used to demonstrate the basic reproduction number

\[
(R_0): R_0 = C\beta D,
\]

where \( R_0 \) is the number of secondary cases generated by an index case in a fully susceptible sexually active population, \( C \) is the weighted average rate of new sexual partner acquisition, \( \beta \) is the probability of transmission per partner contact, and \( D \) is the time an infected person remains...
in the population (21;31). In order for an infection to persist in a population, the $R_0$ coefficient must be equal to or greater than 1.

The transmissibility of an agent $\beta$ varies by pathogen (Table 1.1) and is influenced by the type of sex act (e.g., penile-vaginal, penile-anal, etc.), the variability of number of sex acts per partnership per unit of time, the distribution of phenotypes of the infectious agents, and the host immunity (22). The efficiency of transmission is also affected by co-infection with other STI. This is particularly important in the context of HIV, because STI infection may render the epithelial surface of genital tissues more susceptible to invasion (32;33).

The duration of infectiousness $D$ depends on the natural history of the pathogen and the care-seeking behaviours of the infected individual (Table 1.1). Infectiousness varies over the period of incubation, depending on the STI. The duration of infectiousness for HIV, for example, is for the infected individual’s lifetime, but it can vary considerably depending on time since infection, viral load, and co-infection with other STI (34). Medical treatment of curable STI reduces the duration of infectiousness, but care-seeking behaviours depend on presence of symptoms that are often absent – for example, gonorrhoea or Chlamydia in women (35).

The behavioural component $C$ is very important in terms of STI prevention. The average rate of sexual partner change over a period of time within a population is a strong predictor of STI epidemic growth (36;37). Brunham et al. (38) showed that a mean rate of partner exchange of 0.67 per month resulted in a reproductive rate of 2 for gonorrhoea and 3.6 for Chlamydia, assuming that the frequency distribution of sex partners was normal. In a closed, homogeneously mixing, sexually active population the epidemic potential of an STI depends only on the basic $R_0$ of the infection (31). However, sexual behaviour is not homogeneous, and $C$ is affected by the variability of sexual partnering patterns within the population. May and Anderson (9) modeled the fraction of a population eventually infected by HIV given different $R_0$ and variance in number of new partners per unit of time and the mean number of sex partner changes $m$ weighted by the population variance $\sigma^2$: $C = m + \sigma^2/m$. They demonstrated that, with an $R_0$ of just over 1 in a homogeneously mixing population (i.e., a variance coefficient of 0), most of the population would eventually become infected. With a higher degree of heterogeneity (e.g., a variance coefficient of 3.2), very little spread would occur (31). The variability of $C$ depends disproportionately on the highly sexually active subgroup, or core group, as described
earlier by Yorke et al. (24). Brunham (39) argued that, although core group members may be defined as those with a high rate of partner exchange, their mere presence in a population is insufficient for STI persistence and they must also be highly connected. In this way they become reservoirs for STI in the greater population by allowing opportunities for transmission to new hosts.

1.3.1.2 Core Groups

Research from the mathematical, clinical-epidemiologic, and socio-cultural fields has further refined the core group hypothesis (40-42). For example, Anderson and others (36) included the effect of different subgroup mixing patterns through sexual networks and by age classes when modeling the epidemic trajectory of HIV (43). Stigum et al. (40) included mixing patterns and the effects of migration in the spread of gonorrhoea, Chlamydia, and HIV. Dietz and Hadeler (44) modified the classical $R_0$ model to allow explicitly for the formation and dissolution of pairs, the description of multiple contacts per partner, the rate at which new partners are contacted, and the rate of sexual contacts during the partnership. Dietz and Tudor (45) generalized the models to allow for up to two concurrent partnerships.

The mathematical models described above, and others, condense the many factors associated with STI transmission and describe in quantitative terms the proximate determinants of infection within a population. They can be used to forecast the spread of STI and the effect of interventions, and can provide a natural framework for incorporating statistical inference methods (13;17;42;46). One of the limitations of mathematical models is that they identify target groups characterized only by risky behaviour (e.g., core members with disproportionately high activity). However, there is a distinction between these target groups and those who can actually be reached for intervention, and between target groups and those with risky behaviour in a high prevalence setting.

Clinical-epidemiologic and socio-cultural perspectives of core group theory worked towards defining accessible core groups to which targeted interventions can be applied. From the clinical-epidemiologic perspective, individuals with repeat STI infections and those residing in specific geographical locations were identified as core group members. STI "repeaters" were first described by Watt in 1958 (47), who noted that a small number of his gonorrhoea patients
accounted for a disproportionate number of cases due to repeat infection. Since then, despite variations in the definition of repeaters, empirical studies have consistently shown that small numbers of individuals represent disproportionately large proportions of diagnosed infections. Some have described repeaters as a core group unto themselves (48-51).

Individuals residing in geographical regions of high STI prevalence are also identified as core group members. For example, Rothenberg (52) demonstrated that 50% of gonorrhoea cases in the Albany area resided in 13% of the census tracts which contained 9% of the total population, and that these census tracts were in poor, inner city areas. Similar findings were reported in Colorado, Florida, and California (53-55). Geographical mapping of STI cases also suggested differences in geographical patterns between different STI, hypothesized to be related to the different biological features and risk factors associated with different organisms (56).

One of the limitations of the clinical-epidemiological perspective is the fact that identification of group members relies on their presentation to clinic settings, and therefore undiagnosed infections, individuals who self-treat, and sexual contacts of cases who are not identified through contact tracing methods are excluded (42;57). Furthermore, some individuals may experience repeated infections acquired from a single partner who has sex with multiple partners. Despite these limitations, clinical-epidemiologically defined core groups are by definition easily accessible and can be targeted for screening, treatment, and educational messages, thereby potentially facilitating behavioural change, reducing ongoing transmission, and reducing repeat infections.

The socio-cultural perspective focuses on individuals with membership in an identifiable group with shared culturally normative behaviours, such as FSW, men who have sex with men (MSM), long distance truck drivers, gang members, migrant workers, and military personnel (42;56;58-60). FSW were labelled a core group almost immediately following the introduction of the concept and, with the exception of MSM, socio-culturally-identified core groups generally include populations at risk in whole or in part due to their sexual affiliation with FSW (4;7;42;60). Some of the limitations of this perspective include difficulties in identifying membership and pejorative labelling. Not all individuals who exchange sex for money, drugs, or other things identify themselves as FSW, and in the context of off-street sex work they may be difficult to locate and access (61). Furthermore, using cultural characteristics to label core
groups can lead to stigmatization of group members, regardless of their actual participation in high risk activities (62;63). Socio-culturally identified groups are nonetheless important because they can be targeted for intervention through non-clinical means and through methods that are culturally and contextually sensitive. Targeted interventions and educational messages may also be disseminated through social networks that exist within culturally-defined groups (64-66).

Although the core group hypothesis goes far in attempting to explain the contribution of behavioural heterogeneity to the persistence and propagation of STI, it is problematic for the study of FSW. STI do not originate within FSW and they do not spread infection among themselves. FSW acquire infection from and transmit infection to their clients, their non-commercial partners, and their needle-sharing partners (67).

1.3.1.3 Bridging

Attempts to model STI beyond the core group construct have included the concept of bridging, described as the formation of links between otherwise unconnected groups (68;69). This concept is important in the understanding of transmission of STI from high prevalence to low prevalence groups and is particularly important in the context of commercial sex work. Bridging provides transmission pathways between high prevalence core groups and low prevalence peripheral groups and has been held responsible for much of the annual incident HIV infections in women in some developing countries. In Thailand and Benin, for example, men who reported FSW contact bridged STI and HIV to their wives or girlfriends, a group that would otherwise be considered low-risk (6;60;70;71).

1.3.1.4 Sexual Mixing

Another important behavioural factor to consider in the transmission of STI is sexual mixing. Sexual mixing refers to who has sex with whom (36). Assortative mixing refers to like mixing with like (e.g., people with high numbers of sex partners who have sex with other people with high numbers of sex partners) and disassortative mixing refers to like mixing with unlike. Random mixing assumes there is no preference in terms of partner selection, except for those with high numbers of sex partners who mix proportionately with others (i.e., they mix more with those with high numbers of partners, moderately with those with medium numbers of partners,
and less with those with low numbers of partners). The most important category of mixing is sexual activity class (i.e., the rate of new partner acquisition).

Anderson (22) refined the basic R₀ model to incorporate mixing by sexual activity class. He proposed that, if a population was stratified into HIV acquisition risk groups and groups defined by high, medium, and low rates of partner exchange (Figure 1.1), the definition of R₀ would be based on the mixing between classes or the broader strata. The reproductive number R(0)ᵢⱼ in group j with susceptible individuals in group i could then be defined by

\[ R(0)ᵢⱼ = cᵢ pᵢ βD, \]

where \( cᵢ \) is the mean rate of new partner acquisition in the group and \( pᵢ \) represents the proportion of the sexual partnerships of someone in group i formed with an individual of the same or opposite sex in group j. Viewed this way, STI could persist in a population even if only one subset of these values was greater than 1. Specifically, the highly sexually active core would likely have an \( R(0)ᵢⱼ > 1 \), whereas other groups would have an \( R(0)ᵢⱼ <1 \). The patterns of infection in the overall population therefore depend on the pattern of mixing between the high- and low-activity groups. Tight assortative mixing leads to multiple, uncoupled epidemics with sequential waves of infection (72;73), and random or disassortative mixing tend to generate slower but larger epidemics because infection is able to bridge between groups of higher and lower risk characteristics (74-76).

Sexual mixing across age and ethnic groups are also important considerations. Age-related mixing provides the opportunity for cross-generational spread of infections (77). For example, female adolescents who have sex with older men are at greater risk for STI (78-80). In the case of HIV, this may act to spread disease in younger women who are of reproductive age (22).

Mixing patterns may explain why different ethnic groups experience different rates of STI. Laumann and Youm (81) showed that white Americans were more likely to demonstrate assortative mixing patterns in terms of numbers of partners, and African Americans were more likely to demonstrate disassortative patterns (i.e., low risk individuals tended to mix with high-risk individuals). In this way, low-risk persons were more likely to come into contact with an infected high-risk person, resulting in relatively high STI rates in African Americans as a whole. As well, because African Americans reported limited mixing with other ethnic groups, STI was confined within their networks. Contact tracing data from Colorado Springs also demonstrated
that disassortative ethnic mixing was a predictor of high $R_0$ for both Chlamydia and gonorrhoea (82;83).

A mixing pattern is defined as the average pattern emerging from the collection of relationships classified per the value of a predetermined attribute of each partner in a pair (17;67). The measure $Q$ is ascertained through constructing a mixing matrix that lists the number and proportion of each type of sexual partnering within pre-defined attribute categories (74;84) (Table 1.2). The formula

$$Q = \frac{\sum_{i=1}^{n} w_i - 1}{n - 1}$$

calculates the sum of the proportions on the diagonal, minus one, divided by $n$ (i.e., in an $n \times n$ table) minus one, to come up with the $Q$ value. $Q$ can range from -0.5 to 1 (depending on $n$), with 1 representing 100% assortative mixing, 0 representing random mixing, and -0.5 representing 100% disassortative mixing.

Most empirical studies reported that sexual mixing patterns were primarily assortative in terms of level of sexual activity – that is, people with a high number of sex partners tended to have sex with other people with a high number of partners and vice versa (80;84-86). An exception was a study conducted in Iceland in a population of MSM experiencing an outbreak of HIV (87). Theirs was a disassortative network in which men with fewer partners tended to mix sexually with those with large numbers of partners. In an STI clinic population in Seattle, although sexual activity class mixing was primarily assortative (84), sub analyses on stratified, individual-based data showed that disassortative mixers with respect to age and ethnicity were more likely to be infected with an STI (88).

1.3.1.5 Concurrency

In addition to the duration of infectiousness of an STI, duration of sexual partnerships and the extent of partnership overlap, or concurrency, play an important role in STI transmission dynamics. Concurrency is defined as a situation in which one or both individuals in a sexual relationship have other partners with whom sexual contact occurs during the original partnership (82). Concurrent partnerships potentiate rapid spread of STI because there is less time lost after transmission waiting for the current partnership to dissolve (69;89;90). For example, a person
with concurrent partnerships can acquire and transmit an STI without gaining new partners (22). Furthermore, concurrency may expand the time/space continuum to allow for more partners. This is particularly salient in the context of STI that have short windows of infectiousness (e.g., gonorrhoea), which require either a high rate of new partner acquisition or an overlap of partnerships to spread.

Concurrency is common. In a population survey in the United States, prevalence of concurrent relationships in adult women was 12% overall, and was highest in 18-24 year old women (23%), previously married women (22%), and Black women (21%) (91). Another large population survey of American adolescents showed that over half reported more than two sex partners and of these, 54% were concurrent (92). Findings from a population survey among 18-39 year olds in Seattle also indicated that 27% of men and 18% of women reported concurrent partnerships (93).

Depending on the prevalence of concurrency in a population, its contribution to epidemic growth ranks with that of co-infections and multiple partners (90). Morris and Kretzschmar (89) designed a model that held constant the total number of partnerships in a population (i.e., the density remained constant) and varied the amount of concurrency. Prevalence of HIV increased with increasing concurrency. The prevalence variance widened as concurrency increased, suggesting that HIV incidence may become less predictable in populations with high levels of concurrency. They demonstrated that the spread of an epidemic can be as much as 10 times that shown in a serial monogamy model. Watts and May (94) developed a deterministic model that incorporated concurrency and differential rates of HIV transmission from new partners versus that from previous partnerships. Their model showed an initial high incidence rate that dropped later in the time period. The greater the proportion of concurrency in the population modeled, the faster the initial incidence rate.

Potterat et al. (95) proposed that one of the main reasons the classic $R_0$ model does not consistently estimate reproductive numbers is because it does not take into account concurrency. Potterat et al. (82) demonstrated this empirically by estimating the basic reproduction number of individuals and groups from community-based Chlamydia contact tracing data and found that, although the overall $R_0$ was 0.55 and few subgroups had a value of over 1, concurrency was the most powerful predictor of transmission. They concluded that their empirical evidence strongly
supported models that factor concurrency in their prediction of reproductive number. Rosenberg et al. (96) conducted a study with adolescents and showed that concurrent partnerships were a significant risk factor for gonorrhoea, Chlamydia, and nongonococcal urethritis (OR 1.6, 95% CI 1.1-2.5).

One of the finer points related to concurrency is its influence on individual-level risk of acquiring versus transmitting STI. Morris (97) pointed out that misclassification can occur using standard logistic regression modeling because a monogamous individual with a partner who has concurrent partnerships will not have his or her infection attributed to concurrency. She argued that concurrency at the individual level should be studied as a predictor of transmission, not acquisition. Potterat et al. (82) demonstrated this empirically and showed that concurrency had an OR of 3.2 (p<0.001) in relation to transmission of Chlamydia. Koumans et al. (98) also found that individuals with two or more concurrent partners were three times more likely to be transmitters.

Whereas STI with short durations may require a core group of highly sexually active individuals who frequently acquire new partners to maintain transmission, for STI with long durations (e.g., HIV), individuals with infrequent partner change may still play an important role (22). Regardless of duration of infectiousness, individuals with more than one concurrent partnership play a central role in transmission.

1.3.1.6 Summary

The preceding section highlighted some of the key factors of STI epidemiology. Most research conducted on STI epidemiology and transmission dynamics use analytic models that are based on the assumption of independence of participants and events. However, this assumption is generally violated because sexual partnerships do not occur at random and individuals involved in STI transmission networks are not independent of each other. New methods are needed that take into account the non-independent nature of sexual relationships and the influences of the broader population in which individuals and sexual partnerships exist. Social network analysis, originating from the fields of sociology and anthropology, is increasingly used to study STI epidemiology because it takes into account individual-, partnership-, and population-level factors.
1.3.2 Social Network Analysis

Studies of STI transmission dynamics traditionally focus on individual-level risk factors such as number of partners and condom use (9;12;99). However, risk cannot be adequately explained by individual-level risk behaviours and demographic characteristics, and behaviour must be put into social context. A relatively new approach, SNA, is a contrast to standard epidemiological methods in that it focuses on the relationships among people and the topology of how individuals are sexually linked within a group. SNA produces a set of statistics that describes quality, density, position, and structure of the relationships (100). The fundamental hypothesis of the network approach is that behaviours – for example, partner choice and sexual practices – take place in a social context, a network of interrelated persons, that influences not only the acquisition of partners, but (also) the risk of disease propagation (101). Network analysis is a device that researchers can use to move beyond analysis of aggregated individual-level data to the study of social relations and their implications for both the individual and the group (102). This section provides a description of the social network conceptual framework, followed by several subsections that describe the application of SNA to STI.

1.3.2.1 Conceptual Framework

1.3.2.1.1 Historical Background.

The concept of social structure dates back to the 19th Century (103), but more formalized development of social network theory did not occur until the early 20th Century. According to Scott (104), this development was conducted by scientists from three main traditions: (a) sociometric analysts, who worked with small groups and developed technical advances in the area of graph theory; (b) Harvard sociologists and anthropologists, who explored interpersonal relationship patterns and cliques; and (c) Manchester anthropologists, who used both of these strands to investigate the structure of communities (104). Moreno is most commonly associated with the term sociometric (104). He investigated psychological well-being as it related to the structure of social configurations and founded the journal, "Sociometry," in 1937. Moreno introduced the sociogram as a means of depicting these configuration structures. Further mathematical development within the field of graph theory used the sociogram to depict
individuals (points, or nodes) and specific relations (lines joining the nodes) as a graph that supported the use of a body of mathematical axioms and formulae to describe the properties of the patterns formed by the lines (105). Cartwright and Harary (105) introduced the notion that large, complex social structures could be deconstructed into small simple structures, such as triads (three points, all connected to each other), and that these smaller structures could be analyzed to understand properties of the more complex networks of which they were a part.

The notion of deconstructing complex networks into their constituent subgroups was also a feature of the work conducted by the Harvard researchers. Radcliffe-Brown’s 1937 lectures (106) initiated the exploration of the intuitive foundations of social structure, following which a body of work was conducted examining patterned relationships within society. The work of Mayo and Warner, together with colleagues from the Hawthorne electrical factory research group (as cited in (104)), was among the first to use sociograms to report on group structure and interactions among factory workers. Warner (as cited in (104)) explored the social configurations of a small New England city and introduced the notion of a subgroup he termed the clique, which was an informal association of people among whom existed a shared set of group norms. Homans (as cited in (104)) expanded this work by presenting some of the data in matrix format to depict 18 women’s attendance at 14 social events. Homans’ methods of reshuffling the matrix until cliques emerged have since come to be known as block modeling. These authors articulated social structure comprising elements with ordered arrangements or relationships between them. Elements were variously described as individual human beings or higher order concepts, such as social positions, statuses, roles, groups, or institutions. They also theorized that social structure was not random, and that the study of social structure revolved around examining and explaining patterning and how it can be used to make predictions of the behaviour of individuals (107).

The Manchester anthropologists, most notably Barnes, Mitchell, and Bott, were also influenced by Radcliffe-Brown. They examined the social structures from the perspective of the actual configurations of relations that arose from exercising conflict and power (as cited in (104)). They turned to the mathematics of graph theory that emerged from the sociometric analysts and reformulated them into a sociological framework that could begin to describe the structural properties of social organization. Nadel (as cited in (104)) furthered this work by stressing the need to pursue a mathematical approach. He claimed that social structure was an overall pattern
of relations that an analyst could abstract from empirical data derived from human observation. Mitchell (108) also advocated the study of partial networks that could be conceptualized as comprising larger, total networks. This kind of research involved studying individuals and their direct and indirect links to others. Mitchell introduced the concept of multiplex relations in a network, in that they involved a combination of distinct, meaningful connections. He added an important set of concepts derived from graph theory that described the structure of networks, namely density (the overall connectedness of a network) and reachability (how easily people in a network can connect using a limited number of steps). Barnes (109) added the concepts of cliques and clusters to identify structural sub-groupings within networks.

In the 1960s and 1970s the work of these three traditions was brought together by White and his colleagues (as cited in (104)). Their work led to the emergence of a more coherent social network theory. The key breakthroughs were two mathematical innovations: (a) the application of algebraic models of groups using set theory to model relations; and (b) the exploration of block modeling and multidimensional scaling, which translated relationships into social distances for mapping them in a social space. Granovetter and Lee's empirical studies (as cited in (104)) on how people used social connections to obtain information offered empirical validation to earlier sociometric work and led to the introduction of information flow and tie strength within networks. Both explored network processes through basic frequency tabulations and provided qualitative descriptions of network structure that were considered important early contributions to the analytic development of SNA.

Freeman (107) described further generalizations of the social network construct to allow for issues regarding different types and complexities of data, six of which he described as being developed through structural experiments. First, networks required the examination of more than one type of relation. For example, individuals can report liking or disliking other individuals within the network. This type of data produce a valued graph with numbers representing the degree of a relation that is associated with directed lines in the graph. Second, two or more different levels of social units may be required. For example, analyses may take into account the level of the individual (e.g., FSW), the dyad (e.g., FSW and their individual sex partners), or a subset of the network (e.g., FSW and their co-workers). Third, linkages within networks change over time, depending on the nature of the relationship under study. For example, sibling relationships are static, but sexual relationships can form and dissolve over
time. Fourth, the set of actors in the network must be allowed to grow and shrink over time. Milgram’s small world experiment (as cited in (104)) involved a form of snowball sampling, which began with a small number of “seed” individuals and snowballed over time to a large overall network of acquaintances. Fifth, although not a part of social structure per se, traits or attributes of social units may be relevant to patterning of relations. For example, sexual activity class, socioeconomic status, age, and ethnicity of individuals may influence their selection of and by future sex partners. Sixth and finally, the traits and attributes themselves may change as they are conditioned by the patterns within the network. For example, in a sexual network, a susceptible individual may be the receiver of an infection and may in turn become a transmitter if he or she passes the infection on to another sexual contact.

1.3.2.1.2 Distinctive concepts and features of SNA.

Several fundamental concepts and features distinguish SNA from the more standard analytic methods. Wasserman and Faust (100) defined eight key concepts necessary for the understanding of SNA, including: actors, ties, dyads, triads, subgroups, groups, relations, and social networks. Actors are the social entities that make up a network; can be a discrete individual, group, or place; and are represented in sociograms as nodes or vertices (the points in a graph). Actors are linked to each other through relational ties and are represented as arrows or lines connecting nodes in a graph (also referred to as edges). These ties can represent biological relationships, friendships, information transfer, physical movement, sexual contact, cognitive evaluation by an individual of another, and other types of relations. A dyad consists of two actors and the possible tie between them. This is an important concept because using the dyad as the unit of analysis moves beyond individual-level analyses and views the properties of the tie as the analytic interest. Beyond dyadic relationships exist triads, which consist of a subset of three actors and the possible ties between them. A subgroup of actors is any subset of actors and all the ties among them. A group is a collection of all actors on which ties are measured. The power of SNA is its ability to model relationships within the system. In order to conduct analyses, the group must be restricted to a finite set of actors, defined on conceptual, theoretical, or empirical grounds. A relation is defined as a collection of ties of a specific kind among members of a group, as opposed to the individual ties themselves. For example, a set of friendships within a classroom. Finally, a social network consists of a finite set of actors and the relations defined on them.
In addition to network-specific concepts, Wasserman and Faust (100) described the key features of network theory and measurements that distinguish it from other methods. SNA uses structural and relational data to test theories, and the methods involve describing properties of actors, subgroups, and groups of actors. These properties are quantified by considering relations among actors in a network. Measurements are made of ties between actors, although individual-level data on actor attributes may also be used. In this way, SNA provides the tools to examine networks of individuals at the individual, dyadic, subgroup, and group level.

There are two basic designs in social network analysis: egocentric and sociometric (104) (Figure 1.2). Using sexual networks as an example, in an egocentric study the respondent identifies and provides proxy demographic data on his or her sex partners and the nature of the relationship, but the sex partners themselves are not interviewed. This results in a personal, or egocentric, network. One of the limitations of the egocentric approach is that the actual structure of the entire network cannot be easily determined (110). However, egocentric data can be combined to provide data about interactions as a group and to construct sociometric networks (111).

The sociometric approach, in contrast, entails compiling all ties between people and recruiting as many partners as possible. This results in a sociogram that graphs the topology of relationships between the people in the defined population (Figure 1.2). Whereas the sociometric approach is theoretically ideal for examining the relationship between network structure and distribution of STI, it is operationally challenging and suffers from incomplete-network bias when not all partners are disclosed or when partners cannot be traced and recruited (110). Furthermore, most network STI studies are conducted with individuals presenting to STI clinics or through enhanced contact tracing approaches, which can omit uninfected partners who may be important to the overall network structure. According to Doherty et al. (110), the incomplete ascertainment of sociometric networks is inevitable because people may be reluctant to name their sex partners, unable to provide information about anonymous partners, and unable or unwilling to provide contact information about partners. Their partners may also be difficult to reach. Forgetting is also a cause of missing data. Brewer et al. (112) demonstrated that people with high numbers of partners forgot in proportion to the number of sex partners they had. However, the forgetting seemed to be random in relation to the characteristics of the forgotten partners.
One of the challenges posed to designing and analyzing network research that is particularly relevant to this thesis is that of boundary specification. When designing a social network study, care is required when articulating the criteria for inclusion in the network. Although small amounts of missing data in survey analyses that are concerned with individual-level data may result in slightly biased estimates, the absence of key actors or bridging ties within sociometric network datasets can have substantial consequences in terms of distorting the overall configuration of a network (113). For egocentric networks this is less of a concern because the focus is generally not on the connectedness of the larger network, although care must be exercised when setting out stopping rules in terms of eliciting second-order nodes (i.e., the network members identified by interviewees).

According to Laumann et al. (113), several theoretical perspectives on boundary specification exist, including the realist and nominalist views. Using the realist approach, the vantage point of the actors themselves defines the boundaries of social entities, in that the social entity exists as a collectively shared awareness of all or most of the actors who are members. For example, FSW working in a massage parlour clearly recognize their common employment at that parlour in contrast with FSW who work elsewhere. The nominalist approach allows the investigator to consciously impose a conceptual framework constructed to serve the specific study purpose. For example, targeted selection of low socioeconomic status FSW does not necessarily mean that the individual women share a collective awareness of their membership to this categorization. Defining inclusion criteria for actors is often based on positional or reputational approaches. The positional approach refers to a membership test that looks for the presence or absence of a pre-defined attribute, such as occupancy in a formally constituted group (e.g., FSW in massage parlours or escort agencies). The reputational approach uses key informants who nominate actors based on presence or absence of the attribute (e.g., clients of FSW).

1.3.2.2 Networks and STI

The application of SNA to the study of infectious diseases has primarily developed over the past two decades, beginning with the emergence of AIDS in the early 1980s. In 1984, Auerbach et al. (114) conducted an analysis on homosexual men who were diagnosed with AIDS. The initial 19 patients in Los Angeles were interviewed about their sex partners, some of whom were also interviewed. An additional 21 AIDS patients were discovered who lived in San Francisco, New
York, and other areas of the United States, all of whom were linked sexually to the original 19. The same year, Grimson and Darrow (115) conducted a mathematical analysis on the data and determined that, in the absence of an infectious disease, the probability of the observed sexual links was almost zero. Klovdahl (116) subsequently applied formal SNA techniques to the same data to test the infectious agent hypothesis. He placed the sexual connections within a time and space framework and demonstrated these connections within distinct but connected groups, thereby providing evidence in support of the hypothesis that AIDS was a network disease.

Since then, researchers have conducted much theoretical and empirical work applying social network concepts to explain patterns of STI transmission. Network structure has also become important for the development of mathematical models and is a major determinant of the temporal pattern and magnitude of epidemics (18;19;36;117;118).

1.3.2.2.1 Network structure and consequences for STI transmission.

Several important features of networks facilitate or obstruct disease spread. These include the prominence of individuals within the network, the distribution and size of components, the distribution of microstructures, and the extent of cohesion or interconnectivity of microstructures (95;110).

First, location of individuals within a network is an independent predictor of acquisition and transmission of infection. Network prominence is measured by centrality. More centrally-located individuals who are STI-infected are more likely to cause disease propagation than if they are located in the periphery. Likewise, centrally-located susceptible individuals may be at greater risk for infection due to greater opportunity for exposure. There are a number of centrality measures available, each of which is based on a different theoretical foundation and is computed differently (119;120). A summary of several centrality measures is provided in Table 1.3.

The simplest centrality measure is degree centrality. Degree centrality refers to the number of sex partners an individual has and is graphically depicted as the number of direct links to a person. Although high numbers of sex partners is considered a STI risk factor, it is insufficient to fully explain transmission because an individual’s risk is dependent not only on individual-
level behaviours and attributes, but (also) the behaviours and attributes of his or her partners and the overall characteristics of the network within which he or she resides.

Other centrality measures are available that take into account the relational structure of the overall network. **Information centrality** is an estimate of the mean distance between a given individual and every other person in the network, and involves summing the combined number of paths (sexual links) between an individual and all other individuals using weights that are proportional to the length of the paths (121). An important feature of this measure is that it takes into account the fact that paths other than the most direct (i.e., the shortest, or geodesic) can be relevant to transmission.

**Eigenvector centrality** takes into account the centrality of others to whom a person is linked, highlighting the importance of an individual’s partners’ risk profiles (122). In this way, an individual with a high number of non-central sex partners may be considered less central than someone with fewer, more highly central partners. **Betweenness centrality** is the average number of geodesics between a pair of individuals and refers to the extent to which an individual can act as a conduit of transmission within the network (100).

Researchers have empirically demonstrated the relevance of centrality to STI transmission. De et al. (123) calculated degree, betweenness, and information centrality of individuals involved in a gonorrhoea outbreak. They found that individuals with the highest risk of infection had the highest information centrality in their respective components. **Components** are subgroups of individuals who are all directly or indirectly linked. However, there were no differences in degree centrality, underscoring the limitations of ascertaining risk by number of sex partners alone. Rothenberg et al. (120) computed eight centrality measures for 341 members of a large component of a high-risk sexual and injection drug-using network where very little HIV transmission was observed. They demonstrated that, despite differing theoretical and distributional aspects, the measures produced similar epidemiological results and confirmed the low prominence of HIV-infected individuals (i.e., the HIV-infected individuals occupied non-central, peripheral locations).

Second, because STI propagation depends disproportionately on a highly sexually active, highly connected core group (39), components are required for STI transmission to occur. The number
and size of components within a network determines the extent of potential pathways for STI to travel. In networks with a few large components, there is greater opportunity for STI spread to large numbers of individuals. Conversely, networks with many small components prevent wide-scale spread. For example, Woodhouse et al. (124) presented data on an overall social network of 5162 people. Although high-risk behaviours were highly prevalent, intense HIV propagation had not taken place. When examining the network structure they found that most of the HIV-infected individuals were not included in the large component of 3600 people.

Frequency and distribution of components are also associated with STI epidemic phase. During an HIV epidemic in Colorado Springs, it was only during the early phase that there was a large, connected component that provided sufficient network connectivity to maintain endemic transmission (125). These data were compared to data from a syphilis outbreak in Atlanta in terms of network structural changes over time (126). In the injection drug-using network (Colorado Springs), where one HIV transmission occurred over three years, they observed an increase in number of components and reduction in size (i.e., fragmentation of the larger network). In the heterosexual network of high-risk youth (Atlanta), where 10 transmissions of syphilis occurred, they observed a reduction in the number of components and an increase in both size and frequency of highly connected microstructures (127). In both cohorts individual-level risk-taking behaviours did not change substantially over the study period, strengthening the hypothesis that individual-level behaviours may not be as important as sexual network patterns in presenting opportunities for STI transmission.

Jolly et al. (128) compared Chlamydia contact tracing data from Manitoba to the Colorado Springs data. Taking differing partner notification systems and population sizes into account, component numbers, size, and structure were similar in both networks. Both demonstrated large numbers of small, sparsely-linked components that were peripheral to the core, providing structures that could support low incidence endemic, but not epidemic, Chlamydia transmission.

Component structure has also been shown to be important. Wylie and Jolly (129) analyzed Chlamydia and gonorrhoea contact tracing records in Manitoba and found 1503 components throughout the province. They categorized components into two types of configuration: (a) radial components that contained some people with high degree and were characterized by disassortative sexual mixing in terms of degree (there tended to be a few central individuals with
a large number of connections to individuals with very low degree); and (b) linear components that were characterized by more assortative mixing patterns by degree (most individuals reported between one and four partners). The linear components resembled the structure of an STI core as described by Brunham (39), and, although representing only 1.1% of the 1503 components and 7.4% of the individuals in the database, contained 20% of the gonorrhoea infections. This suggested that linear components were an important reservoir for maintenance and spread of gonorrhoea. Additional analyses conducted on the Colorado data by Potterat et al. (125) suggested that dendritic networks were related to stable or declining endemic phases and that cyclic networks were associated with accelerated transmission.

Third, whereas components refer to macrostructural features of sexual networks, they may contain areas of small, densely cohesive subgroups, referred to as microstructures (100). In network terms, concurrency is represented as a simple form of a cyclic microstructure (82). High levels of concurrency within a network are indicative of high frequencies of microstructures that provide the cyclic substrate upon which disease transmission networks are possible. There are many forms of microstructures, including cliques, k-cores and k-plexes, that are summarized in Table 1.4.

Researchers have empirically demonstrated that microstructure distribution is associated with infectious disease propagation. In the Colorado Springs cohort, higher-order microstructures were virtually absent and only one HIV transmission was observed in three years (126). In contrast, the Atlanta data showed a close relationship between the temporal distribution of 10 new syphilis cases and an increasing complexity and distribution of microstructures (127). The end of the Atlanta outbreak also coincided with fragmentation of the network, despite no significant change in individual-level risk behaviours.

Membership in a microstructure is also an independent predictor of infection. In a study of injection drug users (IDU) in New York, Friedman et al. (130) demonstrated that being a member of a 2-core was a significant risk factor for HIV and that the number of IDU partners and race were not significant predictors. From the graph theoretical perspective, 2-cores (or higher level k-cores) are important because there are more than one potential pathway for every 2-core member, and therefore the removal of a single member, by either treatment, behavioural change, or vaccination, has little effect.
Microstructure frequency is also associated with epidemic phase. In Colorado Springs (125), they demonstrated that during only the early stages of the epidemic was there sufficient cyclic connectivity to sustain HIV spread. During the later stable and declining phases, less microstructures and more loosely connected dendritic structures were common. Chlamydia contact tracing data was used by the same investigative group between 1995 and 1999, during which secular trend data indicated that Chlamydia cases increased by 46% (this was attributed to new testing technology and increased reporting) (131). Sexual network structures were fragmented and dendritic, lacked the cyclic microstructures required for efficient STI transmission, and were indicative of low endemic, rather than epidemic, spread. Wylie and Jolly (129) reported similar findings in their evaluation of Manitoba contact tracing data.

Fourth and finally, inherent to the concepts of components and microstructures, cohesion, or density, of a network refers to its overall connectedness and has distinct implications for STI spread. Density is defined as the proportion of ties between people out of all possible ties within the network (100). Denser networks are a result of higher sexual contact rates within the population, which provide more opportunities for disease to spread. As the number of components decreases, their size increases. As the frequency of microstructures increases, overall network cohesion increases. For example, in the Atlanta syphilis outbreak, network cohesion increased over time, as demonstrated by the evolution of about a dozen small components to one large component of 95 individuals (127).

### 1.3.2.2.2 Scale-free networks

Within the field of physics, a relatively new theory of networks is under development. Scale-free refers to the distribution of the number of links (node degree) in a network graph. Physicists purport that real networks may not follow a Poisson distribution, which is predicted by a random graph, but rather a power law in which a disproportionately large number of nodes have very few links and a very small group, termed hubs, are extremely well connected (132-134). This results in a large standard deviation (and variance) around the mean degree, and the degree distribution can be described by a power law: the probability of having $k$ partners $P(k)$ is directly proportional to $k$ to the minus alpha ($\alpha$): $P(k) = C k^{-\alpha}$ (132). Through research on connectivity of the World Wide Web, the notion of preferential attachment was introduced. Preferential
attachment means that the most well connected nodes in a network acquire links at a greater rate than those with fewer links (i.e., the rich get richer) (133). Several researchers analyzed population sexual behaviour data and found that the distribution of sexual partners followed a power-law curve, suggesting preferential attachment (85;135;136). Whereas in random networks infection spreads throughout the network only if the spreading rate exceeds a critical threshold (e.g., R₀), in scale-free networks there is no threshold, implying that even weakly infectious agents can propagate (137). Researchers proposed that if hubs could be identified and targeted with public health intervention (e.g., STI immunization), overall network connectivity could be reduced and infection could be eradicated (88;138).

1.3.2.2.3 Molecular biology and transmission networks.

With the development of advanced methods of molecular genotyping, more refined identification of transmission networks is now possible (139;140). Jolly et al. (128) pointed out that the assumption underlying these approaches is that the appearance of a different type within a sexual network indicates introduction of the pathogen from outside the network. The ability of genotyping to establish potential epidemiologic links between apparently unconnected components is particularly useful when one considers the challenges posed by the identification of small, dyadic components (i.e., n=2, or a monogamous partnership) which is common in contact tracing. For transmission to have occurred, many of these dyads must have been connected to other dyads or larger components through undisclosed links (141). In Manitoba, a sexual network constructed from contact tracing data was compared with Chlamydia genotyping conducted on network members. A high degree of concordance, based on network and molecular data, was found between transmission events (142). The same data were used to identify 10 geographic clusters of infection that appeared to represent distinct transmission networks within a larger sexual network and that proposed epidemiological connections between smaller groups of unlinked individuals (141).
As mentioned earlier, bridging provides linkages between components and between subgroups of varying risks. In network or graph theoretical terms, bridging is used to describe specific properties of linkages that represent a cut point within a transmission network. Cut points are individuals or groups of individuals (nodes) with sexual linkages (edges) that, when removed, divide a component into two smaller components and prevent the spread of STI from one to another (100). One of the earliest examples of bridging in terms of STI was the flight attendant with AIDS who was credited with spreading the HIV virus through a large sexual network over a large geographic area in the early 1980s (116).

In network terms, disassortative sexual mixing can be conceptualized as a form of bridging within a network. Disassortative mixing between highly sexually active core groups and less sexually active groups through bridging behaviours can introduce STI to populations that may otherwise be considered at low risk. An example of this is male clients of FSW who created a bridge of HIV infection between the highly active commercial sex core and their wives or girlfriends (6;60). Likewise, disassortative mixing by age and ethnicity forms bridges between different age and ethnic groups that may have differing levels of STI prevalence and risk behaviours.

Sexual mixing patterns within networks may also have implications for the control of STI. Newman (138) constructed a theoretical model based on node degree (number of sexual partners per person in the network). He showed that assortative networks were very robust to the removal of high-degree nodes because they tended to be linked to other high-degree nodes that resulted in large, densely connected components that composed a core group. Removal of some of the nodes did not eradicate disease within the network because the network remained well connected. On the other hand, disassortative networks were more likely to have more linkages between highly connected and less well connected nodes (i.e., people of high and low risk) distributed throughout the network. Removal of high degree nodes could in theory fragment the network because it would break it into smaller, disconnected components, thereby decreasing the overall number of transmission pathways.
1.3.2.3 Summary

The preceding section provided an overview of the conceptual underpinnings of SNA and its relevance to the study of STI epidemiology. The theoretical and empirical work conducted over the past two decades has demonstrated that structural and behavioural characteristics of sexual networks are vital considerations that help explain STI persistence and spread within populations. For this thesis, SNA is viewed as a tool to go beyond the measurement of individual-level risk factors in a group of FSW and to include the exploration of their sexual networks and implications for STI propagation.

1.3.3 Commercial Sex Work and STI

FSW have long been viewed as a core group at high risk for acquiring and transmitting STI, and as a reservoir for infection to the general population (4;7;8;143;144). Until the beginning of the 20th Century, it was generally assumed that STI were spread exclusively through sex workers and that the control of sexually transmitted diseases was synonymous with the repression of commercial sex work (145;146). By the 18th Century, prostitution was regulated in many European countries in which FSW were required to report to the police and to be examined by medical doctors. These regulations may have contributed to increased STI spread if infected women were forced to travel from place to place in order to evade the authorities. Regulation activities were stepped up until the early 20th Century, at which time many European countries and the United States adopted laws making prostitution illegal (145-148). By the mid 20th Century, public health officials held the view that as little as 5% of venereal disease was spread through prostitution and that the increase in STI seen in the general population was attributable to sexual “amateurs” (149;150).

Although FSW may not be wholly responsible for continued persistence of STI, the commercial sex industry does play a role in STI transmission, and as a community they are at risk for STI. In this section, an overview of the contribution of the commercial sex industry to the spread of STI and the STI risk environment of commercial sex work is presented.
1.3.3.1 Commercial Sex Work and the Spread of STI

The relative contribution of the commercial sex industry to STI spread depends on the nature of the industry and the transmission dynamics of STI (151). In developed countries, the contribution may be small due to the small proportion of the male population who visit FSW, the high frequency of condom use, and the segmentation of the industry (151;152). However, in developing countries, poverty, selective male migration to urban centres, infrequent condom use, insufficient health resources, and lack of opportunities for women create a large sex industry that experiences high rates of transmission (151).

Findings from studies in developed countries suggest that less than 5% of the male population has ever purchased sex (153;154) and that condom use for commercial sex is common (152;155-158). However, in countries such as sub-Saharan Africa, India, and Thailand, researchers reported that up to 50% of men in the general population have had sex with FSW (159) and that condom use is rare (160-162). FSW patronage is even more common among specific subgroups in both developing and developed countries. These include truck drivers, military personnel, gang members, and migrant workers (83;163-166). Men who patronize FSW experience higher rates of STI (83;151;163;165;166) and in turn provide a bridge between the high-risk commercial sex core and the lower-risk population of wives and girlfriends (6;21;60;71).

Plummer et al. (151) suggested that the segmentation of the commercial sex industry – that is, different types of sex work, such as street-based, brothel-based, escorts, etc. – in developed countries and the infrequent linkages between the different segments may also partially explain the slow spread of HIV. De Graaf et al. (152) found that only 3% of male clients in the Netherlands patronized more than one type of prostitution and that FSW themselves rarely moved from one type of work to another. Findings from other studies also showed that STI prevalence and risk practices vary depending on the type of sex work (156;158;167).

The transmission dynamics of specific STI also have implications in terms of the contributory role of commercial sex work to disease propagation (151). In settings where effective treatment and prevention programs are absent, the transmission efficiency and duration of infectiousness remain relatively stable, and therefore the frequency of sexual contact becomes a more important determinant of STI spread (168). STI with a relatively short duration of infectiveness, such as
chancroid and syphilis, are commonly associated with commercial sex work because they require high rates of partner change to maintain transmission. Plummer et al. (151) suggested that a large proportion of syphilis among the heterosexual population in Europe and North America may be attributable to FSW and their clients. Evidence in support of this claim was the association between prostitution and crack cocaine and other hard drug use (169;170) and the association between syphilis outbreaks and prostitution in urban core areas (171-173). Similarly, chancroid outbreaks are generally associated with commercial sex work in both developed and developing countries, particularly in lower socioeconomic strata FSW, and is often associated with drug use (144;174).

1.3.3.2 The STI Risk Environment of Commercial Sex Work

Because high rates of partner change and frequency of sexual contact are important determinants of the rate of STI acquisition and transmission (151), FSW are at increased risk of acquiring STI due to their high number of sex partners and variable risk behaviour. However, it is important to note that STI do not originate in FSW, nor do they transmit infection among themselves. In contexts where FSW report high levels of condom use with clients, they may not use condoms with non-commercial partners and therefore may be at risk of acquiring STI through these contacts (3;156;175;176). Researchers have also suggested that condom use may present a psychological barrier between FSW and their clients and that it distinguishes commercial from intimate sexual relationships (14;177-180). FSW may therefore acquire STI from non-commercial sex partners, which in turn may circulate within, and be bridged out of, the commercial core group.

In developing countries, where condom use is generally low, HIV prevalence in FSW can be moderate to high, STI prevalence is usually high, and HIV transmission is primarily heterosexual (8;161;162;181;182). FSW from lower socioeconomic strata are at the highest risk due to a higher numbers of partners and a lower prevalence of condom use (4;144;183). In developed countries, FSW generally experience a low prevalence of HIV, but moderate rates of STI may persist (184-186). Injection drug use is common in some FSW populations – particularly street-based FSW in Europe, North America, and some Latin countries – with a corresponding high prevalence of HIV (156;182;185;187). Women who have immigrated from developing countries
have lower levels of knowledge regarding STI and condom use and experience higher rates of STI than local FSW in developed countries (188-191).

STI prevalence and risk behaviours also vary depending on the location and context of sex work. Street-based sex work is often associated with higher rates of HIV and associated risk-taking behaviour (e.g., drug use) than sex work conducted in brothels, escort agencies, dance clubs, and massage parlours (157;158;176;188;192). In some contexts, FSW who work in legalized or regulated establishments may have greater condom negotiation power and the support of establishment policies in terms of the types of sex acts they participate in and the protective measures they take (175;193;194). However, the protective effect of indoor work may be influenced by whether indoor sex work is legal or regulated (5;156), by establishment policies that may or may not promote protective behaviour (16), by the type of establishment (155;195), and by the immigration status of the workers (188;190;196). In settings where outdoor sex work is targeted by the police, oral sex and manual masturbation may be more common due to the need to complete the sex transaction quickly in order to avoid arrest (14). Clients may spend more time with indoor FSW, creating an environment that is more conducive to vaginal or anal intercourse (14). FSW who work indoors may also have a greater frequency of sexual contact with their regular clients than street-based FSW, which may lead to inconsistent condom use with clients with whom they feel familiar (5;14;152;189). Furthermore, the physical isolation of indoor work may make FSW more vulnerable to sexual and physical abuse, which may increase the risk of HIV and STI (5;196).

1.3.3.3 Summary

The preceding section provided a brief overview of the role of the commercial sex industry in the spread of STI and of the risk environment of FSW for acquiring infection. Although FSW are a highly sexually active core group at risk for STI, their contribution to disease spread and their risk of acquiring infection varies depending on the context of the sex work. What is not known about the indoor commercial sex industry is the nature of the sexual networks that form and the implications of these networks for STI propagation.
1.3.4 Summary and Thesis Justification

The preceding literature review provided a broad overview of STI transmission dynamics, of SNA and its application to the study of STI, and of the study target population, indoor FSW. It was beyond the scope of this thesis to apply every concept or methodology described in this review, but it is important to the overall understanding of where this research fits in terms of the research on STI transmission. However, given what little is known about indoor commercial sex work, certain network and related concepts may be particularly relevant, including: the frequency and distribution of connected components, the overall cohesion of the sexual networks, the frequency and distribution of microstructures, the age- and ethnicity-related mixing patterns within the networks, the extent of concurrency, and the extent of bridging, within both the commercial sex networks and between the commercial sex work core and the general population.

Although there is a well-established body of literature describing STI risks for street-based FSW, very little is known about the indoor segment of the commercial sex industry in Canada. One cannot assume that indoor sex work is less risky than outdoor sex work, nor does the literature provide any consensus on this matter. What is clear is that the context of indoor sex work is unique. The patterns of interactions between FSW and clients are very likely different than those in the outdoor industry. Because more clients of indoor FSW may be repeat customers (i.e., “regulars”), this has profound implications to the structural formation of sexual networks and the extent of concurrency within the networks. Furthermore, the opportunity for clients to spend more time with FSW may promote different types of sexual activity and risk-taking behaviours. Given the contextual differences of indoor work, the SNA approach is uniquely suited because the structural factors may in fact be more relevant than to outdoor sex work, where clients are more likely to be “one-timers”. Therefore, it was the purpose of this thesis to use SNA to explore the sexual networks that form within the indoor commercial sex industry and to examine the implications for disease propagation.

1.4 Objectives and Hypotheses

This thesis was organized around two broad study objectives and associated hypotheses.
Objective 1: To determine the network structure and characteristics of the indoor commercial sex industry in the Greater Vancouver Regional District. The general hypothesis was that the network is one that supports the potential for STI growth, as indicated by the following:

- Microstructures, such as k-plexes and n-cliques, will be found in the large network components. The presence of these microstructures indicates that network density will provide multiple pathways for sexual transmission of pathogens;
- Sexual partner concurrency is high among indoor FSW and their clients (i.e., >50%);
- The race or ethnicity of clients is more likely to be the same as that of indoor FSW;
- On average, sex partners are older than indoor FSW; and
- The average rate of partner change among indoor FSW is equal to or greater than that required for successful epidemic growth of Chlamydia (i.e., at least one new partner per month).

Objective 2: To determine the potential for STI transmission to the general population. The general hypothesis was that the potential for STI spread to the general population exists, as indicated by the following:

- Individuals who bridge sexually between indoor commercial sex networks and the general population will be identified, and they may have key roles in the spread of STI into the general population;
- Individuals who bridge between indoor commercial sex establishments will be identified, and they may have key roles for STI spread between establishments and ethnic groups; and
- Bridging individuals will have higher information centrality than non-bridgers.
Table 1.1  Transmission probabilities and duration of infectiousness for different STI
This table was adapted from Anderson (22).

<table>
<thead>
<tr>
<th>Pathogen (disease)</th>
<th>Transmission probability (β) per partnership</th>
<th>Mean duration of infectiousness (D), if untreated, in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neisseria gonorrhoea (gonorrhoea)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Treponema pallidum (syphilis)</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Haemophilus ducreyi (genital ulcer)</td>
<td>0.8</td>
<td>0.08</td>
</tr>
<tr>
<td>HIV (AIDS)</td>
<td>0.05-0.15</td>
<td>8 – 12*</td>
</tr>
</tbody>
</table>

* Or lifetime, if treated

Table 1.2  Example of a sexual mixing matrix across racial or ethnic groups
This table was adapted from Doherty et al. (110).

<table>
<thead>
<tr>
<th>Racial or ethnic group</th>
<th>Number (%) of sexual partnerships by group</th>
<th>Caucasian</th>
<th>Chinese</th>
<th>South Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>95 (95)</td>
<td>5 (5)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Chinese</td>
<td>5 (5)</td>
<td>300 (50)</td>
<td>300 (60)</td>
<td></td>
</tr>
<tr>
<td>South Asian</td>
<td>0 (0)</td>
<td>300 (50)</td>
<td>300 (50)</td>
<td></td>
</tr>
</tbody>
</table>

\[
\sum_{i=1}^{n} w_i - 1 \\
\]

Where \( Q = \frac{\sum_{i=1}^{n} w_i - 1}{(n - 1)} \), \( Q = [(0.95 + 0.39 + 0.50) - 1]/(3-1) = 0.42 \).
Table 1.3  Measures of centrality

All notations and definitions are from Wasserman and Faust (100), except where stated otherwise.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Computation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor (nodal) degree</td>
<td>( d(n_i) = \sum_{j=1}^{L} I_{ij} )</td>
<td>Number of direct connections to each person in the network. In an incidence matrix ( I ), with elements ( {I_{ij}} ), the degree of nodes is equal to the row sums (p. 163).</td>
</tr>
<tr>
<td>Actor information centrality</td>
<td>( C_i(n_j) = \frac{1}{c_{ii} + (T - 2R)/g} )</td>
<td>( C_i ) is the harmonic distance of any actor to all other actors in the network. In a non-directional ( g \times g ) sociomatrix, where ( T ) is the trace or sum of the diagonal entries ( c_{ii} ) of the matrix and ( R ) is any one of the row sums (all row sums are equal)(p. 196).</td>
</tr>
<tr>
<td>Actor betweenness centrality</td>
<td>( C_b(n_i) = \sum_{j&lt;k} g_{jk}(n_i) / g_{jk} )</td>
<td>The frequency with which an individual is on the shortest path between all other pairs of persons, where ( g_{jk} ) is the number of geodesics (shortest path) linking two actors ( j ) and ( k ) and the probability of any given geodesic being used is equal (p.190).</td>
</tr>
<tr>
<td>Actor eigenvector (Bonacich)</td>
<td>( c_i = a\sum A_{ij} c_j^* )</td>
<td>The centrality of persons based on the centrality of the persons to whom s/he is sexually linked. Given an adjacency matrix ( A ) where ( a ) is a parameter.</td>
</tr>
</tbody>
</table>

*Formula and description from UCINET 6 Help files (197).
Table 1.4  Types of microstructures

This table was adapted from Wasserman and Faust (100).

<table>
<thead>
<tr>
<th>Microstructure</th>
<th>Definition</th>
<th>Visualization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clique</td>
<td>A maximally connected subgroup of three or more nodes.</td>
<td><img src="image" alt="Clique example" /></td>
</tr>
<tr>
<td>n-clique</td>
<td>A connected subgroup in which the largest geodesic distance is no greater than ‘n’.</td>
<td><img src="image" alt="n-clique example" /></td>
</tr>
<tr>
<td>k-plex</td>
<td>A subgroup (n = i) of size n where each node is directly connected to at least n – k members of the group.</td>
<td><img src="image" alt="k-plex example" /></td>
</tr>
<tr>
<td>k-core</td>
<td>A subgroup in which all nodes are connected to at least k others in the group.</td>
<td><img src="image" alt="k-core example" /></td>
</tr>
</tbody>
</table>
Figure 1.1  Mixing patterns between different HIV risk groups with three different sexual activity classes within each group

This figure was adapted from Anderson (22).
Figure 1.2  Egocentric and sociometric study designs

Grey circles denote interviewees. (A) Egocentric design involves interviewing circle A and eliciting proxy data on partners (circles) B, C, and D. It is also possible to elicit limited data on secondary partners (e.g., B1, C1, etc.). (B) Sociometric design involves interviewing circle A and subsequently interviewing partners B, C, and D, eliciting relationship data from all, including additional partners.
1.5 References


64. Donegan C. Prostitutes can help prevent the transmission of HIV. Nurs Times. 1996 Jun 26;92(26):38-9.


151. Plummer FA, Coutinho RA, Ngugi E, Moses S. Sex workers and their clients in the epidemiology and control of sexually transmitted diseases. In: Holmes KK, Sparling PF,


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CHAPTER 2
CONDUCTING HIV/AIDS RESEARCH WITH INDOOR COMMERCIAL SEX WORKERS: REACHING A HIDDEN POPULATION

2.1 Introduction

Accessing indoor FSW for the purposes of conducting research is logistically challenging due to the difficulty in identifying and locating sex establishments (1). In Canada, developing trust and gaining access to the indoor FSW community is challenging due to the illegal nature of prostitution, the negative stigma associated with sex work, the physical isolation of working indoors, the control of management or pimps, the cultural and language barriers, and for some, the fact that they are trafficked or illegal immigrants (2-5). These difficulties are compounded when the purpose of the research is to explore sensitive issues such as sexual or illegal behaviour. Furthermore, publishing research results places a hidden population in the spotlight, which may expose them to subsequent harm through legal intervention or societal concerns (6). In this context, large time commitments on the part of the researchers are required to develop trust and credibility within the community and to demonstrate that steps are being taken to reduce the likelihood of negative consequences from the relationship.

There is a recent movement towards partnerships between community-based organizations (CBO) and academics in the study of hidden communities. This is based on recognition of the need to understand risk environments in community context and to enhance communication between academics and the communities they seek to study (7;8). Conducting research with hidden communities presents many challenges, including gaining access to the community members and ensuring that the research questions, results, and interpretations are relevant to the community. Substantial levels of community support are required to gain access to hidden communities, to assist in recruitment, to interpret results, and to develop and conduct interventions. Academics may not conceptualize research questions in the same way as the community, thereby potentially introducing biased results and flawed interpretation. In the unique context of indoor sex work in British Columbia (BC), these challenges are compounded by cultural, language, and immigration factors.

2 A version of this chapter has been accepted for publication. Remple VP, Johnston C, Patrick DM, Tyndall MW, Jolly A. Conducting HIV/AIDS Research with Indoor Commercial Sex Workers: Reaching a Hidden Population. Progress in Community Health Partnerships: Research, Education, and Action.
Another key feature of successful community-based research is the engagement of community members, referred to as peers. Peers with street credentials have privileged access and may be able to better engage the trust and confidence of members of the target community than academics (9; 10).

Within this framework, we describe a community-academic partnership that was applied to gain access to, to recruit, and to collect research data from women in the indoor commercial sex industry in the Vancouver area of BC, Canada.

2.2 Methods

2.2.1 Study Setting and Target Population

The target population was FSW who worked in licensed massage parlours and escort agencies in four cities in the Greater Vancouver Regional District (GVRD). The GVRD is located in southwest BC, is primarily urban, and is comprised of over half of the provincial population. The population is characterized by ethnic and racial diversity, where visible minorities – primarily those of Asian descent – comprise over 50% of the population in some cities (11). Although prostitution is not illegal in Canada, many of the activities required for prostitution are, such as the operation of a bawdy house and the living off of the avails (12). Therefore, although these establishments have business licenses, the sex trade activities that are conducted on the premises are illegal. It is estimated that dozens of licensed sex establishments exist throughout the GVRD (City of Vancouver, oral communication, March 2006) and that many unlicensed, underground establishments are also in operation (13).

2.2.2 Preliminary Work and Partnership Development

In 2002 and 2003, the Asian Society for the Intervention of AIDS (ASIA, a non-profit AIDS service organization) conducted a peer-driven, pilot research project with Asian FSW in Vancouver. The goals of the project were to determine if conducting research with indoor FSW was feasible and to explore the context of HIV and STI risk within the community. Their findings suggested that similarities existed between indoor and other types of FSW in terms of
barriers to consistent condom use, health education, and services (13). Whereas the study findings confirmed that indoor FSW were vulnerable to STI, what surfaced from qualitative inquiry was that indoor sex work was contextually unique. Many establishments employed a disproportionate number of immigrant women, mostly from Asian countries. These women were hidden from view and were largely ignored by service agencies, advocacy groups, healthcare services, and researchers. Contrary to the common notion that working indoors is safer than on the streets (14), some women expressed feeling more vulnerable because they were hidden and isolated. Importantly, the pilot project confirmed that women working in the indoor sex trade viewed HIV and STI research within their community as a priority. Finally, in order to characterize the risk environment and to develop and deliver targeted, socioculturally appropriate health education and services, a project that married novel research methods with a community-based outreach program was required.

In 2003, ASIA and academic researchers established a community-academic partnership to explore the STI risk environment of this population. The partners proposed an operational project, dubbed the “Outreach and Research in Community Health Initiatives and Development (ORCHID)” project. The ORCHID project included outreach, service delivery, and research components (Figure 2.1). Needs assessments conducted during outreach activities provided direction for focusing research questions. The ORCHID project was housed as a program within the ASIA organization which assumed responsibility for outreach and service delivery. All programmatic decision-making was made by the Board of Directors. Leadership of the research component of the program was a shared role between the community team leader and the academic principal investigator (the thesis author). The program was funded by competitive research operating grants that were administered by the University of British Columbia, and by community-based competitive operating grants that were administered by ASIA.
Before finalizing the research plan, the team leaders conducted a community consultation to identify gaps in services and research, to hear advice, and to elicit feedback regarding relevance, feasibility, and potential challenges of the proposed project plan. Over a four-month period, the leaders conducted 10 individual and group meetings with CBO, FSW, academics, and health and social service professionals working with FSW. Participants in the consultation included the 12 peers from the original ASIA pilot study, representatives from five BC CBO, four past and current FSW, six street nurses, one social worker, and four academic researchers. The leaders documented minutes from each meeting and validated them with the participants. Findings from the community consultation indicated that no systematic research had been conducted within the indoor sex industry in BC. Street nursing programs in two regions in the GVRD were conducting outreach, but there were large gaps in service and knowledge about the population’s risk.

The participants raised several important issues during the community consultation. The main concern expressed by the CBO and individual FSW was that research participants and the community must not be subjected to exploitation and further stigmatization as a result of the study. Several individuals expressed distrust of academic researchers, stating that research without a tangible benefit to the community was exploitive and that university-based researchers used marginalized communities to further their own careers. All concurred that provision of service concurrent with research activities was critical to the conduct of ethical research and to engendering trust and credibility, not only within the target community, but (also) within the broader CBO community.

Participants also felt that engaging peers in the development, planning, implementation, and evaluation of the study was critical. Several expressed their concern regarding power distribution in a peer-partnered project. They felt that leadership positions held by highly educated persons could promote an environment of unequal power distribution. They viewed respecting and acknowledging the contribution of peers to be of paramount importance, particularly in terms of their contribution to the entire study process, their decision-making roles, and their employment at a respectful rate of pay.
Based on the findings of the community consultation and the needs assessment, the team established an operational plan. The method for gaining access to sex establishments was through peer and volunteer outreach activities. For our study purposes, we defined peers as women with past or current commercial sex work experience in the indoor commercial sex industry. The community team leader initially recruited two peers that she knew from a previous project. We added five peers through word-of-mouth and referral from other CBO, and three peers were hired later in the project from establishments that were visited by outreach teams. The ASIA volunteer coordinator, with input from the peers, developed and implemented a training program. The training included STI and HIV prevention theory and skills, prostitution and immigration legalities, outreach methods, field note documentation, referral methods, language translation, and self-care strategies. All peers, staff, and volunteers were provided with t-shirts that bore the ORCHID logo, which constituted the outreach “uniform.” Peers were paid on an hourly basis and worked between two to eight hours per week, depending on their availability.

The peers and the volunteer coordinator initially assembled a list of sex establishments from telephone directories (e.g., escort agencies or men’s clubs), community newspapers (e.g., in the Personal Ads), the internet (e.g., escort reviews and establishment websites), and via word-of-mouth through the peers. If we were unsure as to whether or not a business was actually a sex establishment, one of the male volunteers or ASIA staff members called the establishment to ask if they provided sexual services. The volunteer coordinator mapped the establishments, and teams consisting of one peer and one volunteer visited establishments on a weekly basis. The community team leader or one of the peers first contacted the establishments by telephone to inform them that ORCHID teams would be visiting. When outreach teams visited an establishment for the first time, they brought a small gift (e.g., a box of chocolates) for the business and small embroidered fabric purses with condoms, lubricant, and ORCHID business cards for the workers. Outreach activities included delivery of harm reduction materials (condoms, lubricant, gloves, dental dams, etc.) and educational materials. Other services provided by the teams included referrals to health and community services, translation services, and accompaniment to medical appointments, when needed.
The ORCHID team met on a monthly basis to maintain team cohesion, to ensure self-care, and to share ongoing research findings. Each meeting began with a round-table discussion where team members were invited to share what was on their mind in a safe, open environment. The team leaders shared research findings with the group and the whole team contributed to modifying outreach activities and educational messages to meet identified needs. In addition to the monthly meetings, the team leaders held social events every four to six months for team members and their families.

2.2.5 Research Data Collection

The team leaders identified sex establishments for research recruitment through adapted purposive, targeted sampling (15) from the establishment list. We targeted establishments that were representative of different geographical areas and racial or ethnic backgrounds of the FSW, both factors that are known to influence STI risk (16;17). The team leaders consulted with the outreach team members to determine the racial or ethnic distribution of workers at each establishment and to determine the perceived feasibility of recruiting from them. The feasibility issue was very important. For example, the teams reported that in several of the establishments the workers and managers appeared very nervous when ORCHID teams visited. We decided not to recruit from those establishments because we were unwilling to introduce any potential risk to sex establishment or ORCHID personnel. Seven establishments from four cities in the GVRD were targeted. A summary of the complete establishment list and of those from which we recruited is presented in Table 2.1. At the time of the study, the location of many of the establishments was unknown (many were identified through ads that did not provide an address), and the outreach teams had only attempted to access about one quarter of those identified.

The community team leader accompanied outreach teams to meet the management, to explain the study, and to obtain permission to recruit participants. She provided managers with a description of the study purpose, the data collection methods, and the planned use of the data. She emphasized the potential benefits to both the business and individual staff members in terms of promoting the sexual health and knowledge of the workers. She also provided managers with copies of the questionnaires if they requested them, stressing the ethical requirement of maintaining confidentiality, and told managers that we would not disclose participants’ responses to them or to other workers. The ORCHID project did not provide monetary
incentives to management, but outreach teams continued to visit the establishments at least monthly to distribute condoms and other educational and harm reduction materials.

The community team leader approached individual FSW and provided them with the same study explanation as the managers, with greater emphasis on individual sexual health and confidentiality issues. She also emphasized that findings from the research would enable the ORCHID project to advocate for better services for indoor FSW. She conducted in-person, structured interviews in a private room with consenting FSW. The volunteer coordinator or the academic principal investigator accompanied the interviewer to take detailed ethnographic field notes during and after the interview. Participants were given a stipend of 30 Canadian dollars to compensate them for their time.

2.3 Research Conduction

The research was conducted between March, 2004 and February, 2006. Over the duration of the project, nine peers and six volunteers were hired and trained to conduct outreach. The outreach teams made contact with 50 sex establishments in four cities, of which 37 (73%) allowed repeat outreach visits (Table 2.1). Most of the 13 that refused access were from a city that was undergoing massage parlour closures by local enforcement agencies (18), and therefore many of the establishment managers were nervous about having outsiders on the premises. Two of them accepted outreach materials but refused subsequent visits, and two of them were closed the second time the teams visited. Teams visited six to 12 establishments per week. Approximately one third of the establishments allowed the teams to leave materials or come in to talk to management and staff at the first visit. The others required between two and five repeated telephone or in-person contacts, four to six weeks apart, before they eventually allowed access.

The managers at seven of the targeted establishments were supportive of the ORCHID project in general, as well as supportive of the goals of the research. For example, one of the male managers told the community team leader that he wanted her to conduct the interviews because his staff would probably talk to her about “private woman things” (such as STI and condom use) that he couldn’t talk to them about. We invited 51 FSW to participate, and a total of 49 (96% response rate) were interviewed. The study participants were very supportive of the project and three were eventually hired as peers. The two who did not participate did not provide a reason.
The project team members were generally very enthusiastic and committed throughout the project. However, some experienced a number of challenges over the study period. Several of the peers had a history of illicit drug use and experienced personal problems, such as drug relapse, health problems, and other chaotic life situations, that periodically interfered with their work. As well, several of the peers relied heavily on the community team leader and the volunteer coordinator for emotional support, counseling, court accompaniment, financial assistance, and referral to social and legal services. Both responded to these crises by spending time with the peers and ensuring that prompt referrals to the appropriate support services were made.

2.3.1 Dissemination of Research Results

An important feature of the ORCHID project was our policy of translating research findings into action in real-time. We used several key research findings to inform the outreach and service delivery activities. For example, the FSW in our sample had on average very high levels of knowledge related to appropriate condom use, but their knowledge related to HIV and STI transmission and prevention was substantially lower. Most importantly, study participants expressed a desire to learn more about STI and about condom negotiation skills. The ORCHID outreach teams revised their educational messages to reinforce correct knowledge regarding STI prevention and condom use, and focused specifically on counseling workers about the importance of frequent STI screening and treatment.

Reporting to the broader community on an ongoing basis was also an important aspect of the ORCHID project. We prepared summary reports for several establishment managers to help them develop education messages for their staff. As well, we distributed progress notes and research reports in the form of biannual newsletters to CBO, FSW, funding agencies, health and service providers, policy-makers, and academics.

The team leaders presented preliminary findings to a peer advisory group for discussion, interpretation, and approval. In March 2006, we held a large community forum with 24 representatives from other CBO, funding agencies, Vancouver City Hall, service and health care
providers, and FSW. We presented the research findings and elicited input into the proposed objectives for future research.

2.4 Discussion

Throughout the ORCHID project, we experienced many of the successes and challenges cited by other researchers. The enthusiasm, commitment, and insights of the peers and of the broader community were invaluable to the framing of the project and to the development and implementation of the study plan. Partnership with the CBO and the peers was vital to our ability to gain access to this hidden community. Furthermore, by being involved from the outset, the CBO and peers participated in establishing the research objectives and were members of an advisory committee that interpreted and planned dissemination of the study results.

The mistrust we initially encountered from the CBO community is not uncommon between CBO, marginalized communities, and academics (19-21). In our ongoing communication with the CBO community, we strove to adopt an open, non-defensive attitude and to invite and listen to their concerns. Our experience supports others’ recommendations that commitment and engagement with the community and other stakeholders must occur, and that researchers must be prepared to maintain this commitment for an extended period of time (8).

The ORCHID activities met with little resistance from the indoor commercial sex community itself, as evidenced by the high response rate. When working with this population we remained mindful to not inadvertently introduce harm to them from police or immigration enforcement agencies. It is common knowledge that sex work is conducted in these establishments, but enforcement agencies generally turn a blind eye or conduct raids to look for minors or illegal immigrants (City of Vancouver, oral communication, March 2006)(18). In anticipation of the unlikely event of having study documents subpoenaed, we received ethical approval to obtain verbal informed consent only (Appendix A), we did not collect data on immigration status, and we recruited women who were 19 years of age or older. We did not document real names, locations of FSW, or locations of establishments, and we used the vague term indoor sex establishments in presentations and publications to describe the recruitment sites.
The team leaders required considerable amounts of time, energy, and patience to maintain team morale and to address the challenges experienced by the peers. However, we were concerned about team members who continued to struggle with life challenges. Broadhead and Heckathorn (9) describe the potential "moral hazard" of enlisting peers to participate in activities in the context of their previous lives, because this may serve as a trigger for relapse. Whereas it remains unclear as to whether their participation in ORCHID activities precipitated the peers' struggles, we remained mindful that working with peers required taking the responsibility of putting appropriate support mechanisms in place. Elliott et al. (10) cautioned against researchers falling into the role of "quasi-counsellors." Because of this concern, we strove to make it clear to the peers that, although the team leaders were available for support, the primary objective was to assist the peers to avail themselves of appropriate, professional support services. We acknowledged that for many of the peers this was their first "straight" job that required commitment and accountability. Monthly team meetings proved invaluable for maintaining team cohesion and for keeping the work plan on track.

From the research perspective, the external validity of the findings from the study were limited by the use of a non-probability sample. This is a common challenge in studies of hidden populations (15). The establishments we targeted for research recruitment were not fully representative of the establishments we identified. However, because no information was available for the majority of establishments on our list, the extent of over- and under-representation of certain characteristics is unknown.

Finally, the high cost in terms of time and resources for what might be considered relatively small research gain (49 interviews) must be recognized. Schensul (8) advised that an understanding of the high costs in terms of time and money are essential to sustain the commitment required to conduct community research. However, it should be underscored that the benefits from conducting this project far outweighed the costs in terms of establishing a credible presence in the community, providing peers with a marketable skill set, enhancing the capacity of ASIA to conduct community-based research, and successfully conducting a novel study within a previously un-researched community.

The outreach and service delivery aspects of the project remain an ASIA program and could serve as an important public health outreach mechanism should an STI outbreak occur in the
indoor commercial sex population. Based on the success of the first research phase of the project, the study received competitive funding for an addition three years, which will allow us to expand to include more indoor FSW and their male commercial clients. For the phase two research project, the community team leader and the academic principal investigators function as co-principal investigators.

In conclusion, the community-academic partnership that employed a peer outreach model of community access and novel methods of data collection made it possible to conduct research with the indoor commercial sex community in BC. Academic partnerships established with CBO and peers are an effective and rewarding way to conduct research with populations that are highly vulnerable and difficult to access.
Figure 2.1  The ORCHID model and information flow
Table 2.1  Characteristics of all indoor commercial sex establishments identified and those targeted for research recruitment.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total sex establishments identified (n=215)</th>
<th>Establishments targeted for recruitment (n=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. (%)</td>
<td>No. (%)</td>
</tr>
<tr>
<td>Location unknown</td>
<td>97 (45.1)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Location, if known</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burnaby</td>
<td>29 (24.6)</td>
<td>1 (14.3)</td>
</tr>
<tr>
<td>Coquitlam</td>
<td>5 (4.2)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Vancouver</td>
<td>51 (43.2)</td>
<td>3 (42.9)</td>
</tr>
<tr>
<td>Richmond</td>
<td>25 (21.2)</td>
<td>1 (14.3)</td>
</tr>
<tr>
<td>Surrey</td>
<td>8 (6.8)</td>
<td>2 (28.5)</td>
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<tr>
<td>Accessible *</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>37 (17.2)</td>
<td>7 (100.0)</td>
</tr>
<tr>
<td>No</td>
<td>13 (6.1)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Not visited yet</td>
<td>165 (76.7)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Ethnicities of workers unknown</td>
<td>164 (76.3)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Main ethnicities † of workers, if known</td>
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</tr>
<tr>
<td>Chinese</td>
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</tr>
<tr>
<td>Mixed Asian</td>
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</tr>
<tr>
<td>Mixed</td>
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<td>3 (43.0)</td>
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<tr>
<td>Number of workers unknown</td>
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<td>0 (0.0)</td>
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<tr>
<td>Number of workers, if known</td>
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<td></td>
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<tr>
<td>&lt;10</td>
<td>23 (46.0)</td>
<td>2 (28.5)</td>
</tr>
<tr>
<td>10+</td>
<td>27 (54.0)</td>
<td>5 (71.5)</td>
</tr>
</tbody>
</table>

* Refers to establishments that allowed more than one visit by ORCHID outreach teams.
† Defined as greater than 60% of the workers.
2.5 References


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CHAPTER 3
SEXUAL NETWORKS OF THE INDOOR COMMERCIAL SEX INDUSTRY AND IMPLICATIONS FOR HIV AND STI PROPAGATION

3.1 Introduction

Studies of the spread of STI traditionally focus on individual-level risk factors such as number of partners and condom use (1-5). However, it has been proposed that risk cannot be adequately explained by individual risk behaviours and demographic characteristics, and that behaviour must be put into social context (6-9). SNA is used to help explain the spread of STI through focusing on the relationships among individuals in a group, and produces statistics that describe the quality, density, position, and structure of the relationships (10).

Some of the structural features and behavioural attributes of sexual networks that affect the spread of STI include component size and distribution, sexual bridging between populations of varying prevalence and risk characteristics, and patterns of sexual mixing. Components are defined as groups of individuals who are either directly or indirectly linked to each other through relationships (10). Bridging refers to linkages between otherwise unconnected groups. In network or graph theoretical terms, a bridge is formally defined as a line (or linkage) such that a graph containing the line has fewer components than one that is obtained when the line is removed (10). This concept is essential to understand the transmission of HIV and STI from high prevalence core groups to low prevalence peripheral groups, and is particularly important in the context of commercial sex work. Although FSW have long been viewed as a reservoir for transmitting infection to the general population (11;12), STI do not originate in the FSW community, nor do sex workers transmit infection amongst themselves. STI are transmitted to FSW by their clients or non-commercial partners and may be subsequently transmitted back to the general population through the bridging behaviours of their clients (11;13). Finally, sexual mixing refers to who has sex with whom (14). Assortative mixing refers to like mixing with like (e.g., people with high numbers of sex partners are more likely to have sex with others with high numbers of sex partners) and disassortative mixing refers to like mixing with unlike.

3 A version of this chapter has been submitted for publication. Remple VP, Patrick DM, Johnston C, Tyndall MW, Jolly A. Sexual networks of the indoor commercial sex industry and implications for HIV and STI propagation. Int J STD AIDS.
Within this framework, the purpose of this study was to explore the structure and characteristics of the sexual networks of the indoor commercial sex industry to determine whether this population is at risk for an STI epidemic and to determine whether this risk extends to the lower risk general population.

3.2 Methods

3.2.1 Setting and Participants

This research was conducted in seven indoor sex establishments in the BC cities of Vancouver (population ~550,000), Richmond (population ~182,000), Surrey (population ~350,000), and Burnaby (population ~197,000). All four cities are located in south-western BC in a region containing over 50% of the total provincial population. This area is characterized by ethnic diversity, where visible minorities – primarily those of Chinese, South Asian (East Indian), Filipino and Korean descent – comprise up to 50% of the total population (15).

We used adapted purposive, targeted sampling (16) to identify ethnically and geographically diverse sex establishments from which participants were recruited, as these two factors are important in STI risk (7; 17). The phone directory, internet, local newspapers, and word-of-mouth were used to compile a list from which establishments were selected. An experienced female ethnographic interviewer and a second female observer accompanied outreach teams to meet the workers and management in the establishments, to explain the study, to recruit participants, and to conduct interviews. A detailed description of the recruitment activities was presented in Chapter 2. Structured interviews were conducted in a private room. The observer took field notes during the interview. Following interviews, the interviewer and observer reviewed the data for consistency.

Informed, verbal consent was obtained from all participants. Interpreters were used for FSW who were not fluent in English. This study received ethical approval from the University of British Columbia Clinical Research Ethics Board (Appendix A).
3.2.2 Instruments

Two questionnaires were developed for the study (Appendix B). The first consisted of a 102-item instrument containing demographics, work history, client characteristics, HIV and STI-related knowledge, sexual behaviour, and reproductive health questions. The second was a 22-item sexual network instrument that elicited proxy data on sex partners’ attributes and any other known second-order sex partners (for example, clients’ wives, girlfriends, or other commercial sex partners). For the network portion of the interview, FSW were asked to list up to 10 of their most recent sexual partners, including commercial and non-commercial partners. The interviewer completed a network questionnaire for each of the identified partners.

3.2.3 Data Management and Analysis

The principal investigator and the interviewer entered the data together, which facilitated validation of questionnaire data with field notes and identification of duplicate sexual contacts. Two apparently independent contacts identified by two separate respondents were considered the same individual if all of the following characteristics matched: (a) race or ethnicity; (b) location of residence (if available); (c) physical description; and (d) reasonable age match. If available, additional characteristics, such as name, occupation, or unusual sexual preferences, were used to identify duplicates.

The following individuals were included in the network: (a) respondents; (b) first-order sex partners of respondents who were identified during the interviews (commercial and non-commercial partners); (c) second-order, non-commercial partners of respondents’ partners; and (d) second-order commercial partners of respondents’ partners. If a respondent’s client was known to patronize another sex establishment, he was randomly assigned to be sexually linked to one of the n FSW known to be employed at that establishment. If a client was known to be a house regular (a label applied to men who have sex with all the workers at a particular establishment) at an establishment, he was linked to all n workers. In this way, relational data were available for respondents, their first-order sex partners, and the second-order partners of their partners.
Sexual mixing patterns by age and ethnicity were determined using a mixing matrix in which diagonal elements represent “like” partnerships. The sum of the diagonal elements provides a crude measure of the degree of assortative mixing (18). In order to define a quantity $Q$ that measures the degree of assortative mixing, the equation described by Gupta et al (19)

$$Q = \frac{\sum w_i - 1}{n(n-1)}$$

was used, in which $\sum_{i=1}^{n} w_i$ is equal to the sum of the diagonal elements in the mixing matrix.

Data were first entered into EpiData Version 3.1 (20). A data conversion program (Network conversion program © Ann Jolly, 2003) converted relational and attribute questionnaire data contained in EpiData files into text files that were imported into Pajek© Version 1.02 (© Vladimir Batagelj and Andrej Mrvar, 1996) for visualization and analysis. Pajek© network files were imported into UCINET® (21) for descriptive network analyses. Graphical depiction was initially done using Pajek© software. The Fruchterman Reingold energy approach, using a factor setting of 1.1 in 2D, was used to create a preliminary graph. Nodes were then manually moved to create clusters of sex establishments with the appropriate FSW workers and to most clearly depict the extent of linkages and bridging throughout the network. The saved graph was imported into Netdraw© (22) to enable the addition of nodal attributes (e.g., gender and type of person). SPlus® Version 6.1 Academic Site (© Insightful Corp, 2005) was used to conduct descriptive analyses on attribute data.

3.3 Results

3.3.1 Study Respondents (FSW) and Their Sex Partners

We conducted interviews with 49 FSW in seven sex establishments between June 2004 and January 2006. All workers who were onsite when interviewers visited the establishments were invited to participate. Interviewers visited the establishments three to five times at different times of the day in order to recruit as many workers as possible. The characteristics of workers who were not on shift when the interviewers were recruiting are unknown. The overall refusal rate was 4%. A minimum of 40% of the workers at each establishment were interviewed. Approximately half of the respondents were Caucasian and 35% were immigrants, most of
whom (47%) were from China. The demographic distribution of respondents in each of the establishments is summarized in Table 3.1. The median time spent working in an indoor sex establishment was 18 months (IQR 5-36), and for 53% of respondents, sex work was their only source of income. Fifty three percent had a non-commercial sex partner (e.g., husband, boyfriend, or girlfriend). Respondents reported having a median of seven (IQR 4-12, range 0-30) clients over the past week and having a median of 30 (IQR 20-50, range 1-200) unique sex partners over the past month.

The respondents provided proxy data on a median of five (IQR 3-6) sex partners, resulting in data on 256 dyads (partnerships), 227 (89%) of whom were with commercial clients. The characteristics of the 256 sexual dyads are summarized in Table 3.2. Whereas for most of the relationships with clients the partner’s injection drug use, HIV, and STI status were unknown, 6% of the relationships were with partners known to injected drugs, 5% were with partners known to have had an STI, and 1% were with partners known to have HIV. Two (7%) of the relationships with non-commercial partners were also with STI infected partners.

There was a five year or greater age difference in 66% of the partnerships, and 64% of the partners belonged to a different ethnic or racial group than the respondents. Mixing matrices of the 256 dyadic sexual partnerships in terms of race or ethnicity and age are shown in Tables 3.3 and 3.4, respectively. For both types of mixing, the pattern was primarily disassortative. For race or ethnicity the $Q$ value was -0.11 (possible range -0.33 to 1) and for age the $Q$ value was -0.12 (possible range -0.33 to 1).

The types of sexual practices differed between commercial and non-commercial dyads. Whereas most of the sexual activity involved oral and vaginal sex, more anal sex was reported in non-commercial dyads (17% vs. 0.4%, p<0.001). Consistent condom use was reported in 85% and 17% (p<0.001) of the commercial and non-commercial dyads, respectively.

Twelve clients were identified as duplicates. The characteristics, level of agreement, and reliability of the proxy data for the duplicates are summarized in Table 3.5. Because the criteria for duplicate consolidation included name, ethnicity, and reasonable age match, the proportion of agreement was not calculated for these variables (i.e., by definition all were 100%). Agreement
was highest for those variables related to other sexual contacts (e.g., other FSW or spouses) and lowest for HIV and STI status.

Once duplicates were consolidated, there were 234 unique sex partners in the data set, 205 (88%) of whom were clients and 29 (12%) of whom were non-commercial, intimate partners. The demographic characteristics of the 234 first-order sex partners are summarized in Table 3.6. Five (17%) of the respondents' non-commercial partners were also known to have a wife or girlfriend other than the respondent, and two (7%) were known to have sex with other FSW.

### 3.3.2 Network Structure

The final network was a single, connected component of 553 people, with a density (the proportion of all possible sexual ties that actually exist) of 1% and a mean degree (the average number of direct connections to each person in the network) of 5.4 (range 1-64). The network was comprised of 49 (9%) interviewees, 234 (43%) first-order contacts (duplicates removed), and 270 (49%) second-order contacts (Figure 3.1). The component contained 37% FSW, 37% male commercial clients, 21% non-FSW women, and 5% male non-clients. Respondents identified 21% of the clients as house regulars.

Of the 205 clients, 51 (25%) were connected to one FSW at one establishment only, of whom 18 (35%) had a wife or girlfriend; 79 (39%) were connected to two or more FSW at one establishment only, of whom 43 (54%) had a wife or girlfriend; and 75 (37%) were connected to more than one establishment, of whom 47 (63%) had a wife or girlfriend. Forty five (22%) were known as house regulars, of whom 28 (62%) had a wife or girlfriend, and 17 (8%) were known as house regulars and were connected to more than one sex establishment, of whom 11 (65%) had a wife or girlfriend. Figure 3.2 shows an example of a client known to be a house regular at more than one establishment who also had a wife. In graph theoretical terms, 131 (64%) of the clients were cut vertices, defined as individuals whose removal would result in fragmentation of the network into smaller components.
3.4 Discussion

In this study we targeted indoor commercial sex establishments that were very different in terms of neighbourhood characteristics and racial or ethnic composition, assuming that we would find separate networks centered on these establishments. Instead, we found that the sample formed a single, connected component defined by extensive bridging.

All of the establishments were bridged by sexual linkages between clients and FSW in different establishments. Although we only interviewed in seven, there were 18 other known establishments identified by respondents that were included in the network, and several clients were known to visit establishments in Toronto, Shanghai, and Hong Kong (data not shown). Twelve (6%) clients were also known to visit street-based FSW, a population in Vancouver that experiences high rates of HIV and hepatitis C infection due to a high prevalence of injection drug use (23).

The consequences associated with networks characterized by a small number of large connected components are well documented. In a heterosexual network of high-risk youth in Atlanta, where 10 transmissions of syphilis occurred, the network was characterized by a small number of large, densely connected components with a high frequency of cyclic microstructures (24). Conversely, in Colorado Springs, a heterosexual and injection drug using network, where one HIV transmission occurred over three years, was characterized by an increase in the number of components and reduction in size (i.e., fragmentation of the larger network) (25). In both populations, individual-level risk-taking behaviours did not change substantially over the study periods, indicating that they may not be as important as sexual network patterns for presenting opportunities for STI transmission. Contact tracing data from Manitoba was also compared to the Colorado Springs data by Jolly et al. (6). Taking different partner notification systems and population sizes into account, component numbers, size, and structure were similar. Both demonstrated large numbers of small, sparsely-linked components that were peripheral to the core, providing structures that would support low incidence endemic, but not epidemic, Chlamydia transmission. In another analysis of the Manitoba contact tracing data, Jolly et al. (26) reported a network of over 900 people with high rates of recidivism and Chlamydia and gonorrhoea co-infection in which the basic reproductive number (i.e., the average number of secondary cases produced by an infectious case) was greater than 1.
Bridging occurred through concurrent sexual relationships with the “general population” of wives, girlfriends, husbands, and boyfriends by both the clients and the FSW. Bridging provides transmission pathways between high prevalence core groups and low prevalence peripheral groups and is responsible for most annual incident HIV infections in women in many developing countries (11,27).

Bridging between age and racial or ethnic groups also resulted in disassortative sexual mixing patterns. Disassortative mixing can be conceptualized in network terms as a form of bridging, in that there are sexual bridges created between age groups and racial or ethnic groups. The mixing pattern here differs from that found in most population studies, in which mixing is primarily assortative (28). Simulations showed that disassortative mixing can generate larger epidemics (19,29). Sexual mixing across age groups provides the opportunity for cross-generational spread of infections, so that young women who have sex with older men are at greater risk for STI (30,31). Disassortative mixing by race or ethnicity also provides the opportunity for bridging of infection between ethnic or racial groups that may have different underlying prevalences (17).

Our findings must be interpreted with caution due to the nature of the sampling, the network elicitation methods, and the missing data. Although purposive, targeted sampling is considered more rigorous than simple convenience sampling (16), selection bias was undoubtedly introduced. We gained access only to women who worked in licensed establishments with supportive management and who charged relatively high prices (data not shown). This may have biased our sample towards more voluntary sex workers who may have more power to negotiate condom use, who may have more power to determine the sexual activities they are willing to perform, who may see fewer clients, and who may work shorter hours than more vulnerable, hidden women. This also biased the sample towards women with Canadian citizenship, and under-represented immigrant women, particularly from Asia.

Because we specifically asked for the most recent sex partners — generally those they had had contact with over the preceding week — there was a moderate proportion of first-time clients (41%), which may have reduced the amount of proxy information we were able to obtain. We only included links that the respondents knew to exist in the network, and therefore the data we most likely missed were the second order sex contacts. Furthermore, although many of the
women knew that their clients went to other sex establishments, they often didn’t know which establishments and rarely knew the names of the other FSW. This probably diluted the density of the network and produced a conservative estimate of the degree distribution and the overall network cohesion.

Despite these limitations, network data provided valuable information on the broader population and went beyond the basic questions of number of sex partners and condom use. Without a network approach, our data would show that FSW had many sexual partners and that they used condoms with most of them. What it would not provide are the important linkages within the network – namely by obtaining data about their partners’ second-order partnerships. This provides the linkages that bind the network together and demonstrates how densely connected the total network is. Educational messages should target not only the FSW with the message of 100% condom use, but should also target the clients who form the bridging population. For example, educational messages that advocate minimizing the number of concurrent commercial partnerships could serve to fragment the network.

In conclusion, it is clear that the indoor commercial sex industry is characterized by large, dense sexual networks in which bridging between sex establishments, between the commercial core and the general population, between age groups, and between ethnic or racial groups is common. Although the STI prevalence within this population is currently unknown, the structural properties of the network suggest even a small decrease in condom use or the introduction of infected individuals could support the transmission of these pathogens throughout the network.
Table 3.1 Distribution of demographic characteristics of respondents from seven targeted sex establishments in the Greater Vancouver Regional District

<table>
<thead>
<tr>
<th>Individual Establishments</th>
<th>All</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td>City</td>
<td></td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>No. employees</td>
<td>73</td>
<td>15</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>No. interviewed</td>
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<td>6 (40.0)</td>
<td>3 (60.0)</td>
<td>4 (40.0)</td>
<td>11 (73.3)</td>
<td>14 (70.0)</td>
<td>3 (100.0)</td>
<td>8 (53.3)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Median</td>
<td>28</td>
<td>26</td>
<td>40</td>
<td>31</td>
<td>28</td>
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<tr>
<td>Caucasian</td>
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<td>6 (54.5)</td>
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<td>1 (7.1)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
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<td>1 (7.1)</td>
<td>1 (33.3)</td>
<td>0 (0.0)</td>
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<td>0 (0.0)</td>
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<td>0 (0.0)</td>
<td>0 (0.0)</td>
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<td>0 (0.0)</td>
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<tr>
<td>Aboriginal*</td>
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<td>0 (0.0)</td>
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<td>With spouse/partner</td>
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* Includes respondents identifying as Aboriginal, Métis, First Nations, or half Aboriginal
† Includes respondents identifying as Caucasian and South Asian or Latin American
‡ Includes seven from Mainland China and one from Hong Kong
§ Includes one same-sex partnership
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<td>(57.8)</td>
<td>4</td>
<td>(13.8)</td>
</tr>
<tr>
<td>Declined</td>
<td>0</td>
<td>(0.0)</td>
<td>0</td>
<td>(0.0)</td>
<td>1</td>
<td>(3.4)</td>
</tr>
<tr>
<td>Missing</td>
<td>3</td>
<td>(1.2)</td>
<td>1</td>
<td>(0.4)</td>
<td>2</td>
<td>(6.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of sex contact</th>
<th>Total</th>
<th>Clients (n=227)</th>
<th>Non-clients (n=29)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>(%)</td>
<td>No.</td>
<td>(%)</td>
</tr>
<tr>
<td>Vaginal only</td>
<td>51</td>
<td>(19.9)</td>
<td>46</td>
<td>(20.3)</td>
</tr>
<tr>
<td>Oral only</td>
<td>41</td>
<td>(16.0)</td>
<td>39</td>
<td>(17.2)</td>
</tr>
<tr>
<td>Vaginal/oral</td>
<td>124</td>
<td>(48.5)</td>
<td>108</td>
<td>(47.6)</td>
</tr>
<tr>
<td>Vaginal/oral/anal</td>
<td>6</td>
<td>(2.3)</td>
<td>1</td>
<td>(0.4)</td>
</tr>
<tr>
<td>Non-penetrative</td>
<td>33</td>
<td>(12.9)</td>
<td>32</td>
<td>(14.1)</td>
</tr>
<tr>
<td>Missing</td>
<td>1</td>
<td>(0.4)</td>
<td>1</td>
<td>(0.4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency of sex contact</th>
<th>Total</th>
<th>Clients (n=227)</th>
<th>Non-clients (n=29)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>(%)</td>
<td>No.</td>
<td>(%)</td>
</tr>
<tr>
<td>Once only</td>
<td>94</td>
<td>(36.7)</td>
<td>93</td>
<td>(41.0)</td>
</tr>
<tr>
<td>&gt; once/week</td>
<td>42</td>
<td>(16.4)</td>
<td>19</td>
<td>(8.4)</td>
</tr>
<tr>
<td>1-4 times/month</td>
<td>65</td>
<td>(25.4)</td>
<td>63</td>
<td>(27.7)</td>
</tr>
<tr>
<td>&lt; once/month</td>
<td>55</td>
<td>(21.5)</td>
<td>52</td>
<td>(22.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of sex contacts*</th>
<th>Total</th>
<th>Clients (n=227)</th>
<th>Non-clients (n=29)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>(%)</td>
<td>No.</td>
<td>(%)</td>
</tr>
<tr>
<td>Median</td>
<td>8</td>
<td>6</td>
<td>100</td>
<td>0.0</td>
</tr>
<tr>
<td>IQR</td>
<td>3-24</td>
<td>3-13.5</td>
<td>41.3-575</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>2-8760</td>
<td>2-468</td>
<td>2-8760</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condom use frequency</th>
<th>Total</th>
<th>Clients (n=227)</th>
<th>Non-clients (n=29)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>(%)</td>
<td>No.</td>
<td>(%)</td>
</tr>
<tr>
<td>Never</td>
<td>22</td>
<td>(8.6)</td>
<td>5</td>
<td>(2.2)</td>
</tr>
<tr>
<td>Occasionally</td>
<td>3</td>
<td>(1.2)</td>
<td>1</td>
<td>(0.4)</td>
</tr>
<tr>
<td>Most of the time</td>
<td>6</td>
<td>(2.3)</td>
<td>2</td>
<td>(0.9)</td>
</tr>
<tr>
<td>Always</td>
<td>217</td>
<td>(84.8)</td>
<td>212</td>
<td>(93.4)</td>
</tr>
<tr>
<td>Missing</td>
<td>8</td>
<td>(3.1)</td>
<td>7</td>
<td>(3.1)</td>
</tr>
</tbody>
</table>

* P-values for categorical variables were calculated using Chi square, Yates' correction not used, except where noted otherwise. P-values for continuous variables (medians) were calculated using the Wilcoxin rank sum test, 2-sided. Does not include missing values.

† P-value calculated using Fisher's exact test.

‡ Calculated only for those partners with whom respondent has had sex more than once.
### Table 3.3  Ethnicity or racial mixing matrix

No. (proportion) of partnerships, by race/ethnicity category

<table>
<thead>
<tr>
<th></th>
<th>Caucasian</th>
<th>Asian</th>
<th>First Nations</th>
<th>Other</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>73 (0.40)</td>
<td>61 (0.33)</td>
<td>17 (0.09)</td>
<td>34 (0.18)</td>
<td>185</td>
</tr>
<tr>
<td>Asian</td>
<td>61 (0.50)</td>
<td>30 (0.25)</td>
<td>9 (0.01)</td>
<td>21 (0.17)</td>
<td>121</td>
</tr>
<tr>
<td>First Nations</td>
<td>17 (0.63)</td>
<td>9 (0.33)</td>
<td>21 (0.00)</td>
<td>1 (0.04)</td>
<td>27</td>
</tr>
<tr>
<td>Other</td>
<td>34 (0.59)</td>
<td>21 (0.36)</td>
<td>1 (0.02)</td>
<td>2 (0.03)</td>
<td>58</td>
</tr>
<tr>
<td>Totals</td>
<td>185</td>
<td>121</td>
<td>27</td>
<td>58</td>
<td>391</td>
</tr>
</tbody>
</table>

### Table 3.4  Age mixing matrix

No. (proportion) of partnerships, by age group

<table>
<thead>
<tr>
<th></th>
<th>&lt;=20</th>
<th>21-30</th>
<th>31-40</th>
<th>40+</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=20</td>
<td>41 (0.05)</td>
<td>10 (0.37)</td>
<td>6 (0.22)</td>
<td>7 (0.26)</td>
<td>27</td>
</tr>
<tr>
<td>21-30</td>
<td>10 (0.06)</td>
<td>43 (0.25)</td>
<td>86 (0.49)</td>
<td>35 (0.20)</td>
<td>174</td>
</tr>
<tr>
<td>31-40</td>
<td>6 (0.04)</td>
<td>86 (0.58)</td>
<td>29 (0.19)</td>
<td>29 (0.19)</td>
<td>150</td>
</tr>
<tr>
<td>40+</td>
<td>7 (0.09)</td>
<td>35 (0.46)</td>
<td>29 (0.38)</td>
<td>23 (0.07)</td>
<td>76</td>
</tr>
<tr>
<td>Totals</td>
<td>27</td>
<td>174</td>
<td>150</td>
<td>76</td>
<td>427</td>
</tr>
</tbody>
</table>
Table 3.5  Kappa (k) and level of agreement* (percent) between FSW respondents providing proxy data on 12 duplicate clients

<table>
<thead>
<tr>
<th>Client</th>
<th>No. respondents</th>
<th>k (standard error)</th>
<th>p-value</th>
<th>Variables</th>
<th>Location of residence</th>
<th>Marital status</th>
<th>HIV status†</th>
<th>STI status‡</th>
<th>House regular</th>
<th>Patronizes other FSW</th>
<th>Patronizes other establishments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0.57 (0.09)</td>
<td>&lt;0.0001</td>
<td></td>
<td>40%</td>
<td>100%</td>
<td>20%</td>
<td>60%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0.65 (0.16)</td>
<td>&lt;0.0001</td>
<td></td>
<td>67%</td>
<td>100%</td>
<td>0%</td>
<td>33%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>0.78 (0.13)</td>
<td>&lt;0.0001</td>
<td></td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
<td>50%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0.42 (0.16)</td>
<td>0.005</td>
<td></td>
<td>100%</td>
<td>100%</td>
<td>50%</td>
<td>50%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0.72 (0.30)</td>
<td>0.008</td>
<td></td>
<td>100%</td>
<td>50%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>0.62 (0.15)</td>
<td>&lt;0.0001</td>
<td></td>
<td>50%</td>
<td>100%</td>
<td>0%</td>
<td>25%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0.72 (0.30)</td>
<td>0.008</td>
<td></td>
<td>100%</td>
<td>50%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>-0.03 (0.19)</td>
<td>0.56</td>
<td></td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>0.41 (0.10)</td>
<td>&lt;0.0001</td>
<td></td>
<td>50%</td>
<td>100%</td>
<td>25%</td>
<td>50%</td>
<td>100%</td>
<td>100%</td>
<td>75%</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>0.00 (0.11)</td>
<td>0.50</td>
<td></td>
<td>50%</td>
<td>100%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>0.25 (0.29)</td>
<td>0.19</td>
<td></td>
<td>100%</td>
<td>50%</td>
<td>0%</td>
<td>50%</td>
<td>100%</td>
<td>100%</td>
<td>50%</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>0.60 (0.34)</td>
<td>0.05</td>
<td></td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Agreement* is defined as any answers other than "unknown" that were identical. E.g., 0% indicates that all respondents answered "unknown."

† Calculated using StatsDirect 2.5.7 © 1990-2005. For two respondents Cohen’s kappa (unweighted) was used. For greater than two respondents the Fleiss-Nee-Landis test was used.

‡ In all cases the status was either known as “definitely yes” or unknown. That is, none of the disagreement was as a result of one respondent stating “yes” and another stating “no.”
### Table 3.6  Demographic and behavioural characteristics of 234 first-order sex partners

<table>
<thead>
<tr>
<th>Characteristic*</th>
<th>Clients (n=205)</th>
<th>Non-clients (n=29)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No.</strong></td>
<td><strong>(%)</strong></td>
<td><strong>No.</strong></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>205</td>
<td>(100.0)</td>
</tr>
<tr>
<td>Female</td>
<td>0</td>
<td>(0.0)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>IQR</td>
<td>29-43</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>19-70</td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity/Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>105</td>
<td>(51.3)</td>
</tr>
<tr>
<td>Chinese</td>
<td>14</td>
<td>(6.8)</td>
</tr>
<tr>
<td>Aboriginal</td>
<td>1</td>
<td>(0.5)</td>
</tr>
<tr>
<td>Black</td>
<td>4</td>
<td>(2.0)</td>
</tr>
<tr>
<td>South Asian</td>
<td>62</td>
<td>(30.2)</td>
</tr>
<tr>
<td>Other Asian</td>
<td>8</td>
<td>(3.9)</td>
</tr>
<tr>
<td>Latin American</td>
<td>5</td>
<td>(2.4)</td>
</tr>
<tr>
<td>Other/mixed</td>
<td>6</td>
<td>(2.9)</td>
</tr>
<tr>
<td><strong>Marital status</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wife</td>
<td>86</td>
<td>(41.9)</td>
</tr>
<tr>
<td>Girlfriend</td>
<td>25</td>
<td>(12.2)</td>
</tr>
<tr>
<td>Single</td>
<td>50</td>
<td>(24.4)</td>
</tr>
<tr>
<td>Sex worker†</td>
<td>0</td>
<td>(0.0)</td>
</tr>
<tr>
<td>No other known partners</td>
<td>0</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Unknown marital status</td>
<td>44</td>
<td>(21.5)</td>
</tr>
<tr>
<td>Known as house regular§</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>43</td>
<td>(21.0)</td>
</tr>
<tr>
<td>No</td>
<td>162</td>
<td>(79.0)</td>
</tr>
<tr>
<td><strong>Known to patronize other sex workers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>148</td>
<td>(72.2)</td>
</tr>
<tr>
<td>No</td>
<td>57</td>
<td>(27.8)</td>
</tr>
<tr>
<td><strong>Known to patronize street FSW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>12</td>
<td>(5.9)</td>
</tr>
<tr>
<td>No</td>
<td>193</td>
<td>(94.1)</td>
</tr>
<tr>
<td><strong>Known to patronize more than one sex establishment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>98</td>
<td>(47.8)</td>
</tr>
<tr>
<td>No</td>
<td>107</td>
<td>(52.2)</td>
</tr>
<tr>
<td><strong>Known sexual partnering patterns</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One FSW only</td>
<td>45</td>
<td>(21.9)</td>
</tr>
<tr>
<td>One FSW and main partner</td>
<td>40</td>
<td>(19.5)</td>
</tr>
<tr>
<td>Multiple FSW</td>
<td>52</td>
<td>(25.4)</td>
</tr>
<tr>
<td>Multiple FSW and main partner</td>
<td>68</td>
<td>(33.2)</td>
</tr>
</tbody>
</table>

*For duplicates (see Table 3.5), responses that achieved the highest level of agreement were assigned. In cases where agreement was less than 50% due to unknown responses, the known response was assigned (e.g., if 1 out of 4 respondents answered “definitely yes” to HIV status, the
partner was coded as HIV infected).
* Denotes a wife or girlfriend other than the respondent
† The intimate partner of one respondent was a female co-worker (sex worker)
§ Defined by FSW as clients who frequent the establishment and have sex with all the workers
Figure 3.1  Complete sexual network (n=553)

Nodes represent people: squares denote clients, circles denote FSW, and triangles denote the general population. Grey nodes are male and white nodes are female. Clusters of FSW nodes (white circles) represent sex establishments. Lines represent sexual contact. The seven establishments in which recruitment took place are circled. The sample client depicted in Figure 3.2 is enclosed in a square box.

Figure 3.2  Example of a client known to be a house regular at three sex establishments who also has a wife.
3.5 References


CHAPTER 4
CLIENTS OF INDOOR COMMERCIAL SEX WORKERS: HETEROGENEITY IN PATRONAGE PATTERNS AND IMPLICATIONS FOR HIV AND STI PROPAGATION THROUGH SEXUAL NETWORKS

4.1 Introduction

Clients of FSW are an elusive population, and as such are rarely the subjects of research or the targets of STI prevention strategies. With the exception of when they are attending an indoor sex establishment (e.g., visiting a brothel) or in police custody (e.g., enrolled in "Johns’ School"), they are invisible within the general population (1-3). Although clients are considered key to the spread of infection from the commercial sex core to the general population (4;5), STI prevalence, sexual behaviours, and FSW patronage patterns vary, and therefore it may not be reasonable nor efficient to lump them all into one high-risk category. Furthermore, little is known about the structure and context of the sexual networks that form between clients and FSW, particularly within the indoor commercial sex industry.

Social network analysis is increasingly being used to help explain the spread of STI by focusing on the relationships among individuals in a group. SNA produces statistics that describe the quality, density, position, and structure of relationships (6). Certain network structures provide the potential pathways for rapid propagation if shifts in behavioural patterns occur (e.g., reduction in condom use) or if a pathogen is introduced (see Table 4.1 for a summary and definitions of selected network concepts). For example, 2-cores are subgroups in which all individuals are connected to at least two others in the group. These highly connected microstructures provide the pathways for transmission of HIV or STI through sexual contact or needle sharing and have been empirically demonstrated to be associated with HIV and STI infection (7). The frequency and distribution of cliques (fully-connected subgroups of three or more people) and other microstructures in a network have been empirically associated with rapid syphilis transmission (8).

A version of this chapter has been accepted for publication. Remple VP, Patrick DM, Johnston C, Tyndall MW, Jolly A. Clients of indoor commercial sex workers: heterogeneity in patronage patterns and implications for HIV and STI propagation through sexual networks. STD.
The positions of individuals in a network also have implications for acquisition and spread of infection. Centrally located infected individuals are more likely to result in disease propagation than if they were located in the periphery. Likewise, centrally located susceptible individuals are at greater risk for infection due to greater opportunity for exposure (7-10).

The importance of sexual networks to STI epidemiology and control is becoming more widely accepted (11-13). However, conducting network studies can be logistically challenging, particularly when targeting hidden populations. It was therefore the purpose of this study to determine whether a classification of higher risk clients that could be validated by network analysis was possible through interviewing indoor FSW. In theory, this could allow straightforward identification of high-risk clients for the purposes of targeted intervention. The research questions we examined in this paper were whether so-called high-risk clients occupied important network positions, such as high centrality or membership in 2-cores or cliques. We also tentatively explored the question of whether or not high-risk clients were more likely to be HIV and STI infected.

4.2 Methods

4.2.1 Data Collection

This research was conducted in seven indoor commercial sex establishments in the Canadian cities of Vancouver (population ~550,000), Richmond (population ~182,000), Surrey (population ~350,000) and Burnaby (population ~197,000). All four cities are located in south-western British Columbia in a region containing over 50% of the total provincial population.

A detailed description of the study methods was provided in Chapter 2. In brief, structured interviews were conducted in a private room at the sex establishments. Respondents were asked to list up to 10 of their most recent sexual partners, including clients and non-commercial partners. The interviewer completed a separate proxy questionnaire for each of the identified partners. Respondents were asked to describe each of their partners in terms of names (nicknames), age, appearance, ethnicity, city of residence, and marital status. Detailed information on their sexual relationships was collected, including dates of first and last sexual contact, number of sexual contacts, frequency of sexual contact, types of sex acts, and frequency
of condom use. Each respondent was asked whether her contacts had HIV, had had an STI during their relationship, had sex with other FSW, or had patronized other commercial sex establishments or street-based FSW.

4.2.2 Data Management and Analysis

The data entry, data validation, and duplicate consolidation methods were described in Chapter 3 (see section 3.2.3). Respondents’ sex partners were coded as HIV or STI infected if the respondent answered “definitely yes” to the questions: “Do you think this person has HIV/AIDS?” or “Do you think this person has had an STD since you’ve known him?” If a respondent identified a contact as HIV or STI infected, the interviewer probed to find out how she knew. In each case the respondent was definitely sure because the client had disclosed his status to her. Unless respondents were sure of their partner’s infection status, the partner’s status was recoded as “maybe”.

A detailed description of the network construction and visualization methods was provided in Chapter 3 (see section 3.2.3). UCINET® (14) was used to extract microstructures and to assign membership to structures and measures of centrality for all network members. SPlus® Version 6.1 Academic Site (© Insightful Corp, 2005) was used to conduct statistical analyses. Relationships between risk category (i.e., high and low) and variables of interest were analyzed using non-parametric cross-tabulation (Chi-square and Fisher’s Exact Test) and the Mann Whitney U Test for categorical and continuous data, respectively.

4.3 Results

Between June 2004 and February 2006, 49 FSW in seven sex establishments were interviewed. The demographic, behavioural and employment characteristics of the 49 respondents were reported in Chapter 3. Once duplicates were consolidated, proxy data was available for 234 unique partners, 205 (88%) of whom were commercial clients.

The demographic and behavioural characteristics and HIV and STI status of the 205 clients are summarized in Table 4.2. Despite reporting on their most recent sexual contacts only, respondents were able to provide detailed information on most of their clients with the
exception of their infection status and their street-based FSW patronage. Two (1%) and eight (4%) of the clients were known to be HIV infected or to have had an STI during the partnership, respectively. The respondents were unaware of the infection status of approximately half of the clients.

The complete sexual network was composed of a fully-connected component of 553 people with an overall density of 1% (Figure 4.1). The mean degree (number of sexual partners) was 5.4 (standard deviation 9.1, range 1-94). There were 115 cliques of size 3 and a single 2-core of 230 individuals comprised of FSW and clients.

Although most of the 205 clients (72%) were known to have had sex with more than one FSW, two unique categories of clients emerged from the interview data. We defined these as high-risk because of their apparent role in creating multiple sexual linkages between FSW and multiple sexual linkages between sex establishments. The first, which FSW referred to as house regulars, were men who did not restrict their patronage to one or two workers, but who had sex with all the workers at the establishment. Anecdotally, the respondents reported that these men also visited the establishments the most frequently - many visited several times per week and, in some cases, even daily. The median number of times respondents reported having sex with the house regular clients was 3 (IQR 1-3) and ranged between 1 and 200 times. Several house regulars also had the reputation of seeking out higher-risk activities, such as anal sex, sex without a condom, and GFE, or “girlfriend experience” (GFE is a sexual encounter that involves what FSW consider higher levels of physical contact. This may include kissing, cunnilingus, or oral and vaginal sex without a condom.)

The second category, dubbed establishment bridgers, was comprised of clients who were known to patronize more than one sex establishment or segment of the sex industry. Forty eight percent of the clients were known to patronize more than one establishment and 6% were known to patronize street-based FSW. The median number of times respondents reported having sex with establishment bridgers was 4 (IQR 2-10) and ranged between 1 and 100 times (data not shown). Thirty (15%) clients were known as both house regulars and establishment bridgers (data not shown).
In total, there were 111 (54%) clients who were categorized as high-risk through their house regular or establishment bridging patterns (Figure 4.1). The demographic and network characteristics of the high- and low-risk clients are compared in Table 4.3. High-risk clients were significantly more likely to be members of the large 2-core, to be members of a clique, and to be cut vertexes. They also had significantly higher centrality measures than the lower risk clients. Furthermore, all of the HIV and STI infections were reported in the high-risk clients, although for HIV this did not achieve statistical significance. Although more high-risk clients created sexual bridges to the general population through wives or girlfriends, this difference was not statistically significant (59% vs. 39%, p=0.07).

4.4 Discussion

In this study we found that the indoor commercial sex network was a dense, fully-connected network that was characterized by bridging by clients, both between commercial sex establishments and between the commercial sex network and the general population. Based on straightforward interviewing of FSW, we were able to ascertain that the client population was not homogeneous in terms of sex-buying behaviour and that bridging behaviours existed that could introduce substantial risk to the overall network through creating myriad transmission pathways.

We were able to classify over half of the clients identified in our sample as high-risk in terms of what respondents knew about their patronage patterns. House regulars may increase the overall level of concurrency within the network through their frequent, repeated sexual contact with multiple FSW concurrent with sexual relations with wives or girlfriends. These concurrent partnerships may potentiate rapid spread of STI because there is less time lost after transmission waiting for the current partnership to dissolve (15-19). This may be particularly salient in the context of STI that have short windows of infectiousness and that require either a high rate of new partner acquisition or partnership overlap to spread.

Clients who patronize more than one commercial sex establishment create bridges between different local networks (i.e., those centered around a particular establishment) that may differ in terms of risk behaviour patterns, HIV and STI prevalences, and racial or ethnic groups. For example, clients who patronize both street-based and indoor FSW form bridges between the
indoor and outdoor population, where the prevalence of injection drug use and HIV is high (20). As well, condom use and GFE practices may vary among establishments, depending on the socioeconomic status of the workers, the management policies, and the house rules. Establishment bridgers may also contribute to the overall concurrency levels within the network if they go to different establishments, or have sex with the same group of FSW repeatedly, concurrent with sexual relations with wives or girlfriends.

When we compared our categorization of high- and low-risk clients, striking differences in terms of network importance were discovered. High-risk clients were more likely to be members of dense microstructures, such as 2-cores and cliques, and to be cut vertexes. From the graph theoretical perspective, 2-cores are particularly robust to fragmentation because they do not contain an individual whose removal would fragment the network structure. The implications of this are that there is more than one potential transmission pathway for every 2-core member, and that network fragmentation is reliant on group- versus individual-level behaviour change. Cliques are microstructures that resemble a fully-connected triangle of three individuals and are particularly important in terms of their frequency and distribution within a network. A high frequency of microstructures in networks has been shown to be an important predictor of HIV and STI spread (8;21).

High-risk clients were also significantly more central in the network than lower risk clients, based on all four different centrality measures. Although each are based on a different theoretical framework (22) and are computed in different ways, these measures have been shown to be highly correlated with each other (10). High centrality measures put high-risk clients in a better position to both acquire and transmit infection through multiple transmission pathways.

All of the proxy-reported HIV and STI infections in the client population were in high-risk clients. Recognizing the limitations of relying on proxy-reported infection status, it is nonetheless important to underscore the potential implications of this finding. Given the high-risk clients’ sociometric prominence in the network, they may play a key role in terms of introducing and spreading infection throughout the network and in terms of bridging to different establishments and the general population.
Our findings have several implications in terms of developing STI prevention strategies. First, theoretical removal of high-risk clients from the network would cause dramatic fragmentation of the overall network by reducing the amount of potential transmission pathways (Figure 4.2). From the practical perspective, it is not reasonable to literally remove a large segment of the client population from the commercial sex industry. However, weakening the transmission pathways through consistent, correct condom use may dramatically reduce the effectiveness of these pathways. The educational message of 100% condom use remains very important, especially in the context of regular partners and those clients whom the FSW know are house regulars or patrons of other establishments. This message cannot be overstated, given the unique context of indoor sex work where clients and FSW spend longer periods of time together, where sexual relationships may extend over months or years, and where condom use may become lax. During this study, some of the study participants disclosed that condom use was more likely to be inconsistent with regular clients whom they felt they knew well or liked, a finding which has been reported by others (23;24). The network diagrams could be used as educational tools to reinforce this message, enabling outreach workers to show FSW how the network is linked and how STI could be spread through it.

Second, although more logistically challenging, providing the same educational messages to high-risk clients may be possible. In addition to the 100% condom message, clients could be encouraged to reduce the number of concurrent FSW and establishments they patronize. However, this may be viewed as “bad for business” by establishment owners and FSW themselves. Educational messaging could be facilitated by the FSW and establishment owners – for example, by showing and explaining the network diagram to their regular clients or allowing print materials, such as posters or pamphlets, to be made available in the waiting rooms of escort agencies or massage parlours. FSW may also be willing to distribute cards or educational materials that promote STI screening services to clients referring. The internet is also a powerful dissemination tool in the commercial sex trade. Many of the indoor commercial sex establishments have websites and it may be possible to post information or links on them. As well, there are several high-volume websites where male sex buyers communicate that may allow links and postings for health education.

This research has several important limitations. First, the study used a non-probability sample of FSW to obtain proxy data on commercial clients. Although purposive, targeted sampling is
considered more rigorous than simple convenience sampling (25), selection bias has undoubtedly been introduced and therefore our findings cannot be generalized to all commercial sex networks.

Second, proxy-reporting of behaviours and attributes of the most recent sex partners may have introduced recall bias in the form of “first-time” clients whom respondents knew less well than some of their more familiar, regular clients. Because of this, misclassification of high-risk clients as low-risk clients may have occurred due to respondents simply not knowing some of the first-timers’ patronage habits. However, it is unlikely that this type of misclassification resulted in qualitative changes in the differences of network importance because most of the network characteristics (e.g., centrality measures and membership in microstructures) were by definition attributed to those who had multiple sex partners and who bridged between establishments.

Third, the method used to ascertain HIV and STI status was not rigorous. It is likely that the client HIV and STI “prevalences” of 1% and 4% were underestimated, given that, for 55% and 46% of the clients, the respondents were unaware of their HIV and STI status, respectively. Any generalizations based on these results must be extremely tentative and these findings should only be used to guide further inquiry.

In conclusion, we demonstrated that it is possible to identify theoretically high-risk commercial sex clients from the network perspective using simple data collection and categorization approaches. These findings may assist health providers and educators to provide targeted, contextually-appropriate education messages to women who work in the indoor commercial sex industry and to their male clients.
Table 4.1  Definitions of selected network concepts

All definitions from Wasserman and Faust (6) and Scott (26).

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>A group of connected individuals in which there is a path of some length</td>
</tr>
<tr>
<td></td>
<td>from all persons to every other individual in the network.</td>
</tr>
<tr>
<td>2-core</td>
<td>A subgroup in which all individuals are connected to at least two others</td>
</tr>
<tr>
<td></td>
<td>in the group.</td>
</tr>
<tr>
<td>Cut vertex</td>
<td>An individual whose removal results in an increase in the number of</td>
</tr>
<tr>
<td></td>
<td>components (i.e., network fragmentation).</td>
</tr>
<tr>
<td>Clique (n=3)</td>
<td>A maximally connected subgroup of three individuals.</td>
</tr>
<tr>
<td>Degree centrality</td>
<td>The number of direct connections to each individual in the network</td>
</tr>
<tr>
<td></td>
<td>(or, the number of sex partners).</td>
</tr>
<tr>
<td>Information centrality</td>
<td>The harmonic distance of any individual to all other individuals in the</td>
</tr>
<tr>
<td></td>
<td>network.</td>
</tr>
<tr>
<td>Eigenvector centrality</td>
<td>The centrality of individuals based on the centrality of the</td>
</tr>
<tr>
<td></td>
<td>individuals to whom he or she is sexually linked.</td>
</tr>
<tr>
<td>Betweenness centrality</td>
<td>Frequency with which an individual is on the shortest path between all</td>
</tr>
<tr>
<td></td>
<td>other pairs of individuals in a component.</td>
</tr>
<tr>
<td>Characteristic</td>
<td>No.</td>
</tr>
<tr>
<td>----------------</td>
<td>-----</td>
</tr>
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<td>Mean age (SD)</td>
<td>37 (11)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
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</tr>
<tr>
<td>South Asian</td>
<td>62</td>
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<tr>
<td>Chinese</td>
<td>14</td>
</tr>
<tr>
<td>Other Asian</td>
<td>8</td>
</tr>
<tr>
<td>Mixed/other</td>
<td>16</td>
</tr>
<tr>
<td>City/town of residence</td>
<td></td>
</tr>
<tr>
<td>Same as sex establishment</td>
<td>115</td>
</tr>
<tr>
<td>Different than sex establishment</td>
<td>68</td>
</tr>
<tr>
<td>Unknown</td>
<td>22</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>86</td>
</tr>
<tr>
<td>Girlfriend</td>
<td>25</td>
</tr>
<tr>
<td>Single</td>
<td>45</td>
</tr>
<tr>
<td>Unknown</td>
<td>49</td>
</tr>
<tr>
<td>Known to patronize more than one FSW</td>
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<td>Yes</td>
<td>148</td>
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<td>No</td>
<td>33</td>
</tr>
<tr>
<td>Unknown</td>
<td>24</td>
</tr>
<tr>
<td>Known as a house regular</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>43</td>
</tr>
<tr>
<td>No</td>
<td>137</td>
</tr>
<tr>
<td>Unknown</td>
<td>25</td>
</tr>
<tr>
<td>Known to patronize more than one sex establishment</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>98</td>
</tr>
<tr>
<td>No</td>
<td>37</td>
</tr>
<tr>
<td>Unknown</td>
<td>70</td>
</tr>
<tr>
<td>Known to patronize street-based FSW</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>11</td>
</tr>
<tr>
<td>No</td>
<td>23</td>
</tr>
<tr>
<td>Unknown</td>
<td>171</td>
</tr>
<tr>
<td>Is “definitely” HIV infected</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
</tr>
<tr>
<td>Maybe</td>
<td>5</td>
</tr>
<tr>
<td>No</td>
<td>84</td>
</tr>
<tr>
<td>Unknown</td>
<td>114</td>
</tr>
<tr>
<td>Has “definitely” had an STI</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>8</td>
</tr>
<tr>
<td>Maybe</td>
<td>6</td>
</tr>
<tr>
<td>No</td>
<td>94</td>
</tr>
<tr>
<td>Unknown</td>
<td>97</td>
</tr>
</tbody>
</table>

*Sex establishment in question was the work place of the respondent from whom proxy data was obtained.
Figure 4.1  Complete network (n=553)

Nodes represent people: squares depict clients; circles depict FSW; and triangles depict non-commercial partners (wives, girlfriends, husbands, and boyfriends). High-risk clients are black (n=111). Clusters of FSW nodes (white circles) represent sex establishments. Lines represent sexual contact. Network members known to be HIV infected (n=2) are indicated with block arrows. Enlarged nodes represent individuals known to have had an STI (n=13).
Figure 4.2 • Network with high-risk clients theoretically “removed”
Table 4.3 Differences between high-risk and low-risk clients (n=205)

<table>
<thead>
<tr>
<th>Variable</th>
<th>High-risk (n=111)</th>
<th>Low Risk (n=94)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>56 (50.5)</td>
<td>49 (52.1)</td>
<td>0.48</td>
</tr>
<tr>
<td>South Asian</td>
<td>31 (27.9)</td>
<td>30 (31.9)</td>
<td></td>
</tr>
<tr>
<td>Chinese</td>
<td>8 (7.2)</td>
<td>6 (6.4)</td>
<td></td>
</tr>
<tr>
<td>Other Asian</td>
<td>4 (3.6)</td>
<td>4 (4.3)</td>
<td></td>
</tr>
<tr>
<td>Other/mixed</td>
<td>10 (9.0)</td>
<td>5 (5.3)</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>2 (1.8)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
<tr>
<td>City or town of residence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same as sex establishment</td>
<td>58 (52.3)</td>
<td>57 (60.6)</td>
<td>0.30</td>
</tr>
<tr>
<td>Different than sex establishment</td>
<td>38 (34.2)</td>
<td>30 (31.9)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>15 (13.5)</td>
<td>7 (7.5)</td>
<td></td>
</tr>
<tr>
<td>Member of 2-core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>83 (74.8)</td>
<td>19 (20.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No</td>
<td>28 (25.2)</td>
<td>75 (79.8)</td>
<td></td>
</tr>
<tr>
<td>Member of a clique (size 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>23 (20.7)</td>
<td>1 (1.1)</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>No</td>
<td>88 (79.3)</td>
<td>93 (98.9)</td>
<td></td>
</tr>
<tr>
<td>Bridges to general population</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>65 (58.6)</td>
<td>43 (38.7)</td>
<td>0.07</td>
</tr>
<tr>
<td>No/unknown</td>
<td>46 (41.4)</td>
<td>51 (61.3)</td>
<td></td>
</tr>
<tr>
<td>Is a cut vertex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>88 (79.3)</td>
<td>43 (45.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No</td>
<td>23 (20.7)</td>
<td>51 (54.3)</td>
<td></td>
</tr>
<tr>
<td>Centrality measures: mean [SD]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree</td>
<td>11.6 [14.9]</td>
<td>1.8 [1.1]</td>
<td>0.00</td>
</tr>
<tr>
<td>Information</td>
<td>0.72 [0.19]</td>
<td>0.51 [0.10]</td>
<td>0.00</td>
</tr>
<tr>
<td>Eigenvector</td>
<td>0.032 [0.06]</td>
<td>0.003 [0.005]</td>
<td>0.00</td>
</tr>
<tr>
<td>Betweenness</td>
<td>2308 [4729]</td>
<td>261 [291]</td>
<td>0.00</td>
</tr>
<tr>
<td>Known to be HIV positive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2 (1.8)</td>
<td>0 (0.0)</td>
<td>0.50†</td>
</tr>
<tr>
<td>No/unknown</td>
<td>109 (98.2)</td>
<td>94 (100.0)</td>
<td></td>
</tr>
<tr>
<td>Known to have had STI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>8 (7.2)</td>
<td>0 (0.0)</td>
<td>0.01†</td>
</tr>
<tr>
<td>No/unknown</td>
<td>103 (92.8)</td>
<td>94 (100.0)</td>
<td></td>
</tr>
</tbody>
</table>

* p-values ignore missing values. Categorical variables were tested using Chi square test, continuous variables tested using Mann Whitney U-Test for non-normal data.
† Categorical variables in which cell values are <5 were tested using Fisher's Exact Test.
4.5 References


CHAPTER 5
DISCUSSION AND CONCLUSIONS

5.1 Summary of Research Findings

The goal of this research was to use social network analysis to explore the STI risk environment of the indoor commercial sex industry. The network approach emphasized the context of sexual relationships and provided a paradigm for analyses at the level of the individual, the partnerships, and the overall network in which commercial sex takes place. The overarching hypothesis was that the network structure was such that STI propagation could occur. The research objectives were: (a) to determine the network structure and characteristics of indoor commercial sex workers in the GVRD, and (b) to determine the potential for STI transmission to the general population. Although each of Chapters 3 and 4 included a discussion of the findings, the following provides a synthesis and discussion of the findings for the eight thesis hypotheses. Additional analyses that are referenced can be found in Appendix C.

5.1.1 Hypothesis #1: Microstructures, Such as k-plexes and n-cliques, Will be Found in the Large Network Components

Instead of multiple components centred on individual commercial sex establishments, the indoor commercial sex network was a single, connected component with 553 individuals. The network had a very high frequency of many different types of microstructures including cliques, k-plexes, k-cores, and bicomponents (Appendix C, Table C.1). Microstructures create the dense, cyclic network structures that provide the necessary infrastructure for transmission networks (1). Furthermore, microstructures make networks robust because they cannot be fragmented by the removal of a single individual. For example, the presence of a large 2-core means that each individual within the microstructure has more than one opportunity and more than one independent route for acquiring and transmitting infection. Reducing the STI transmission risk potential in this type of a structure relies on group- rather than individual-level behaviour change.

A high frequency of microstructures was associated with HIV and STI in other networks. When compared to other studies, it was clear that the current study sample was much more highly
connected and experienced a far greater frequency of microstructures than other studies in which syphilis and HIV were highly prevalent (2-4). Approximately 11% of the first-order network (respondents and first-order partners) were members of the 116 cliques, a finding similar to that reported by Rothenberg et al. (2). Furthermore, the number of 2-cliques (size 3) as a proportion of the overall network was substantially higher in this study sample than the syphilis and HIV studies. In Atlanta, Rothenberg et al. (3) found that all of the syphilis cases during an outbreak were reported during the time when the network experienced the highest frequency of microstructures.

Any conclusions based on these comparisons should take into consideration the differences in clinical epidemiology of different STI and the differences in data sources used for analyses. For example, transmission probabilities vary greatly between pathogens, such as *Treponema pallidum* (the infectious agent for syphilis), which has an estimated probability of 0.6 per partnership, and HIV-1, which has an estimated probability of 0.05-0.15 per partnership (5). Genetic variability in the host also plays a role in the course of infection in an individual and the spread of infection within a population (6;7). These features are not accounted for in network analysis.

In terms of data sources, the comparison studies used different data collection methods, including annual network interviewing of high-risk individuals recruited from sexually transmitted disease, HIV testing, and methadone clinics (8), standard epidemiologic interviews with syphilis cases and contacts during an outbreak (3), and network interviewing of high-risk individuals recruited through street-based outreach (2), all of which may ultimately influence the network findings. Despite these considerations, the findings of the current study support the hypothesis that the indoor commercial network structure is one that would support STI spread.

5.1.2 Hypothesis #2: Sexual Partner Concurrency is High Among Indoor FSW and Their Clients (i.e., >50%)

Several types of concurrency were found that support this hypothesis. First, the findings presented in Chapter 3 showed that 53% and 50% of the FSW respondents and their sex partners, respectively, were known to have both non-commercial and commercial sex partners. All of the FSW reported that they were sexually active with their non-commercial partners. If one assumes
that all or most of the clients were also sexually active with their wives or girlfriends, the prevalence of concurrent behaviour was at least 50% within the FSW and client group. Mathematical modeling demonstrated that, in a population where half of the partnerships are concurrent, the number of incident HIV infections can be 10 times greater than a population where serial monogamy prevails (9). This particularly risky form of concurrency is enhanced by bridging between the commercial sex industry and the general population and has been largely responsible for the transmission of HIV and other STI to the lower-risk population of wives and girlfriends in some countries (10-13).

Second, concurrency within commercial sex relationships was found, both from the FSW and the client perspectives. Fifty nine percent of the FSW reported having sex with a particular client more than once (note that this figure applies only to the 205 clients included in this study), and they reported a median of six sexual contacts with repeat clients. Figure C.1 (Appendix C) provides a typical example of a single respondent’s sexual partner overlap by first and last dates of sexual contact. The figure clearly demonstrates that high levels of concurrency occur with multiple regular clients. Furthermore, the findings presented in Chapter 4 showed that 21% and 48% of clients were known as house regulars and establishment bridgers, respectively. This suggests that commercial sex relationships also overlap substantially over time, with multiple partners.

Third, in graph theoretical terms there were 116 cliques found in the component. Cliques are microstructures that resemble a fully-connected triangle of three individuals, and are particularly important in terms of their frequency and distribution within a network. In a 100% heterosexual population, cliques do not form because of unequal gender distribution (that is, two of the three are either males or females who do not have sex with each other). However, in this network cliques formed in two ways: (a) as a result of “duos,” or group sex, between two FSW and one male client (i.e., a client who pays for two FSW for one session) and (b) as a result of two FSW who were lesbian lovers and who had some of the same clients. In the context of commercial sex networks, this form of concurrency may be particularly important because infection can be transmitted simultaneously through group contact. Although STI transmission between women may be less efficient than through heterosexual contact (14), there is evidence that it does occur (15). Furthermore, the sharing of sex toys as well as a male partner during a commercial sex duo may enable transmission of infection between three people at once. In an Atlanta syphilis...
outbreak (3), concurrency and overlapping exposure in infected people through group sex was a strong predictor of epidemic spread, and it was only after the frequency of these microstructures diminished over time that an abatement of transmission occurred.

Several different types of concurrency have also been reported in the literature, in terms of short-term versus long-term (16), and in terms of taxonomies of concurrency based on contextual differences that promote different types of risk behaviour (17). Regional and sociocultural variations in the nature of concurrency and in different patterns of concurrency may also have different implications for the efficiency of STI spread across populations (17). For example, disease is more likely to spread if both infectiousness and sexual contact with concurrent partners occurs repeatedly over time. In this study it was clear that several different types of concurrency occurred with high frequency. This overall behaviour pattern creates a fertile environment for the spread of infections that have both long and short durations of infectiousness.

5.1.3 Hypothesis #3: The Ethnicity of Clients is More Likely to be the Same as that of Indoor FSW

Sixty six percent of the reported sex partnerships were discordant by race or ethnicity. Sixty seven percent and 45% of commercial and non-commercial partners, respectively, were discordant. Furthermore, the Q value (a measure of the degree of assortative mixing) for the ethnicity or racial mixing matrix showed that the general mixing pattern was primarily disassortative. This finding was contrary to the hypothesis, which was based on the literature that shows that people tend to mate assortatively by race or ethnicity (18;19). The reasons for disassortative mixing in the commercial sex context were not explored in this study. However, it is possible that men seek commercial sex partners or sexual experiences that are different from what they experience with non-commercial partners (i.e., wives or girlfriends). Furthermore, the factors that promote assortative heterosexual mate selection, such as education, socioeconomic status, and reproductive potential of a prospective partner (18;20) may not be relevant within the commercial sex context. This form of disassortative mixing forms a bridge between different ethnic or racial groups that may experience different prevalences of STI (21-24).
5.1.4 Hypothesis #4: On Average, Sex Partners are Older than Indoor FSW

In Chapter 3, the findings showed that in 66% of the 256 sex partnerships reported by the respondents there was an age difference of five years or greater. The absolute age difference between respondents and their clients was a median of 9 years with clients and a median of 4.5 years with non-commercial partners. Overall, 56% of all respondents’ sex partners were at least five years older. The Q value for the age mixing matrix also indicated that the overall mixing pattern was primarily disassortative. This form of mixing may expose younger FSW and younger commercial clients to infections that are more prevalent in older populations, such as herpes simplex virus-2 or HIV (5;18;25).

5.1.5 Hypothesis #5: The Average Rate of Partner Change Among Indoor FSW is Equal To or Greater Than That Required for Successful Epidemic Growth of Chlamydia Trachomatis (i.e., ≥ One New Partner Per Month)

This hypothesis was originally stated based on the assumption that the study data could be used as a parameter in the reproductive number (R₀) formula. The findings presented in Chapter 3 showed that the median number of unique partners among the 49 respondents was 30 (IQR 20-50, range 1-200) per month. However, if one wishes to calculate the reproductive number for a population, the standardized average rate of new partner acquisition must be calculated for the entire population. Because the first- and second-order partners (i.e., clients and non-commercial partners and their wives and girlfriends) were not interviewed, it was not possible to know the average rate of partner change in the total network. Applying the R₀ formula to these data is additionally problematic because, even if heterogeneity of sexual contacts were incorporated, the model still assumes random mixing in terms of how sexual contacts form and it assumes that sexual contacts follow a normal distribution. However, non-random mixing is not unique to these study results. The study data showed a non-normal one-month sex partner distribution for the respondents that was right-skewed (Appendix C, Figure C.2), a finding reported in other empirical studies (26;27).

The degree distribution of the network graph may resemble a scale-free network, although incomplete sex partner data makes this difficult to ascertain. In scale-free networks most nodes have a degree of 1 or 2, but a few have a very high degree and are known as hubs (26). As
shown in Appendix C (Table C.1), for the total network of 553 people the average degree was 5.4 with a standard deviation of 9.1 (variance of 83). Figures C.3 and C.4 show the degree distribution curves for the complete network and the first-order subgroup (i.e., respondents and their first-order partners), respectively. In both graphs it appears that the distribution does not decay rapidly, but rather has a slowly decaying “fat” tail that is characteristic of scale-free distributions (27). Liljeros et al. (26) hypothesized that certain individuals may have increased skill in acquiring new partners as the number of previous partners grows due to varying degrees of sexual attractiveness and the motivation to have many new partners to sustain self-image. In the context of these data, preferential attachment (the creation of hubs) may be conceptualized as FSW who become more skilled at attracting large numbers of clients as their expertise increases, and as clients who increase their FSW patronage to sustain their sexual needs (e.g., house regulars). Whereas in random networks infection spreads throughout the network only if the spreading rate exceeds a critical threshold, Barabasi and Bonabeau (28) suggested that in scale-free networks there is no threshold, meaning that even weakly infectious agents can propagate. Despite the difficulties in determining an epidemic threshold for these data, FSW and their commercial sex partners represent a core group that is highly sexually active. According to Brunham (29), core group members may be defined as those with a high rate of partner exchange. He also pointed out that they must be highly connected in order to become reservoirs of STI for the greater population. In this study, it was clear that FSW and their partners were a highly sexually active core group with a high level of interconnectivity and connection to the general population. It is also possible that infected people remained in this highly active population for long periods of time (i.e., parameter $D$ in the $R_0$ model). Almost one quarter of the FSW interviewed reported that they received STI screening less than once per year (Appendix C, Table C.2). This finding suggests that certain infections, especially those that are asymptomatic, may remain in the network for long periods of time.

5.1.6 Hypothesis #6: Individuals Who Bridge Sexually Between Indoor Commercial Sex Networks and the General Population Will Be Identified and They May Have Key Roles in the Spread of STI into the General Population

As discussed under hypothesis #2, there was substantial bridging between the commercial sex network and the general population through sexual connections with non-commercial partners.
In Table C.3 (Appendix C), a comparison between FSW respondents and clients who had non-commercial partners, and FSW and clients who did not have non-commercial partners, shows that individuals who bridged to the general population were also significantly more prominent by all four centrality measures. However, with the exception of degree, this finding is to be expected, given the fact that an individual who bridges is by definition more central. Although self- and proxy-reported STI and HIV infection were more prevalent in bridgers, these findings did not achieve statistical significance. Nonetheless, these findings suggest that individuals who bridge between the commercial sex and general populations may be uniquely situated to acquire and transmit infection. As discussed previously, transmission of STI by clients to the low-risk population of wives and girlfriends is well documented (10-13). Furthermore, non-commercial partners of FSW may transmit infection to FSW through inconsistent condom use. In this study, two (7%) of the FSW’s non-commercial partners were known to have had an STI during their relationship (see Table 3.2). This finding is also consistent with other studies that conclude that FSW are at risk for STI from their intimate partners (30-32). STI may therefore be transmitted to FSW by their non-commercial sex partners, may circulate within the commercial sex core, and may be bridged out of the commercial core group to the general population.

5.1.7 Hypothesis #7: Individuals Who Bridge Between Indoor Commercial Sex Establishments Will Be Identified and May Have Key Roles for STI Spread Between Establishments and Ethnic Groups

In Chapter 4, the importance of high-risk clients who played a key role in creating potential transmission pathways between multiple FSW and between multiple sex establishments was underscored. The high-risk clients may play a key role in STI transmission, in that all of the STI and HIV known to exist in the client group were in the high-risk category. Furthermore, given their highly central location within the network, they may be in a unique position to propagate spread of infection both within the commercial sex network and to the general population through their multiple links and bridging behaviours.

In addition to bridging clients, several of the respondents reported working in more than one establishment or segment of the sex industry. This type of bridging may also introduce a link between potentially higher-risk sex environments; for example, if a FSW works both on the street and indoors.
It was beyond the scope of this analysis to fully explore the extent to which this bridging behaviour could propagate STI between ethnic groups. However, of the seven establishments in which FSW were recruited there was heterogeneity in terms of the ethnic or racial backgrounds of the women who worked there. For example, there were two parlours that were comprised of mainly Chinese women, whereas the other five parlours had more Caucasian and other ethnicities or races represented. It is therefore possible that clients who patronized different sex establishments from different districts created potential transmission pathways between different ethnic or racial groups.

5.1.8 Hypothesis #8: Bridging Individuals Will Have Higher Information Centrality than Non-Bridgers

Initially we included only information centrality in the research plan, but ultimately we compared four different centrality measures. Information centrality has theoretical importance because it takes into account the fact that infection may not take the most direct route (or geodesic, in graph theoretical terms) between two people. Rather, it evaluates and weights the amount of information of every path between nodes in a graph (33). The high-risk clients scored significantly higher on all four measures of centrality than the low-risk clients. FSW and clients who bridged to the general population were significantly more central by all four measures. Whereas the network graph clearly demonstrated that some nodes were more prominent than others, the centrality measures provided concrete scores rather than simple recognition of the network structure by the human eye, which is subject to error.

Although there are theoretical and mathematical differences between the measures, they were highly correlated (Appendix C, Table C.4). Similar findings were reported elsewhere (33;34). For example, Rothenberg et al. (34) found that multiple measures confirmed the non-centrality of HIV infected persons within the low-prevalence, low-incidence network in Colorado Springs. Conversely, De et al. (35) found that individuals with the highest risk of gonorrhoea infection had the highest information centrality in their respective components in an outbreak in Alberta. Rothenberg et al. (3) also demonstrated that network members with syphilis were more central by betweenness than non-cases.
5.2 Limitations

5.2.1 Sampling

The external validity of this study was limited by the use of a non-probability sample. Although many indoor commercial sex establishments are licensed businesses, and therefore locatable (all of the ones participating in this study were licensed), there are likely far more that are “underground” and truly hidden. The hidden segment of indoor sex work is conducted by FSW in unlicensed micro-brothels (which are generally operated out of private residences) and by independents who work out of their homes (“in-call”) or who travel to their clients’ homes or hotels (“out-call”) (36-39). Furthermore, because of the large amounts of time and resources required to gain access to establishments, most of the establishments we identified had not been visited by the outreach teams at the time of this research (see Table 2.1).

As a result of this approach, the study sample may be biased towards FSW who are Canadian citizens, who are legal immigrants, who have access to healthcare, who have a higher level of HIV- and STI-related knowledge, and who are arguably involved in the sex trade by choice. Furthermore, the sample may under-represent the large population of Asian immigrant women who are purported to be involved in the sex trade in BC and women who may be working under duress (38;40;41). These biases may have resulted in collecting data from women who had more power to negotiate condom use, who had more power to choose the sexual activities they were willing to perform, who worked shorter hours, and who saw fewer clients than more vulnerable, hidden women. The results of this study cannot be generalized to all segments of the indoor commercial sex industry or to other countries where contextual differences in the sex trade exist. However, the study sample should be viewed as illustrative, rather than representative, of the types of networks that exist within the commercial sex industry, and it therefore may be possible to tentatively generalize the study findings to the sex trade that occurs in licensed establishments in Canada (42).

Another limitation is related to the timeframe of the study. All of the network graphs and analyses were generated assuming a static timeframe. However, participants were interviewed over a 20-month study period. To provide a “true” sexual network, it would be ideal to interview all respondents within a short timeframe – for example over a one-month period – and
to collect data on all of their partners during that timeframe. However, this was not feasible. It required weeks or even months of relationship-building to allow recruitment of some of the participants. Nonetheless, because each respondent provided proxy data on their most recent sex partners, the data may be a theoretical representation of the network as it exists at any point in time. As well, given the high proportion of repeat partners (those with whom the respondents had had sex more than once), the representation of the first-order network may be realistic.

5.2.2 Data Collection and Handling

Several limitations were introduced by the data collection and handling methods. First, respondents were asked to report on only their most recent 5-10 sex partners. Although this approach may have minimized recall bias, it resulted in missing data due to a moderate proportion of clients whom the respondents had met for the first time.

Because the number of partners was limited, there were missing data in the form of under-representation of the number of sex partners the respondents had (i.e., artificially low degree centrality). This resulted in an under-representation of the full size, density, and connectivity of the overall network. Missing sex partners of both the respondents and the second-order sex partner also precluded computation of epidemic thresholds for the network. Missing data in network studies is a common phenomenon (8;43) and may result in an underestimation of the risk of infection and the infection routes in a population (44).

Additional limitations were introduced by using individuals as the sampling unit to collect data on partnerships (dyadic-level data) and network structures (network-level data). Ghani et al. (44) proposed that biased estimates of measures of partnerships and of network structure may result in misinterpretation of empirical data and underestimation of infection risk within a population. They constructed a Monte Carlo simulation model to evaluate three different methods of network data collection – individual reports (similar to the method used for this thesis), snowball sampling, and contact tracing – and found that every method underestimated the degree of assortative mixing and the proportion of mutual concurrency. The latter limitation supports the notion that missing data in this study resulted in an underestimation of the degree of connectivity within the network.
The data-handling methods may have imposed artifactual relationships within the data. For example, the high-risk clients described in Chapter 4 had significantly higher centrality measures than those who were not high-risk. This could be an artifact of the interviewing because the house regular designation resulted in automatically generating links to all FSW at the specific establishment, thereby potentially creating artificially higher degree measures for these clients compared to those who were not identified as house regulars. The same may have occurred with the other measures of centrality due to high correlation between them. Furthermore, misclassification of low-risk clients due to missing or unknown data resulted in lower centrality scores and a lower likelihood of being included in microstructures such as cliques or 2-cores. The same is true for clients who were known to patronize other sex establishments, in that by definition they would be expected to have high information and betweenness centrality and to be members of microstructures due to their reported bridging behaviours.

Another limitation of the data analysis was similar to that described by Rothenberg et al. (34). In order to quantify the probability of acquiring or transmitting infection, some form of weighting must be applied. In these data, each link was by default assigned a value of 1 and represented only the presence of a connection. Sexual linkages between individuals in the network were not weighted based on the probability of transmission. Not all sexual contact ensures transmission, and transmission probabilities vary depending on the infectiousness of the pathogen, the type of sex act, the use of condoms, the frequency of contact, the presence of other STI, and other factors. This makes differences in centrality measures difficult to interpret. For example, an individual with a degree of 20 who used condoms for all penetrative sex acts would be in a completely different risk category than someone with the same or lower degree who never used condoms, particularly if his or her partners also demonstrated high-risk behaviours.

Finally, the non-rigorous method of ascertaining HIV and STI status precluded testing of any hypotheses about the association between network structures and infection. Some respondents reported STI infection over the preceding six months, but many had not been tested or were unsure about their status (Appendix C, Table C.2). At the outset of the study, HIV and STI testing was planned, but during the community consultation and planning stages it became apparent that, because this was a first attempt at community partnership research with this group, testing was too invasive. Funding, personnel, and time constraints also made it unfeasible within the confines of this thesis. Although proxy-reported HIV and STI status of respondents’ sex
partners was confirmed by the interviewer, this may have only strengthened reliability rather than validity of the data (45). Furthermore, when evaluating the reliability of respondent reports for the 12 duplicate clients (see Table 3.5), HIV and STI status were the two variables that had the lowest level of agreement and were largely responsible for low kappa scores. In most cases the lack of agreement was due to the fact that the infection status of the sex partners was simply not known. As well, it is questionable as to whether or not respondents were correct in stating that some partners were “definitely not” infected with HIV or an STI. As discussed in Chapter 4, this likely resulted in an under-reporting of HIV and STI infection status, both for the respondents themselves and for their first-order sex contacts.

5.3 Unique Contributions and Impact

To my knowledge this is the first study to apply network methods to conduct an in-depth exploration of the STI risk environment of the indoor commercial sex industry. As was underscored in the introduction, there is a paucity of literature describing the context of indoor sex work and how this may contribute to STI risk for FSW and for their partners. Research in this segment of the sex industry is clearly needed because there are essential differences between different types of sex work. Furthermore, indoor sex work comprises the vast majority of the commercial sex industry in Canada (37), and the findings from Chapters 3 and 4 may provide direction to healthcare providers and educators who plan and implement interventions.

Chapter 4 represents a very important contribution to the small body of literature on patrons of the sex industry. HIV and STI risk occur within the context of a sexual transaction between two (or sometimes three) people, but virtually all research and interventions are targeted at FSW, who represent only one half of the equation. The findings in the client manuscript may assist health educators to provide more informed education messages to FSW, to establishment managers, and to clients.

Although the challenges and limitations posed by network methods cannot be ignored, applying these methods to studying commercial sex workers provides richer insights than the traditional approach of individual-level data collection. If only individual-level data from the FSW were analyzed, the study findings would be similar to those presented by others – namely that FSW have a high number of partners, and that for the most part they report consistent condom use.
with commercial partners and inconsistent condom use with non-commercial partners (30;46;47). Because of the apparently low prevalence of HIV and injection drug use in this population, it may also have been inferred that overall the risk of HIV spread within the population is low. Whereas this may be true, when viewed as a total network it is apparent that even small changes in individual-level behaviours may have greater consequences than may be evident when viewing individual-level data alone (1). For example, if condom use becomes lax between a FSW and one of her regular clients, this has farther-reaching consequences than risk within that partnership alone, particularly if the client also patronizes many other FSW and has a wife or girlfriend.

This research has also provided an important contribution to the literature on community-based research and on accessing hidden or hard-to-reach populations. The study demonstrated that it is feasible to reach this segment of the sex industry and that conducting research with indoor FSW is acceptable to the target population. The commercial-sex risk environment varies depending on the type of sex work (48-50), and it is therefore important to include indoor FSW in research studies. Because the majority of the Canadian commercial sex industry is conducted indoors (37), studies that include only outdoor FSW may overestimate the prevalence of HIV and STI and the relative contribution of FSW to disease propagation. Furthermore, the paucity of information about this large segment of the sex industry makes it difficult to develop prevention programs that recognize the contextual diversity of the industry.

A final, important contribution of this research has been increasing the ability of the community-based organization, ASIA, to foster partnerships with academic partners, to participate in research, and to develop and implement a sustainable, evidence-based outreach education and prevention program for the indoor FSW community. Although the data collection for this project ended in February, 2006, the ORCHID project remains a permanent program within ASIA and the outreach teams continue to visit 15 to 20 sex establishments per month. To date, nine FSW have been hired, trained, and mentored as peer outreach workers and they remain an integral part of the ASIA team. ASIA team members have presented the project model and research findings at six national and international conferences and have contributed as co-authors and contributors to the manuscripts contained in this thesis. The community team leader also entered graduate school and will be using the next phase of the research as a part of her Masters thesis. Finally, thus far ORCHID is proving to be a sustainable service and research program.
Funding for an additional three years was secured from the Canadian Institutes of Health Research for a community-based research grant, on which ASIA community leaders are co-principal and co-investigators.

5.4 Conclusions and Recommendations

The findings from this research led to several important recommendations in terms of STI prevention within the indoor commercial sex industry. First, reinforcement of 100% condom use with all partners must be underscored. Perhaps the greatest challenge to FSW is using condoms with non-commercial partners, particularly in situations where the partnership is long-term (e.g., with a spouse or common-law partner) or if a partner is not aware of her profession. Inconsistent condom use with main partners is a common finding in sex worker research (51-54).

One of the main findings in this study, namely the heterogeneity in client risk profiles, underscores the need to reinforce the 100% condom use message with regular clients. In the study sample most of the respondents stated that they always used condoms with clients. However, for the few who admitted to inconsistent condom use, this was with clients whom they had known a long time and whom they claimed to know well and to trust. It was beyond the scope of this thesis to fully explore the context of inconsistent condom use with different types of clients. However, the findings presented in Chapter 4 clearly indicate that regular clients, who may also be house regulars or patronize more than one establishment, are in a unique position to transmit infection throughout the network. Other studies also reported inconsistent condom use with regular clients (48;55), and this remains an important area for further research.

Second, from the network perspective, intervention strategies could be devised that serve to minimize the effectiveness of transmission pathways. This can be conceptualized as a lower-risk sex act with correct condom use – for example, non-penetrative sex (hand jobs) and oral and vaginal sex with condoms and lubricant. Conversely, more effective pathways can be conceptualized as incorrect or absent condom use and specific sex acts that are considered more risky, such as dry sex (sex without use of a lubricant), anal sex, or having sex concurrent with other STI or genital sores.
Third, the findings related to network structures suggested that measures could be taken to effectively fragment the network. For example, encouraging FSW to only work at one place at a time would reduce bridging between establishments and other segments of the sex industry. Educational messages to clients encouraging condom use and patronizing only one FSW or establishment at a time could be given. We presented several recommendations along this line in Chapter 4.

Fourth, if the scale-free theory holds true for the indoor commercial sex network, STI control strategies should be targeted towards the most sexually active people, or those with the highest degree (the hubs) (27). Frequent STI screening is recommended for FSW (56), but this recommendation should also extend to those commercial clients who are known to have particularly high numbers of commercial sex partners, namely the house regulars. For example, it may be possible to ask FSW or managers to distribute STI information and health service referral pamphlets to known house regulars, or to post information posters in establishment waiting areas, bathrooms, etc.

Fifth, it may be possible to target individuals or groups who are highly prominent in the network to act as hubs for information transfer. In the same way that central individuals are uniquely positioned to acquire and transmit infection, they are also well positioned to reach the largest amount of people with STI prevention messages. For example, prominent, senior FSW may be recruited as “champions” to provide educational counselling and materials to new staff and to clients. Given the high familiarity that workers have with house regulars, it may be possible to ask FSW or managers to provide these materials to them and to recommend that they spread the word.

Targets of intervention and education messages need to include managers and owners of sex establishments, not just the workers. Providing owners and managers with information related to STI risks, and promoting the health and welfare of their staff is important. However, as pointed out in Chapter 4, management may not be keen on having clients minimize concurrency because it may be perceived as a potential loss of revenue. The same could be true for the workers. It may therefore be more acceptable to recommend implementing house policies and rules (such as 100% condom use and a ban on GFE) that promote safety of the workers and the clients. This approach has been used with success in other settings (57;58).
5.5 Future Directions

This research project raised many important questions that merit further study. First, although several intervention strategies were recommended throughout this thesis, their feasibility and acceptability to the target population is unknown. Because this study applied a community-based approach, it is important to continue working within this framework to explore whether the proposed interventions are viewed as appropriate by the target community, whether they would be feasible, and whether their implementation would introduce any potential pitfalls or inadvertent harms. For example, it may be naïve to expect that FSW are able or willing to provide educational messages to their clients. It may also be unrealistic to assume that FSW and managers will embrace a strategy that could result in reducing the volume of their clientele. It would therefore be presumptuous and a potential waste of time and resources to impose an intervention strategy upon the population without first establishing its potential for success.

Second, in-depth inquiry into the context of FSW' decision-making regarding condom use with different types of clients may shed further light on the extent of the risk environment within the industry. This should be approached using mixed quantitative and qualitative methods to fully explore the extent and context of condom use. It is also important to explore the potential role of female condoms with this group. Female condom use was not specifically addressed in this study, but the acceptability and feasibility of their use, both with commercial and non-commercial partners, should be examined. Findings from this type of research would further guide the development of prevention messages.

Third, conducting research with the clients of FSW is critical to an understanding of the context of risk-taking within the commercial sex industry. Risk perception, STI-related knowledge, and the context of risk decision-making should be explored. However, these studies are difficult to conduct because commercial sex patrons are invisible within the general population. It may be possible to distribute questionnaires at sex establishments or to advertise for study volunteers in places where male sex buyers are more likely to literally, or virtually, congregate – for example, by posting ads at exotic dance clubs, at adult entertainment stores, on prostitution-related websites, on massage parlour and escort websites, and in the personal ads sections in newspapers and magazines. These methods have been used successfully by others (59).
Fourth, a systematic STI prevalence study with FSW and clients would allow testing of the hypothesis that network structures and characteristics are associated with infection. This would also allow for "mapping" of STI and behavioural patterns. This type of mapping is important because in the absence of STI, even if high-risk behaviours and risky network structures exist, disease propagation cannot occur (60;61). Longitudinal studies would also shed light on the relationships between structural and behavioural pattern changes within the network and on changes in incidence of infection.

Fifth, from the methodological perspective, different sampling approaches should be compared to determine which provides the most information. This was done theoretically by Ghani et al. (44;62) and empirically by Jolly et al. (62). Although a probability sample may not be possible, other methods, such as respondent-driven sampling, have provided mathematically representative samples in other hidden populations, including hard-to-reach FSW (63;64).

Sixth, these and future data may be used to advance the field of concurrency research. Long-term concurrency is considered an important determinant of HIV and STI spread (9;16), but there is no consensus on what duration of overlap, or what frequency of contact, is required to consider it long-term (M. Morris, oral communication, May 2006). In Thailand, for example, commercial sex patronage patterns create a form of short-term concurrency because male clients tend to visit FSW infrequently and to see a different FSW each time (13). The current data showed a different pattern – many FSW reported that they have sex with regular clients for months or years at a time and that the frequency of contact varies. Many of the FSW and clients in these cases also have a main partner, which could constitute a form of long-term concurrency. However, these data are not sufficient to determine how this may impact disease propagation.

Seventh and finally, mathematical models of STI spread across the networks that incorporate concurrency, relationship duration, contact frequency, variable condom use, and mixing patterns would be valuable for predicting the potential for disease spread in the indoor commercial sex population. For example, these data may help quantify the extent of long- and short-term concurrency attributed to commercial sex work in concurrency models (65), the type and extent of mixing within networks (66), and the structural topology of networks (67). If data on the number of sex partners of FSW' first-order contacts, particularly the clients, were available, a
more accurate determination of the degree distribution would also be possible. Examining the degree distribution within this highly sexually active group, many of whom constitute the “fat” tail of the distribution curve, may help answer the question of whether or not sexual networks are driven by preferential attachment. Mathematical models could also be used to conduct sensitivity analyses of the data. For example, Monte Carlo simulation similar to that conducted by Ghani et al. (44) could be used to investigate the biases introduced to the estimated measures of the sexual network as a result of non-response, missing data, and data coding decision-making (e.g., the way linkages to second-order sex partners were generated).

In conclusion, using social network analysis to study risk networks of the indoor commercial sex industry goes beyond individual-level risk assessment to help us better understand the potential for infection spread within this population. This thesis demonstrated that the indoor commercial sexual network is one that would support HIV and STI propagation, both within the commercial core and between the core and the general population. It is noteworthy that the network approach is well-suited to evaluate not only the context of risk, but (also) to provide direction for developing contextually-appropriate, targeted intervention and control programs. The knowledge gained from this work will also serve as a starting point for more focused research that can more clearly articulate the risks and implications associated with the indoor commercial sex work environment.
5.6 References


APPENDIX A

UBC CLINICAL RESEARCH ETHICS BOARD APPROVAL CERTIFICATE AND
STUDY INFORMATION FORM
Massage Parlour Women's Health Study
Study Information Form

Study Investigators:
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Dr. Gina Ogilvie, BC Centre for Disease Control

What we are doing: We are conducting a survey that assesses health issues with women who work in massage parlours in the Lower Mainland. We are particularly interested in women's reproductive and sexual health issues, such as sexually transmitted diseases (STD) and risk for HIV or AIDS. Many women who work in the parlour industry do not have access to regular healthcare and may be at risk for getting STDs or HIV. The overall purpose of this study is to find out how much risk of STD and HIV there is for women in this industry, the type of healthcare needs they have, and the type of healthcare services that would be acceptable, accessible, and socially and culturally appropriate.

What we are asking you to do: If you agree to participate in this study, you will be asked to spend about one hour in a private interview. The interview will be conducted in a quiet, private location of your choice (for example, a coffee shop, your home, the ASIA office downtown, a friend's home, or another location where you feel comfortable). There will be questions about your background, your health, your sexual health, sexual behaviours, and sexual partners. Your responses to the questions are important, but we understand that some of them may make you uncomfortable and it is your right to refuse to answer any question.

You will also be asked to provide a urine sample (a few tablespoons). The urine will be tested for Chlamydia, gonorrhoea, and human papilloma virus (HPV, the virus that causes genital warts). Some STD, such as Chlamydia, are very common (up to 1 in 20 women who are sexually active may have Chlamydia), and can cause pelvic inflammatory disease and infertility in women if it's not treated. Many women do not know they have STDs because there are often no symptoms. Providing a urine sample is optional, and if you decide not to do so, you can still participate in the interview.

Because we are not asking you to provide your name or any other information that identifies you, we cannot give you the results of your urine test because we will have no way of linking your urine specimen to you. However, regular testing for STDs is very important for all women,

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5 Collection of urine specimens was not feasible, and therefore was not included in the study.
APPENDIX B

STUDY QUESTIONNAIRES
B.1 Questionnaire Development

We developed a structured questionnaire for the study that consisted of two parts. Part I elicited individual-level demographic, work environment, HIV risk factor, sexual behaviour, STI and HIV knowledge, preventive practices, risk perception, and reproductive health data from respondents (egocentric data). Part II elicited sexual network data consisting of demographic and behavioural information of the respondents' identified sex partners (proxy dyadic and network data). Because this study was conducted in partnership with a community-based organization (ASIA), ASIA team members provided substantial input into Part I of the questionnaire in order to collect data for their programming purposes. As a result, much of the data collected with this section of the questionnaire was not used in the thesis analyses.

To develop the questionnaire, the academic principal investigator (thesis author) conducted a literature review to determine if relevant, validated instruments existed that could address the objectives of the project. Ford et al. (1) published an instrument for use with FSW in Indonesian brothels. With permission from the authors (K. Ford, email communication, May 25, 2004), the HIV and STI knowledge and condom self-efficacy scales were incorporated into Part I of the questionnaire. Additional items related to demographics, to risk perception, and to behaviour were included based on the expertise of the investigative team and input from ASIA. The relevant social network literature and content experts in the social network field were consulted for the network section of the questionnaire.

Four working groups of FSW assessed the content validity of both parts of the instrument. The working groups were conducted at the ASIA office and were led by the academic principal investigator and the community team leader. There were a total of 10 working group participants from Aboriginal, Chinese, Korean, Caucasian, and Vietnamese backgrounds. Face validity was evaluated by asking participants to provide feedback regarding their understanding of each item and to comment on its clarity, relevance, and language use. Working group members were also invited to provide feedback on their overall impressions of the study in terms of the importance of the research objectives, the feasibility of the research plan, and the likelihood of successfully eliciting detailed proxy data about FSW's sex partners.
Overall, the working group participants thought that the instruments were clear and relevant. For several of the items, they recommended changes in language use in order to make them more colloquial (e.g., Part I, items 75 to 79) and for several of the items they suggested revisions to categorical response options to make them more clear (e.g., Part I, items 71 and 72). Finally, they recommended removing two items related to HIV and STI knowledge because they felt that the answers were too obvious and patronizing. The knowledge questions were taken directly from a questionnaire that was developed for use with FSW from low educational backgrounds in a developing country (1). It was therefore not surprising that the participants found some of the questions inappropriate. Once the inappropriate items were removed, the resulting questionnaire was a 102-item Part I, and 22-item Part II instrument.
B.2 Part I: Egocentric Questionnaire

Massage Parlour Women’s Health Study

[INTERVIEWER] I am going to conduct an interview that will take approximately 40-60 minutes. The types of questions I will ask include general questions about your background, your work, your health, and your knowledge of certain health issues that are important to women. I understand that some of these questions may make you feel uncomfortable or embarrassed. Please remember that this survey is completely voluntary and all information you give me will remain confidential. This means that none of the information you give me during this survey will be shared with anyone outside of the ORCHID study team. Your friends, family, co-workers, employer, and clients will not have any access to the answers or information you give me. Also, you can decide not to answer any of the questions that you find too uncomfortable or embarrassing, and you are free to stop the interview at any time. The information you share will be valuable in providing health-related services for women in your community and I encourage you to be as honest as possible.

INTERVIEWER SECTION

Has this participant given fully informed, verbal consent? □ YES

Interviewer name: ____________________________

Interviewer signature: ________________________ date ______________

Participant ID: P ___ ___ Establishment ID: ___ ___

Date of questionnaire: _________________________ (DD/MM/YY)

DEMOGRAPHICS

[INTERVIEWER] I am going to begin by asking you some questions about your background and current life situation.

1. What is your birth date? ___________ (DD/MM/YY) □ Declined

2. What city/town do you live in? ________________________________ □ Declined

3. Do you (check one) .............?
   □ Live alone □ Live with partner/husband/boyfriend
   □ Live with family □ Live with co-workers
   □ Live with friends □ Other (describe): __________________________
   □ Declined
4. Are you (check one) ...........?
   □ Single       □ Married/common-law partner       □ Longterm relationship
   □ Other (describe): ______________________________________________________
   □ Declined

5. What language(s) do you speak (check all that apply)?
   □ English
   □ Mandarin
   □ Cantonese
   □ Punjabi
   □ Hindi
   □ Thai
   □ Tagalog
   □ Vietnamese
   □ Korean
   □ Japanese
   □ Other (list): ____________________________________________________________

6. How long have you been in Canada? ____________ yrs
   □ Declined
   □ N/A - born in Canada

7. How would you describe your race/ethnicity (family background)? (check one)
   □ Caucasian/White
   □ Chinese
   □ South-Asian (e.g. Indian, Pakistani)
   □ Other Asian (e.g. Vietnamese, Japanese)
   □ Latin American
   □ Middle Eastern
   □ Black
   □ Other, specify
   □ Unsure/don't know
   □ Declined

8. What country were you born in? __________________________ □ Decline

9. What is the highest level of education you've completed (check one)?
   □ None
   □ Elementary/grade school
   □ Some High School
   □ Completed Grade 12 (GED)
   □ Partial college, university, or post-secondary technical/trade school
   □ Completed college, university, or post-secondary technical/trade school
   □ Other (describe): ______________________________________________________
   □ Declined
10. What are your sources of income?
   • Regular job (not sex work)
   • Sex work
   • Welfare/social assistance/disability
   • EI
   • Student loans
   • Sex trade (other - describe): ________________________________
   • Other (describe): ________________________________
   • Declined

WORK

[INTERVIEWER] Now I'm going to ask you some questions about your work. Remember that all the information you provide during this interview will remain confidential and none of this information will be made available to your employer, your co-workers, any organizations, or your clients. You can also decide to not answer any questions that make you uncomfortable.

11. Have you worked in more than one establishment in the past 30 days?
   • NO   • YES – how many other? __________
   Name(s) and location(s)? _________________________________________
   • Declined

12. Have you worked in more than one establishment in the past 6 months?
   • NO   • YES – how many other? __________
   Name(s) and location(s)? _________________________________________
   • Declined

13. Do you currently get money from (check all that apply) ............?
   • Escort agency   • Private ad out-call   • Internet/film model
   • Private ad in-call   • Nightclub   • Exotic dance clubs/show lounge
   • Outside (track/streets)   • Regulars only   • None of the above
   • Declined

14. How many months have you worked in an indoor sex establishment (in total)?
   __________ mos   • Declined

15. How many days a week do you work now? __________   • Declined

16. How many hours a day do you work now, on average? __________ hrs   • Declined

17. How many clients did you have, in the past 7 days? ______   • Declined
18. What are the three most common race or ethnicities of your clients in the last 7 days?
- Caucasian/White
- Chinese
- South-Asian (e.g. Indian, Pakistani)
- Other Asian (e.g. Vietnamese, Japanese)
- Latin American
- Middle Eastern
- Black
- Aboriginal
- Other, specify: _______________________________________
- Unsure/don't know
- Declined

19. To the best of your knowledge, where do most of your clients from the past 7 days live (check one)?
- In the same neighbourhood as the establishment
- In another area of the Lower Mainland
- From out of town (e.g., tourists, sailors, travelling businessmen)
- Other, specify: _______________________________________
- I don't know
- Declined

20. To the best of your knowledge, what are the most common types of professions of your clients in the past 7 days (check all that apply)?
- Professional (e.g., doctors, teachers, lawyers, engineers, etc.)
- Police
- Businessmen, salesmen
- Students
- Labourers (e.g., mill workers, taxi drivers, physical jobs, etc.)
- Sailors/seamen
- Other: _______________________________________
- I don't know
- Declined

21. To the best of your knowledge, how many of your clients in the past 7 days are married or have girlfriends (check one)?
- All or most
- About half
- Few or none
- I don't know
- Declined
HIV RISKS

[INTERVIEWER] I'm now going to ask you some questions about certain types of activities that are important because they may put you at risk for HIV. Please remember that all the information you provide will be kept confidential, and nothing you tell me will be made available to your employer, co-workers, government agencies, or your clients. You may also choose not to answer any questions that make you uncomfortable.

22. Have you ever injected drugs?
   □ YES
   □ NO (skip to Q31)
   □ Declined (skip to Q31)

23. How old were you the first time you injected drugs? __________ yrs

24. When was the LAST TIME you injected drugs? ____________ DD/MM/YY

25. The first time you injected drugs, where were you? ________________

26. The first time you injected drugs what kind of setting were you in?
   ________________

27. What drug did you inject?
   □ Heroin
   □ Cocaine
   □ Speed (crystal methamphetamine)
   □ Morphine
   □ Other, specify ________________
   □ Declined

28. Why did you inject that day (record answers)?

29. The first time you injected, did someone inject you?
   □ YES
   □ NO
   □ Don’t remember
   □ Declined

30. Where did you get the syringe? ____________________________
31. Do you have any tattoos/body brands/body piercing?
   □ YES - from a professional (sterilized needles) □ YES □ NO □ Don’t know
   □ NO
   □ Declined

32. Have you ever received a medical injection or blood transfusion in a developing country?
   □ YES - where? _______________ When? _________yr(s)
   □ NO
   □ Don’t know
   □ Declined

33. To your knowledge, have you ever had sexual contact with someone who is infected with HIV?
   □ YES
   □ NO
   □ Maybe
   □ Don’t know
   □ Declined

SEXUALITY
[INTERVIEWER] Now I am going to ask you some questions about your sexual history. We are concerned with preventing the spread of sexually transmitted infections among women by close or intimate contact. For our purposes, SEXUAL CONTACT includes people with whom you have:
   • Had vaginal or anal intercourse with
   • Given oral sex to
   • Received oral sex from
In other words, because we are concerned with your overall sexual health, we are interested in a broad range of sexual contacts.

34. How old were you the first time you had penetrative sexual contact with anybody? __________yrs
   □ Declined

35. How many sexual partners have you had in your lifetime, including clients? ______
   □ 1-5           □ 100-500
   □ 6-20          □ None
   □ 21-100        □ Declined

36. How many sexual partners have you had in the past 12 months, including clients? ______
   □ 1-5           □ 100-500
   □ 6-20          □ None
   □ 21-100        □ Declined

37. How many sexual partners have you had in the last month, including clients? ______
   □ Declined

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38. How many sexual partners have you had in the last 7 days, include clients? _______
   □ Declined

39. How often do you use condoms with clients? (check one)
   □ Always, no exceptions (skip to 41)       □ Rarely
   □ Almost always, occasional exceptions     □ Never
   □ Most of the time                         □ Declined
   □ About half of the time                   □ Some of the time (less than half)

40. If not ALWAYS, what would make you decide not to use a condom with a client (record answers)?

41. How often do you use condoms with NON-clients (e.g., boyfriend, partner, dating, etc)?
   □ Always, no exceptions (skip to 43)
   □ Almost always, occasional exceptions  
   □ Most of the time                      
   □ About half of the time                
   □ Some of the time (less than half)     
   □ Rarely                                
   □ Never                                 
   □ Declined                             

42. If not ALWAYS, what would make you decide not to use a condom with a non-client (record answers)?

43. Do you ever do “duos” with any of the other girls in the establishment (or other places where you may work)?
   □ No
   □ Yes
   □ Declined
HIV/STD KNOWLEDGE

[INTERVIEWER] I’m now going to ask you some questions about certain types of diseases that are important for all women to know about. Please remember that all the information you provide will be kept strictly confidential, and nothing you tell me will be made available to your employer, co-workers, government agencies, or your clients. You may also choose not to answer any questions that make you uncomfortable.

44. Have you ever heard of HIV or AIDS?
   - □ YES
   - □ NO (skip to Q60)
   - □ Declined (continue)

45. Where did you first hear about HIV or AIDS (check one)?
   - □ A doctor/nurse
   - □ My friends
   - □ My co-workers
   - □ My employer
   - □ My family
   - □ A pamphlet given to me
   - □ Advertisement (describe): __________________________
   - □ Media (describe):____________________________________
   - □ Other (describe):____________________________________
   - □ Declined

[INTERVIEWER] Now I am going to ask you some questions about HIV/AIDS and I want you to answer YES or NO, depending on what you think – it is also ok for you to say that you don’t know or are UNSURE.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES (Y)</th>
<th>NO (N)</th>
<th>unsure (U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>46. Can a person infected with the HIV/AIDS virus look perfectly healthy?</td>
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<tr>
<td>47. Can a person who is already infected with the HIV/AIDS virus but still appears healthy spread the disease to other people?</td>
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<tr>
<td>48. Can people catch HIV/AIDS by exchanging clothes, eating from the same dish, or shaking hands with someone already infected with the virus?</td>
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<tr>
<td>49. Can an infected woman who is pregnant spread the HIV/AIDS virus to her unborn baby?</td>
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<tr>
<td>50. Can a person catch the HIV/AIDS virus by urinating in the same place as a person with HIV/AIDS?</td>
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<tr>
<td>51. Do some indoor sex workers already have HIV/AIDS?</td>
<td></td>
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<tr>
<td>52. Do some clients who visit indoor sex workers already have HIV/AIDS?</td>
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<td></td>
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<tr>
<td>53. Can women who work inside become infected with HIV/AIDS?</td>
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<tr>
<td>54. Can HIV/AIDS be prevented by taking medicine/getting injections regularly?</td>
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<tr>
<td>Question</td>
<td>YES (Y)</td>
<td>NO (N)</td>
<td>Unsure (U)</td>
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<tr>
<td>55. If a condom is used during sex, can it be used to prevent HIV/AIDS, as long as it does not break?</td>
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<tr>
<td>56. Can a person who gets HIV/AIDS be cured?</td>
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<tr>
<td>57. Is HIV/AIDS spread through:</td>
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</tr>
<tr>
<td>(a) Body sweat</td>
<td>(a)____</td>
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<tr>
<td>(b) body contact</td>
<td>(b)____</td>
<td></td>
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<tr>
<td>(c) kissing on the mouth</td>
<td>(c)____</td>
<td></td>
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<tr>
<td>(d) intercourse without using a condom</td>
<td>(d)____</td>
<td></td>
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<tr>
<td>(e) injection drug use</td>
<td>(e)____</td>
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<tr>
<td>(f) blood transfusions</td>
<td>(f)____</td>
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<tr>
<td>(g) injection using used needles</td>
<td>(g)____</td>
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<tr>
<td>(h) eating contaminated food</td>
<td>(h)____</td>
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<tr>
<td>58. Will you die if you get HIV?</td>
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<tr>
<td>59. Is there any medication that can prolong the life of someone with HIV/AIDS?</td>
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</tbody>
</table>

**STD KNOWLEDGE**

60. Have you ever heard of sexually transmitted diseases *(give examples)*?
- □ YES
- □ NO *(skip to Q70)*
- □ Declined *(continue)*

[Interviewer] Now I am going to ask you some questions about sexually transmitted diseases and I want you to answer YES or NO, depending on what you think – it is also ok for you to say that you don’t know or are unsure.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES (Y)</th>
<th>NO (N)</th>
<th>Unsure (U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>61. Can a person infected with a sexually transmitted disease look healthy (without symptoms)?</td>
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<tr>
<td>62. If all of your sexual partners wear a condom, can you be protected against catching all these diseases?</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>YES (Y)</td>
<td>NO (N)</td>
<td>Unsure (U)</td>
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<tr>
<td>-------------------------------------------------------------------------</td>
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<tr>
<td>63. Can all these diseases be prevented by taking antibiotics before or after having sex?</td>
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<tr>
<td>64. Can all these diseases be prevented by cleaning the genitals after having sex?</td>
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<tr>
<td>65. Can all these diseases be prevented by not drinking from the same glass as someone who has an STD?</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>66. Can all these diseases be prevented by not changing sexual partners?</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>67. Can some of these diseases cause sterility/inability to get pregnant/have children?</td>
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<tr>
<td>68. If a doctor or nurse gives medicine for any STD, do you have to continue the medicine until it is finished, even if symptoms are gone beforehand?</td>
<td></td>
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</tr>
<tr>
<td>69. Can some of these diseases lead to death?</td>
<td></td>
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</tr>
</tbody>
</table>

**PREVENTION AND CONDOMS**

[Interviewer] I'm now going to ask you some questions about preventing HIV/AIDS and STDs. Please remember that all the information you provide will be kept confidential, and nothing you tell me will be made available to your employer, co-workers, government agencies, or your clients. You may also choose not to answer any questions that make you uncomfortable.

**PREVENTIVE PRACTICES** *(skip to Q69 if subject has NEVER heard of HIV/AIDS or STDs)*.

70. How do you protect yourself from HIV/AIDS or other STDs *(note responses – if they say NOTHING, ask why)*?
PERCEIVED SUSCEPTIBILITY

71. How likely do you think it is that you will ever get HIV/AIDS in your lifetime (check one)?
   □ Not at all likely (I am 100% sure I will NEVER get HIV/AIDS)
   □ Not very likely (there might be a very small chance I will get HIV/AIDS)
   □ Somewhat, of 50/50% likely (there is a 50/50 chance I will get HIV/AIDS)
   □ Very likely (I will probably get HIV/AIDS, there is a very high chance)
   □ 100% likely (I am sure I will eventually get HIV/AIDS)
   □ Not sure
   □ Declined

72. How likely do you think it is that you will ever get an STD (check one)?
   □ Not at all likely (I am 100% sure I will NEVER get an STD)
   □ Not very likely (there might be a very small chance I will get an STD)
   □ Somewhat, or 50/50% likely (there is a 50/50% chance I will get an STD)
   □ Very likely (I will probably get an STD, there is a very high chance)
   □ 100% likely (I am sure I will eventually get an STD)
   □ Not sure
   □ Declined

CONDOM BELIEFS

73. In your opinion, are there any advantages of using condoms, and if so, what are they? (record answer)

74. In your opinion, are there any disadvantages of using condoms, and if so, what are they? (record answer)
CONDOM KNOWLEDGE

[INTERVIEWER] Now I am going to ask you some questions about condoms and I want you to answer YES or NO, depending on what you think – it is also ok for you to say that you don’t know or are unsure.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES (Y)</th>
<th>NO (N)</th>
<th>Unsure (U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75. Is it ok for a man to put on a condom only just before he is ready to cum?</td>
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<tr>
<td>76. Does a condom need to be held when a man pulls out after cumming?</td>
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<tr>
<td>77. Can a male condom be used more than once if it is washed out carefully with soap and water?</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>78. Can a condom be used if it seems to be dried out?</td>
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<td></td>
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<tr>
<td>79. When using condoms, is it better to withdraw the penis soon after cumming?</td>
<td></td>
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</tbody>
</table>

CONDOM SELF-EFFICACY

[INTERVIEWER] I am now going to read out some statements related to using condoms with clients and with partners who are not clients - for example, your husband, boyfriend, or someone you’re dating. Please tell me how sure you are that you can do these things: are you very sure, not very sure, or not at all sure that you can.

<table>
<thead>
<tr>
<th>Statement</th>
<th>CLIENT</th>
<th>NON-CLIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>80. I am brave enough to tell a partner to use a condom</td>
<td>1 = very or 100% sure</td>
<td>1 = very or 100% sure</td>
</tr>
<tr>
<td>81. I can buy a package of condoms</td>
<td>2 = not very sure</td>
<td>2 = not very sure</td>
</tr>
<tr>
<td>82. I can tell a partner to put on a condom or I can put it on him myself if he is high on alcohol/drugs</td>
<td>3 = not at all or 0% sure</td>
<td>3 = not at all or 0% sure</td>
</tr>
<tr>
<td>83. I can put a condom on my partner correctly or make sure he has put it on correctly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>84. I can talk with a new partner about using condoms before having sex the first time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
YOUR HEALTH

[INTERVIEWER] Now I am going to ask you some questions about your general health, as well as some specific questions about women’s health issues. Although some of these questions may be embarrassing, they are very important because a lot of women have women’s health problems that they don’t know about. Some of these health problems are quite common and may not have any symptoms, and some can affect a woman’s ability to have children in the future if she doesn’t get treatment. Please remember that all the information you provide will be kept confidential, and nothing you tell me will be made available to your employer, co-workers, government agencies, or your clients. You may also choose not to answer any questions that make you uncomfortable.

85. I can talk to friends or co-workers about using condoms

<table>
<thead>
<tr>
<th>Statement</th>
<th>CLIENT</th>
<th>NON-CLIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 = very or 100% sure</td>
<td>1 = very or 100% sure</td>
</tr>
<tr>
<td></td>
<td>2 = not very sure</td>
<td>2 = not very sure</td>
</tr>
<tr>
<td></td>
<td>3 = not at all or 0% sure</td>
<td>3 = not at all or 0% sure</td>
</tr>
</tbody>
</table>

86. Do you have a regular health care provider?
   □ Yes
   □ No

   What is the main reason you do not have a regular health care provider (check one, then skip to Q89)
   □ No care card
   □ No money
   □ Do not know how to find health care
   □ Language barrier
   □ Don’t feel the need to have health care
   □ Someone is preventing me from seeking health care
   □ No family physician has space to take on new patients
   □ Other (describe): __________________________

87. Who is your regular healthcare provider (check all that apply)
   □ Family doctor
   □ Community health clinic
   □ Public health nurse or public health unit
   □ Street Nurse
   □ Other (describe): __________________________
   □ Declined

88. Is your care provider aware of your profession?
   □ Yes
   □ No – why not? __________________________
   □ Declined

144
89. How often do you get a PAP test (*may need to explain what this is*)?
   □ Never (skip to Q91)
   □ Every 1-5 months □ Every 6 months □ Every year □ Every 2-5 years
   □ More than every 5yrs □ Declined

90. When was your last PAP test? ______________________ (MM/YY)

91. Have you been pregnant in the past 6 months?
   □ No
   □ Yes – currently pregnant? □ No □ Yes
   □ Don’t know □ Declined

92. Are you currently using birth control?
   □ No
   □ Yes – what kind? ________________________________
   □ Declined

93. How often do you get tested/a check up for sexually transmitted infections (such as chlamydia, gonorrhea, genital herpes, genital warts, etc.)?
   □ Never (skip to Q96)
   □ Only once in my life
   □ Don’t know – never heard of STDs (skip to Q97)
   □ Every 1-5 months □ Every 6 months □ Every year □ Every 2-5 years
   □ More than every 5yrs □ Declined

94. When was your last STD test/check up? ______________________ (MM/YY)

95. Have you had a positive STD test in the past 6 months?
   □ YES – type: ____________________________  How long ago? ____________ weeks
   □ NO
   □ Not sure
   □ Declined

96. Have you been treated for an STD in the past 6 months?
   □ No
   □ Yes
   □ Don’t know
   □ Declined
97. Have often do you get tested for HIV/AIDS?
   - Never (skip to Q102)
   - Only once in my life
   - Don’t know – never heard of HIV/AIDS (skip to Q102)
   - Every 1-5 months  □ Every 6 months  □ Every year  □ Every 2-5 years
   - More than every 5 yrs
   - Declined

98. When was your last HIV test? ______________________ (MM/YY)

99. Where, or by whom, were you tested?
   - Family doctor
   - Community health clinic
   - Public health nurse or public health unit
   - Street Nurse
   - Other (describe): ____________________________________ □ Declined

100. What was the result of your last HIV test?
   - Positive – when was your first positive test? _________________ (MM/YY)
   - Negative
   - Don’t know – why not? ____________________________________________
   - Declined

101. Why did you get tested? (record answers)

102. Have you experienced any of the following symptoms (check all that apply)?

<table>
<thead>
<tr>
<th>Symptom</th>
<th>In past week</th>
<th>In past 6 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genital itching, burning</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
<tr>
<td>Painful/burning urination</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
<tr>
<td>Having to urinate more than usual</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
<tr>
<td>Unusual discharge from vagina</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
<tr>
<td>Unusual discharge from urethra</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
<tr>
<td>Sores on genitals/buttocks</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
<tr>
<td>Painful sexual intercourse</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
<tr>
<td>Abnormal Bleeding</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
<tr>
<td>Crampy lower abdominal or lower back pain</td>
<td>☐ NO ☐ YES →</td>
<td>☐</td>
</tr>
</tbody>
</table>
   - Declined all
SEXUAL PARTNERS
INTERVIEWER] Now I am going to ask you some questions about your sexual relationships. We are concerned with preventing the spread of sexually transmitted infections among women who work in parlours by close or intimate contact. For our purposes, SEXUAL CONTACT includes people with whom you have:

- Had vaginal or anal intercourse with
- Given oral sex to
- Received oral sex from
- Given a hand job to

In other words, because we are concerned with your overall sexual health, we are interested in a broad range of sexual contacts.

It is very important that you give me as much information about each of the sexual contacts you’ve identified as possible. All information you give me will be kept confidential. Nobody except the study staff will ever see any of the information you give me.

INTERVIEWER SECTION

Has this participant given fully informed, verbal consent? □ YES

Participant ID: P ___ ___ ___

Interviewer name: _______________________

Interviewer signature: _______________________ date _______________________
[Fill out a separate questionnaire for each partner identified.]

SEXUAL PARTNER ID: S C ___ ___

1. Date of interview: ____________________ (dd/mm/yy)

2. What is this person's name? ________________________________

3. Please describe what this person looks like (tattoos, jewellery, birthmarks, other nicknames, detailed physical description).

4. How old is this person? ______

5. Sex:  □ Male  □ Female  □ Transgender (biologically □ MALE  □ FEMALE)

6. How would you describe this person's race/ethnicity (check one)?
   □ Caucasian/White
   □ Chinese
   □ South-Asian (e.g. Indian, Pakistani)
   □ Other Asian (e.g. Vietnamese, Japanese)
   □ Latin American
   □ Middle Eastern
   □ Black
   □ Aboriginal
   □ Other, specify ________________________________
   □ Unsure/don't know
   □ Declined

7. What town or city does this person live in? ________________________________
   □ Don't know  □ Declined
8. What is your relationship with this person? (check one):
- Spouse/live-in partner
- Boyfriend
- Client from establishment who gives you money in exchange for sex
- Person NOT from establishment who gives you money in exchange for sex
- Person who gives you drugs in exchange for sex (non-establishment)
- Person who gives you food, shelter, clothing, or something other than drugs or money in exchange for sex (non-establishment)
- Non-paying casual partner
- Employer/pimp/etc.
- Person who forced you to have sex
- Other:
- Declined

9. Where did you first meet this person?
- Sex establishment – this one
- A different one (name):
- Drinking establishment/bar (name):
- Street
- Own house
- Friend’s house
- School
- Other (describe):
- Declined

10. When did you first have sex with this person (as close to exact date as possible)?
- (DD/MM/YY) • Declined

11. How long did you know this person before you first had sex? ______
- Immediately (same day) • Declined

12. When was the last time you had sex with this person (as close to exact date as possible)?
- (DD/MM/YY) • Declined

13. To the best of your knowledge, has this person ever injected drugs?
- YES
- NO
- Don’t know
- Declined

14. Do you think this person has had an STD since you’ve known him/her (read out response options)?
- Definitely yes (confirm how she knows)
- Maybe
- Definitely no
- I don’t know
- Declined
15. Do you think this person has HIV/AIDS?
   - Definitely yes (confirm how she knows)
   - Maybe
   - Definitely no
   - I don’t know
   - Declined

16. Have you had sex with this person more than once?
   - NO – was a condom used?  
     - NO  
     - YES – condom break?  
       - NO  
       - YES (skip to Q 21)
   - YES (more than once)
   - Declined

17. Can you remember how many times you’ve had sex with this person?
   - YES – How many times? ______ times.
     - How many times did you use a condom? ______ times
   - NO (can’t remember how many times)
   - Declined

18. Approximately how often do you have sex with this person?
   - more than once per week
   - 1 – 4 times per month
   - less than once per month
   - Declined

19. How often do you use condoms for vaginal, anal, or oral sex with this person?
   - Never
   - Occasionally
   - Most of the time
   - Always
   - Declined

20. How many times has the condom broken or fallen off during sex with this person? ______ times

21. Which kind of sex do you have most often with this person (check all that apply)?
   - Oral -  
     - give  
     - receive
   - Anal
   - Vaginal
   - Hand job
   - Other (Describe – e.g., frottage, dress-up, masochism, etc.) ___________________________
   - Declined

22. To the best of your knowledge, does this person have (check all that apply) ______?  
   21a.  
   - Spouse/live-in partner
   - Girlfriend (not me)
   - Boyfriend or other male sex partner
   - None of the above (I’m his only girlfriend/lover/etc)
   - Declined
21b.  □ Visits "street" sex workers  
□ Visits other "off-street" sex workers (other massage parlours, escorts, karaoke bars, strip bars, in-home, etc.)  
□ Don't know  
□ None of the above (knows this with certainty)  
□ Declined

23. To the best of your knowledge, does this person ever have sex with anyone you know, such as your friends or co-workers, or anyone else?  
□ NO (end interview)  
□ Don't know (end interview)  
□ YES (complete next page)  
□ Declined (end interview)
[INTERVIEWER] I am now going to ask you to tell me the people this person has sexual contact with. This information is important because it will show how STI and HIV can spread through sexual contact networks. All information you give us will be kept confidential. Nobody except the study staff will ever see any of the information you give us. [collect information on other FSW, other sex establishments, etc.]

☐ Declined

<table>
<thead>
<tr>
<th>NAME (or other identifying information)</th>
<th>RELATIONSHIP TO RESPONDENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
B.4 References

<table>
<thead>
<tr>
<th>Measure</th>
<th>ORCHID Value</th>
<th>Atlanta pilot project$^+$ Value</th>
<th>Atlanta syphilis outbreak$^+$ Value</th>
<th>Colorado Springs cohort 1$^+$ Value</th>
<th>Atlanta urban networks$^+$ Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodes</td>
<td>553</td>
<td>381</td>
<td>99</td>
<td>250</td>
<td>90</td>
<td>Individuals within the network. Lines connecting nodes (sexual contact between individuals).</td>
</tr>
<tr>
<td>Edges</td>
<td>1502</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIV prevalence$^+$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total network</td>
<td>0.4%</td>
<td>6.3%</td>
<td>-</td>
<td>2.9%</td>
<td>13.3%</td>
<td></td>
</tr>
<tr>
<td>FSW</td>
<td>0.0%</td>
<td></td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clients</td>
<td>1.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syphilis prevalence</td>
<td></td>
<td>12.6%</td>
<td>10.0%</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>STI prevalence$^{**}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total network</td>
<td>2.0%</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>FSW</td>
<td>6.1%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Clients</td>
<td>3.9%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Cohesion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (SD)</td>
<td>0.01 (0.1)</td>
<td>0.003</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Proportion of all possible sexual ties (i.e., everyone in the network has sex with everyone else) that actually exist. For each pair of nodes, the number of edges in the shortest path (geodesic) between them.</td>
</tr>
<tr>
<td>Average distance</td>
<td>4.57</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Distance-based cohesion</td>
<td>0.25</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Range of 0 to 1: Larger values indicate greater cohesion.</td>
</tr>
</tbody>
</table>
### Regions

<table>
<thead>
<tr>
<th>Measure</th>
<th>ORCHID Value</th>
<th>Atlanta pilot project(\dagger) Value</th>
<th>Atlanta syphilis outbreak(\dagger) Value</th>
<th>Colorado Springs cohort 1(\dagger) Value</th>
<th>Atlanta urban networks(\dagger) Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected components</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Number</td>
<td>1</td>
<td>27</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>No. nodes in largest</td>
<td>553</td>
<td>276</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Bi-components</td>
<td></td>
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<tr>
<td>Number</td>
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<td>-</td>
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<td>-</td>
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<tr>
<td>No. nodes in largest</td>
<td>230</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>2-core</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>1</td>
<td>-</td>
<td>-</td>
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<td></td>
</tr>
<tr>
<td>No. nodes in largest</td>
<td>230</td>
<td>33</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

A group of connected individuals in which there is a path of some length from all individuals to every other individual in the network.

A component that does not contain a node (cut vertex) whose deletion increases the number of components in the network.

A subgroup in which all individuals are connected to at least two others in the group. A 2-core is the same as a bi-component of minimum size 3.

### Centrality

<table>
<thead>
<tr>
<th>Measure</th>
<th>ORCHID Mean (SD)</th>
<th>Atlanta pilot project(\dagger) Mean (SD)</th>
<th>Atlanta syphilis outbreak(\dagger) Mean (SD)</th>
<th>Colorado Springs cohort 1(\dagger) Mean (SD)</th>
<th>Atlanta urban networks(\dagger) Mean (SD)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree</td>
<td>5.42 (9.1)</td>
<td>2.05</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Average number of direct connections to each individual in the network (average number of sexual partners).</td>
</tr>
<tr>
<td>Range</td>
<td>1-64</td>
<td>1-34</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>nBetweenness</td>
<td>0.65 (1.76)</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Average frequency with which an individual is on the shortest path between all other pairs of individuals (normalized).</td>
</tr>
<tr>
<td>Range</td>
<td>0-20.6</td>
<td>0-0.71</td>
<td>-</td>
<td>-</td>
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<td></td>
</tr>
<tr>
<td>Information</td>
<td>0.58 (0.21)</td>
<td>0.23</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Harmonic mean of the distance of any individual to all other individuals in the network.</td>
</tr>
<tr>
<td>Range</td>
<td>0.16-0.99</td>
<td>0.1-0.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>nEigenvector</td>
<td>2.40 (5.51)</td>
<td>1.91</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>The centrality of individuals based on the centrality of the individuals to whom she or he is sexually linked (normalized).</td>
</tr>
<tr>
<td>Range</td>
<td>0-29</td>
<td>1-34</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Measure</td>
<td>ORCHID</td>
<td>Atlanta pilot project</td>
<td>Atlanta syphilis outbreak</td>
<td>Colorado Springs cohort</td>
<td>Atlanta urban networks</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------</td>
<td>-----------------------</td>
<td>---------------------------</td>
<td>-------------------------</td>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Subgroups</td>
<td>Value</td>
<td>Value</td>
<td>Value</td>
<td>Value</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>Clique (n=3)</td>
<td>116</td>
<td>26</td>
<td>9</td>
<td>0</td>
<td>5</td>
<td>A group of 3 individuals in which every individual is connected to every other individual (in this case, a fully connected triangle)</td>
</tr>
<tr>
<td>N-cliques</td>
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<tr>
<td>2-clique (n=3)</td>
<td>422</td>
<td>93</td>
<td>61</td>
<td>30</td>
<td>15</td>
<td>A subgroup (n = i) of size ‘N’ in which each individual is n or fewer steps from every other individual; connections outside the N-cliques are used to count the steps.</td>
</tr>
<tr>
<td>2-clique (n=4)</td>
<td>359</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>3-clique (n=3)</td>
<td>2083</td>
<td>80</td>
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<tr>
<td>4-clique (n=3)</td>
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</tr>
<tr>
<td>5-clique (n=3)</td>
<td>597</td>
<td>49</td>
<td>-</td>
<td>-</td>
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<td></td>
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<tr>
<td>5-clique (n=4)</td>
<td>597</td>
<td>44</td>
<td>-</td>
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<td>5-clique (n=5)</td>
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<td>K-plexes</td>
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<tr>
<td>2-plex (n=3)</td>
<td>82,821</td>
<td>2102</td>
<td>518</td>
<td>1847</td>
<td>124</td>
<td>A subgroup (n = i) of size n where each individual is directly connected to at least n – K members of the group.</td>
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<td>2-plex (n=4)</td>
<td>75,986</td>
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<td>135</td>
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</tbody>
</table>

*This table was adapted and contains data from other epidemiologic studies found in Rothenberg et al (1)
† Data from a pilot project applying network techniques to traditional syphilis control methods (1)
‡ Data from an outbreak of syphilis in an Atlanta suburban community (2)
§ Data from a study of IDU and FSW in Colorado Springs (2)
‖ Data from a study of social networks of urban drug users in Atlanta (3)
¶ In the current sample, respondents were coded as HIV infected if they answered “positive” to the question “What was the result of your most recent HIV test?” Clients were coded as HIV infected if respondents answered “definitely yes” to the question “To the best of your knowledge, is this person infected with HIV?”
** In the current sample, respondents were coded as STI infected if they reported an STI diagnosis or had genital sores within the previous six months. Clients were coded as STI infected if respondents answered “definitely yes” to the question “To the best of your knowledge, has this person had an STD since you’ve known him/her?”
Figure C.1. Temporal overlap of sexual partnerships as reported by a single respondent

The interview occurred at month 12, and therefore the graph represents a one-year retrospective snapshot of the duration of sexual relationships with the respondent’s most recent 11 sex partners only. Note that partners #9-11 were clients whom she reported having had sex with for the first time within the week prior to the interview. Sex partner #2 is her husband.
Figure C.2  Frequency distribution of number of sex partners over one month for 49 FSW
Figure C.3  Degree distribution of the complete network (n=553)

Figure C.4  Degree distribution of the first-order network

The first-order network includes 49 FSW respondents and the 234 sex partners they provided proxy data on (n=283).
Table C.2  Sexual behaviour and HIV and STI status of 49 respondents

<table>
<thead>
<tr>
<th>Variable</th>
<th>No.</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at sexual debut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>IQR</td>
<td>14-18</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>11-26</td>
<td></td>
</tr>
<tr>
<td>No. lifetime sex partners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>0</td>
<td>(0.0)</td>
</tr>
<tr>
<td>6-20</td>
<td>1</td>
<td>(2.0)</td>
</tr>
<tr>
<td>21-100</td>
<td>6</td>
<td>(12.2)</td>
</tr>
<tr>
<td>101-500</td>
<td>12</td>
<td>(24.5)</td>
</tr>
<tr>
<td>&gt; 500</td>
<td>24</td>
<td>(49.1)</td>
</tr>
<tr>
<td>Missing</td>
<td>6</td>
<td>(12.2)</td>
</tr>
<tr>
<td>No. sex partners in past 12 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>0</td>
<td>(0.0)</td>
</tr>
<tr>
<td>6-20</td>
<td>2</td>
<td>(4.1)</td>
</tr>
<tr>
<td>21-100</td>
<td>15</td>
<td>(30.6)</td>
</tr>
<tr>
<td>101-500</td>
<td>20</td>
<td>(40.8)</td>
</tr>
<tr>
<td>&gt; 500</td>
<td>3</td>
<td>(6.1)</td>
</tr>
<tr>
<td>Missing</td>
<td>9</td>
<td>(18.4)</td>
</tr>
<tr>
<td>No. sex partners in past month</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>IQR</td>
<td>20-50</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>1-200</td>
<td></td>
</tr>
<tr>
<td>No. sex partners in past week</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>IQR</td>
<td>4-12</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0-30</td>
<td></td>
</tr>
<tr>
<td>Diagnosed with an STI in past 6 mo</td>
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</tr>
<tr>
<td>Yes</td>
<td>3</td>
<td>(6.1)</td>
</tr>
<tr>
<td>No</td>
<td>34</td>
<td>(69.4)</td>
</tr>
<tr>
<td>Not tested</td>
<td>12</td>
<td>(24.5)</td>
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<tr>
<td>Genital sores in part 6 mo</td>
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<td></td>
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<tr>
<td>Yes</td>
<td>1</td>
<td>(2.1)</td>
</tr>
<tr>
<td>No</td>
<td>48</td>
<td>(97.9)</td>
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<tr>
<td>STI screening frequency</td>
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<td></td>
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<tr>
<td>Never</td>
<td>6</td>
<td>(12.2)</td>
</tr>
<tr>
<td>Once only</td>
<td>1</td>
<td>(2.0)</td>
</tr>
<tr>
<td>Less than once a year</td>
<td>4</td>
<td>(8.2)</td>
</tr>
<tr>
<td>Once a year</td>
<td>6</td>
<td>(12.2)</td>
</tr>
<tr>
<td>More than once a year</td>
<td>32</td>
<td>(65.4)</td>
</tr>
<tr>
<td>HIV status</td>
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<td></td>
</tr>
<tr>
<td>Negative</td>
<td>41</td>
<td>(83.7)</td>
</tr>
<tr>
<td>Positive</td>
<td>0</td>
<td>(0.0)</td>
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<tr>
<td>Unsure</td>
<td>2</td>
<td>(4.1)</td>
</tr>
<tr>
<td>Unknown (never tested)</td>
<td>6</td>
<td>(12.2)</td>
</tr>
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</table>
Table C.3  Characteristics of respondents (n=49) and clients (n=205) who bridged to the general population, compared to those who did not

<table>
<thead>
<tr>
<th>Variable</th>
<th>Bridgers (n=138)</th>
<th>Non-bridgers (n=116)</th>
<th>p-value*</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>36.3</td>
<td>34.3</td>
<td>0.31</td>
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<tr>
<td>SD</td>
<td>11.3</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>19-70</td>
<td>19-60</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Caucasian</td>
<td>67 (48.6)</td>
<td>62 (53.4)</td>
<td>0.44</td>
</tr>
<tr>
<td>Asian</td>
<td>54 (39.1)</td>
<td>43 (37.1)</td>
<td></td>
</tr>
<tr>
<td>Other/mixed</td>
<td>17 (12.3)</td>
<td>9 (7.8)</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>0 (0.0)</td>
<td>2 (1.7)</td>
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</tr>
<tr>
<td>Mean centrality [SD]</td>
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<td></td>
</tr>
<tr>
<td>Eigenvector</td>
<td>0.030 [0.052]</td>
<td>0.019 [0.043]</td>
<td>0.13</td>
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<tr>
<td>Information</td>
<td>0.69 [0.20]</td>
<td>0.63 [0.20]</td>
<td>0.01</td>
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<tr>
<td>Betweenness</td>
<td>2336 [3851]</td>
<td>1463 [3415]</td>
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<tr>
<td>Degree</td>
<td>10.0 [11.9]</td>
<td>7.0 [11.5]</td>
<td>0.0</td>
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<tr>
<td>High information centrality†</td>
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<td></td>
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<tr>
<td>Yes</td>
<td>86 (62.3)</td>
<td>56 (48.3)</td>
<td>0.03</td>
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<tr>
<td>No</td>
<td>52 (37.7)</td>
<td>60 (51.7)</td>
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<td>Clique member</td>
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<tr>
<td>Yes</td>
<td>21 (15.2)</td>
<td>9 (7.8)</td>
<td>0.07</td>
</tr>
<tr>
<td>No</td>
<td>117 (84.8)</td>
<td>107 (92.2)</td>
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<tr>
<td>HIV infected</td>
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<td></td>
<td></td>
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<tr>
<td>Yes</td>
<td>2 (1.5)</td>
<td>0 (0.0)</td>
<td>0.19</td>
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<tr>
<td>No/unknown</td>
<td>136 (98.5)</td>
<td>116 (100.0)</td>
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<td>STI infected</td>
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<td></td>
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<td>Yes</td>
<td>8 (5.8)</td>
<td>3 (2.6)</td>
<td>0.21</td>
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<tr>
<td>No/unknown</td>
<td>130 (94.2)</td>
<td>113 (97.4)</td>
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</table>

*P-values ignore missing values. Categorical variables were tested using Chi square test, continuous variables tested using Mann Whitney U-Test for non-normal data.
† Defined as scores equal or greater to the median (0.613) of the first-order network.
Table C.4  Correlations\(^*\) of four centrality measures for the complete network (n=553)

<table>
<thead>
<tr>
<th></th>
<th>Information</th>
<th>Betweenness</th>
<th>Degree</th>
<th>Eigenvector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
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<td>0.74</td>
<td>0.64</td>
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<td>-</td>
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<td>0.63</td>
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<tr>
<td>Degree</td>
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<td></td>
<td>-</td>
<td>0.87</td>
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<tr>
<td>Eigenvector</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

*Calculated using Pearson's r coefficient
C.1 References

