INTERAGENCY WORKSHOP-CONFERENCE ON PREVALENCE ESTIMATION TECHNIQUES

EXECUTIVE SUMMARY

NATIONAL INSTITUTE ON DRUG ABUSE
DEPARTMENT OF HEALTH AND HUMAN SERVICES

NATIONAL INSTITUTE OF JUSTICE
DEPARTMENT OF JUSTICE

NATIONAL INSTITUTE ON DRUG ABUSE
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NOVEMBER 3-4, 1988

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Dear Colleague:

This letter is directed primarily to those individuals who attended the November, 1988 Prevalence Estimation Techniques Conference, and also to those who expressed an interest in the results. Thank you for your patience during the lengthy preparation of the enclosed executive summary. We hope you find it useful.

Since then, our group has produced three papers related to cocaine prevalence estimation: "Techniques for the Estimation of Illicit Drug-use Prevalence: An Overview of Relevant Issues," "A System Dynamics Simulation Model of Cocaine Prevalence," and "Multiple-capture Estimation of Population Size with Dynamic State Change and Excluded Data." If you would like reprints of any of them, please direct your requests to Joanie Chung at the address listed above.

Sincerely,

Doug Anglin

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NIDA Technical Review Meeting

INTERAGENCY WORKSHOP-CONFERENCE ON
PREVALENCE ESTIMATION TECHNIQUES

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Marc Brodsky, National Institute on Drug Abuse (NIDA), welcomed the participants and said that he would like to subtitle the meeting "Prevalence Estimation of Relatively Rare Behavior."

Dr. Edgar Adams, NIDA, also welcomed the participants and said that the primary purpose of the workshop is the examination of prevalence estimation of rare events, particularly important to the health of the Nation with respect to intravenous (IV) drug use, AIDS, and the aging heroin abuse populations. Good estimates of these populations will have a major impact on policy over the next few years. He said that he hopes that an area of cooperation among States and agencies and an agenda of future efforts will result from the conference.

Dr. Bernard Gropper, National Institute of Justice (NIJ), said that the focus of the workshop will be on the "how" of better estimates. There has been cooperation between NIJ and NIDA for a long time. NIJ would like to know the size of the drug abuse population and any associated trends for policy purposes. The prime focus of NIJ is crime. Estimates of costs are needed at local and State levels. Better estimates of all aspects of the drug problem are a top priority. He said that NIJ has initiated the Drug Usage Forecasting System (DUF), which provides periodic sampling for purposes of estimating prevalence in the criminal justice population.

Brodsky added that, not only is there a need for estimations of the number of IV drug users and those who share their needles, but there is also a need to know the demographic breakdown of the estimates in detail.

Dr. Douglas Anglin, UCLA Drug Abuse Research Group, added that the extent of the need for good prevalence estimation had become clear and that many estimation techniques could be generically applied. Therefore, this conference would be a generic focus on techniques cutting across a number of fields. He asked that the participants introduce themselves, which they did.

I. COMMON ISSUES, PROBLEMS, AND TECHNIQUES

Introduction: Purpose and Plan of the Conference

In discussing the aim of the conference, Anglin emphasized what the workshop participants have in common. They are people who personally or professionally are interested in prevalence estimation, which has been defined as counting the hard-to-count and measuring the hard-to-measure. Every decision maker must have a basis for making decisions, and where justification is lacking in developing the numbers to be used, his decisions are subject to political or legal controversy. Anglin said that the workshop was likely to emphasize the deficiencies that need to be corrected in the system. Problems must be recognized and potential solutions sought in a collective effort. The Federal Government needs improvements in implemented data-collection systems and suggestions for alternate data-acquisition strategies. He hopes that the workshop is the beginning of an informal network of people who will stay in touch and share information.

Dr. Philip Cooley, Research Triangle Institute (RTI), related two modeling anecdotes. In the early 1900s, Richard Ross was the first to identify the mosquito's role in the spread of malaria, and he developed the first model that portrayed the interactions between the mosquito and the human being. This model represented the state of the art for over 30 years, although it did not properly portray one aspect of the problem: that when an infected mosquito reinfects an infected human being, the human being does not get much sicker. In the early fifties, McDonald refined the Ross model to account for this problem. After 10 years, the World Health Organization (WHO) began to use the model to assess various control strategies for the eradication of malaria. There were two main strategies: massive use of insecticides and massive use of antimalarials. The model demonstrated that the most efficient choice was the insecticide, and in the sixties, the WHO instituted an effective program of attacking the mosquito populations, substantially reducing the incidence of malaria within 2 years. There was later, however, a renewed outbreak of the disease resulting from the proliferation of insecticide-resistant mosquitoes. The model was not broad enough to reveal the optimal solution, because it contained no genetic components that could have demonstrated long-term prospects.

Those attempting to monitor the AIDS epidemic have been hampered by the lack of studies of the behavior and size of the AIDS risk groups. For gay men, the definitive and most recent study is the Kinsey in 1942. As a result of the Kinsey study, gay men are often assessed at 10 percent of the male population, which has contributed to an inflated estimate of the size of the gay population at risk for AIDS. Working backward from the number of AIDS cases to infection rates has led to a reevaluation of the size of the gay risk group and its reduction by a factor of 4 in, for example, New York. The moral of the story is that alternative models that use different approaches and data sources are necessary to validate each other. Cooley believes that models improve over time because of increased understanding of the process being

modeled and the incorporation of new information into the modeling process.

Cooley suggested that the major purposes of the conference are to discuss common problems, to identify useful information, and to constructively criticize the models presented. The emphasis should be on the interaction of methodologies with data.

Discussion: Raymond Shreckengost, RSS Associates, suggested that good definitions are needed for "heroin user," "cocaine user," "and needle user." Anglin agreed that clear and consistent operational definitions are needed. Brodsky said there is no problem in defining a heroin user. Emergency room blood testing that identifies the presence of morphine suggests the use of opiates by the blood donor. He added that the prevalence of relatively rare behaviors may be determined by the local environment of a person. Gropper suggested that the focus of most workshop participants would be on estimates of population size of drug-related phenomena such as AIDS and drug-related crime and on how good a model is needed to answer the questions. Bruce Mendelson, Denver Department of Health, said that knowledge is needed not only of the number of IV needle sharers, but with whom and how often they are sharing.

Common Issues Encountered in Prevalence Estimation

Dr. Herman Diesenhaus, National Academy of Sciences (NAS), reviewed his experiences in the field beginning in 1967 in the planning of mental health services in Illinois using the methodologies developed by some of the workshop participants. His interest was in measurement questions. The definition of "case" was critical, because case definitions vary according to their usage in a study. At that time, the number of cases was maximized in order to maximize the funding that could be captured from the National Institute of Mental Health. The mental health field was then incorporating alcohol, drug abuse, and criminal justice statistics as one aggregate. The Illinois Department of Mental Health, for example, began to develop plans specifically for drug abuse, and NIDA created its own program for estimating the number of drug abusers that the States were required to follow. The National Institute on Alcoholism and Alcohol Abuse also required the development of various estimates.

A bill (Aid to Psychiatrically Impaired Impacted Areas) was drafted by a community mental health center in a Chicago area known as a psychiatric ghetto. A catchment area of 136,000 people contained 15,000 ex-State hospital patients, 7,000 of whom were on conditional discharge from the State hospital. The majority were chronic schizophrenics; some were alcoholic-schizophrenics, a dual diagnosis. The bill was based on the number of ex-State hospital patients residing in a catchment area. The methods used to count the patients were imperfect, particularly if the patients moved from conditional to full

discharge. This illustrates the critical issue of the definition of a "case." (Diesenhaus stressed that his comments reflected his personal view.)

Leaving the psychiatric ghetto, Diesenhaus returned to research as the director of a Colorado drug-alcohol project. Again, submission of a need statement was required before the awarding of a research grant. The study replicated for Denver some of the ways of estimating alcohol and drug use that had been used in Illinois in developing the predictive model for the number of mentally ill persons. In the sixties, but not in the seventies, the number of mentally ill individuals included alcoholics and drug addicts. Therefore, Diesenhaus was involved in the development at the State level of a treatment needs model that used the best estimates of prevalence to determine the level of investment required by State, local, and Federal governments and the treatment resources needed to reduce prevalence. An attempt was made to convince the State legislature that acute models did not fit what was happening in alcoholism and drug abuse. There was also an attempt to use the model for criminal justice planning.

Diesenhaus then moved to the private sector to work for a large psychiatric hospital management company in competition to build psychiatric and chemical dependency beds. He found that averaging the predictions of many models optimized results for the private company.

Diesenhaus currently holds the position of associate director of a Congressionally mandated study of the effectiveness of alcohol treatment programs. He said that there is no single acknowledged best approach to needs estimation for alcohol and drug abuse or mental disorders. There is an inconsistent approach to prevalence estimation in the United States, and the level of investment needed to reduce the incidence of drug abuse must be determined. Is the formula for the allocation of funds at the Federal level adequate?

Diesenhaus is currently analyzing the Nation's inconsistent approach toward prevalence estimation as the primary method of determining the need for services. He has found that there is no systematic use of prevalence data. There is a lack of an accepted model that can be used to guide decision makers in their choice of policy options. The NAS feels that there is a need for on-going surveillance using a technique such as the ecological catchment area project.

The Committee on National Statistics at NAS is looking at health and criminal justice statistics as they apply to health and criminal justice problems. Policy makers will be made aware that they have paid inconsistent attention to these problems and that there are common methodological issues. Pure epidemiologists should be interacting with specialty epidemiologists, and both should be interacting with planners and policy analysts.

Charles Cowan, U.S. Department of Education, introduced his discussion by saying that he had formerly been with the Bureau of the Census, dealing with the question of measuring rare or elusive populations. With accompanying slides, he discussed an example of the watering point model. In Somalia, south of Egypt on the Indian Ocean, 60 percent of the population are nomadic herders who must return periodically to various watering points in the dry season. The people move about and do not remain in a well-defined area, making it difficult to take a census. Their movements depend on when the animals need water. Men herd camels; children herd cattle; and women herd sheep and goats. Therefore, the data collection process is untidy, and the census data are redundant as groups overlap families. Deleterious to the model are the facts that the country's borders are undefined, and that city dwellers move in and out of the city depending on the wetness or dryness of the season. Similar problems would exist in a study of the New York Port Authority, where there are flows in and out of three airports. To capture cargo, one would have to go to the points where cargo might be found.

Cowan said that he has been involved in an NAS study of the homeless. In Baltimore, he used capture and recapture eight times in 1 year to determine the number of homeless persons moving in and out of the city. Missions and shelters were the "watering points," and also at issue was the type of transient population in the city. Missing children are another issue, because they do not go to convenient points. Most go to friends' houses for 2 or 3 weeks, so appropriate sources of data were social service agencies.

Cowan stressed that, in dealing with counting problems, flexibility of approach is key. For example, to estimate the number of people missing in a census, he used computerized records such as a Bureau of the Census demographic analysis that gives a global view of the United States population by age, race, and sex. One can also go to "watering points" to find the people missed in the survey of housing units. Studies of the homeless can expand beyond the shelters to the flow process, such as a seasonal migration in and out of a city. The use of outreach in the establishment of a watering point, such as a social worker in contact with missing children, is helpful in finding them.

Cowan said that he has dealt with some strange populations but that there is also a great deal of information on the general population. Using this global information, one can fill in relationships, i.e., combine two or three data sets. One also can project outside a population. For example, Cowan took eight samples at shelters in a 1-year period in Baltimore and said confidently at the end of the year that 20 percent of his population were hard-core homeless. It was possible to make a projection as he watched capture-recapture rates decline. One can also make small area estimates and estimates of different types of populations. After making a count in Somalia, Cowan was able to formulate a better description of regional population size and of a special population of interest to the United Nations.

Discussion: In answer to a question on cost vs. benefit in the various techniques, Cowan said that, as opposed to a faulty Chicago study costing $450,000 that gave an estimate of 2,000 homeless in the city, his Baltimore record-match study cost $15,000 and gave a lower bound to the number of homeless individuals. With limited resources, you need a validity check on a model. Cowan's validity check was a separate study that picked up street people and checked the frequency of use of a mission or shelter. Models need validation.

Dr. Charles Holzer, University of Texas Medical Branch, began his presentation by saying that, in any process of estimation, one must decide whether the goal is purely scientific, an attempt to influence social policies, or an attempt to influence local or Federal management decisions. Working within these various contexts may result in differing costs associated with the types of random error and bias in the estimates. For example, the goals of the Epidemiologic Catchment Area Project (ECA) were largely scientific, seeking to establish national prevalence estimates and to relate that prevalence to risk factors and utilization of services.

Scientific goals are different from those of a State seeking guidance in allocation of resources and different from the goals of a hospital documenting the need for short-term substance abuse beds.

The size, heterogeneity, and accessibility of the population for which estimates are required influence the choices, costs, and methodology used. If the population is being studied in terms of a special characteristic, the estimation problem is compounded, because one must estimate both the numerator and the denominator. For example, a mistaken assumption can be made that the prevalence of a particular characteristic in a group is generalizable to its larger group, e.g., redefining the denominator from all drug users to drug users in treatment or persons arrested for drugs.

The most difficult problem involved in efforts to determine the prevalence of a phenomenon is arriving at an adequate theoretical definition. Most terms such as "alcoholism" or "drug abuse" are broadly defined. A proper definition tends to reduce the probability of misinterpretation of results. For example, some studies such as ECA have selected a subset of disorders rather than dealing with all of mental health.

Much of synthetic estimation is based on a general model that looks at relationships in a survey data base and then determines empirical relationships. There is a requirement that the data base be adequate, which is difficult to obtain when the phenomenon is rare. Also, a linkage method is necessary so that some of the same variables in the survey data base exist locally. Often, however, there is not full cross-classification of all variables of major interest.

Holzer is continuing to work with synthetic estimates for the State of Texas, differentiating between mental disorders and drug abuse.

Discussion: In response to a question, Holzer said that it is important to check whether estimates made in a particular location are reasonable. Dr. Gary Tischler, Yale University, said that only 25 percent of people who are diagnosed are in treatment at any given time. From a planning perspective, difficulties result from a tendency to assume that a diagnosed case should be treated. This may not be so. Therefore, prevalence estimates may have nothing to do with the projections needed in relation to health services. Mendelson agreed and said that prevalence estimation and needs assessment are two separate processes. Ron Manderscheid, NIMH, suggested that, to use limited money effectively, one must consider whether to spend it on prevention or cure. Holzer added that one could easily put all the resources into treating the most severely mentally ill and ignore the people who could be helped and returned to work.

New Data Sources in Drug Abuse Estimation and Further Data Improvements

James Kaple, NIDA, began by giving a review of his background. He is currently with the Office of Finance and Coverage Policy at NIDA, which is responsible for health services research to assist the people who make decisions about finance, reimbursement, and coverage of substance abuse services. Recommendations are made for the Medicare and Medicaid programs, commercial insurance plans, State programs, the self-insured, and groups such as HMOs.

Before Kaple joined ADAMHA, he was with the Health Care Financing Administration, managing research, demonstration, and statistical activities from 1977 to 1983, during which changes were occurring in the financing of health care. Cost containment was emphasized; development of the prospective payment system took place; new coverage decisions were made about ambulatory surgery and hospices; and HMOs were seen as the wave of the future. He then spent 3 years with the Bureau of Data Management and Strategy.

Medicare has the best data base in the world for client-specific information on its beneficiaries. It has kept data since 1965 on every hospital encounter and since 1980 on every ambulatory encounter, and it has been a valuable data base for decision making about financing and coverage policy issues in the commercial and private insurance fields as well as in Medicare. The substance abuse treatment and delivery system is at the same point in its evolution as was the general medical delivery system in the mid-sixties. Tough questions are now being asked about what works and where limited funds should be allocated.

The 1989 Drug Abuse Act has significant implications for epidemiologists, health services researchers, and others dependent upon data in this field. In the Act, there are some specific data

requirements tied to the block grant requirements for alcohol, drug, and mental health services. In addition to requiring that information be collected at the Federal level, the Act identifies resources to assist in the collection of this information--unique in legislative experience. The money set aside is between 5 and 15 percent of the total block grant moneys ($40 million to $120 million per year) for 1989 for data collection, health services research, and technical assistance to the States. The Act requires the Secretary to use the 5 percent level, but he may use as much as 15 percent. For NIDA, there was an additional research allocation of about $20 million for data collection and analysis, technical assistance, and health services research related to substance abuse treatment.

Kaple said that he is concentrating on the treatment and services data collection requirements, data on the client in service, and data on the service delivery providers. There has been close collaboration with State substance abuse directors to determine the feasibility of developing a common client-based information system to be used to track clients through State-sponsored treatment facilities. The system will involve the electronic capture and transfer of data at the point of service, and the substantive content of the data set should be updated to make it consistent with the drugs used and the providers available to deliver services. During the development process, the State directors and the provider representatives at the national level are becoming involved in the identification of the data elements that are meaningful and useful to them. It is hoped that data can be pooled if uniform gathering techniques are used throughout the States.

Kaple feels that this is an opportunity to improve the availability of data for management purposes, to inform services research activities, and to provide the basis for policy decisions. The draft content of the system should be available within the next 4 to 6 months.

Discussion: Dr. Donald Des Jarlais, New York State Division of Substance Abuse Services, said that it was his experience that the quality of unused data sets deteriorates rapidly. Data sets that are being used improve as the epidemiology changes. Therefore, there is a maintenance cost for continually updating the system. Kaple agreed and said there is an incremental absolute cost associated with collecting and transmitting the data to a national repository. He added that it might be useful to obtain client-specific information that can be linked over time in order to track the clients through the service delivery system. Mendelson said that Colorado implemented the use of an algorithm (first and last names, date of birth, etc.) in a client-tracking system and that he hopes to focus on the concept of continuing care in addition to relapse rates.

Dr. Yoshio Akiyama, Federal Bureau of Investigation (FBI), spoke on the Uniform Crime Reporting Program (UCR), which collects data from law enforcement agencies throughout the Nation. With incident-based crime

reporting, there are 22 crime categories linking people to their crimes. The data are also broken down into various types of drug-related crime and the quantity of drugs confiscated. There are 18 categories of drug type.

Recently, three volumes of UCR report descriptions were produced. Volume I is a general data base description. Volume II consists of submission specifications. Volume III is a description of implementation. Those interested in the details of drug data available on incidence should request Volume I, Data Collection Guidelines, UCR Program 2023245015.

Akiyama pointed out that there is no linkage between sex and age in the data, there are no data on juveniles, and the UCR program is voluntary.

Discussion: Gropper asked for an operational definition of drug offense. Akiyama said that a case is defined by the local law enforcement authorities. Gropper said that he feels at a disadvantage because a crime is not reported as drug-related unless there is also a drug charge. Holzer asked about the plans for the dissemination of the UCR data. Akiyama said that the data will become available in the summer of 1989 in response to requests.

Paul Cascarano, NIJ, spoke on Drug Usage Forecasting (DUF). About 4 years ago, it was found that 20 percent of those arrested were drug users, based on self-reports. The information was considered somewhat unreliable, so urine sampling was instituted to determine the extent of drug use by type of crime committed. The purpose of the sampling was to provide each city with information that could help it to detect drug use epidemics early, to aid in the planning and allocation of law enforcement resources, and to aid in the determination of the future need for prevention and treatment. There was also a need to determine the impact of reallocation of resources on drugs and crime. In addition, there was hope that the information could provide a view from the national level of the shifts occurring in the use of drugs.

Voluntary interviews and urine specimens have been acquired from male and female arrestees in about 20 communities. The response rate is about 95 percent. In 1988, testing of juveniles began, and it is expected that the program will be expanded to 25 cities. An impediment to the program is that police departments across the country did not want to be compared to each other.

Drug use among arrested felons ranges from 90 percent in New York City to 54 percent in Indianapolis. If marijuana is excluded, the rate in Indianapolis is only 23 percent, resulting in a significant variation. For two or more drugs, San Diego and New York have the highest rates. For PCP, the highest rates are found in Chicago and the District of Columbia. For cocaine, the rate is 83 percent in New York and 15 percent in Indianapolis. For opiates, the rate is 27 percent in New

York, and the Centers for Disease Control (CDC) report that 60 percent of these opiate users are seropositive for AIDS. Twenty percent of prisoners leaving New York City for the New York State Prison are seropositive for AIDS. If the rate for heroin is added to that for amphetamines, the number becomes more significant, because people are injecting amphetamines, particularly in San Diego.

Cocaine use has been increasing rapidly in New York City, jumping from 14 to 55 percent within 18 months among 16- to 20-year-olds. It has also been increasing rapidly in Washington, DC, where the number of shootings has increased as the market has changed. The DC Police Chief recently speculated that, when the market is organized by organized crime, the number of killings will decrease. Women are as well-represented as men among drug users.

Cascarano is currently working with others on the implications of AIDS in the prisons and its impact on judges' decisions on sentencing.

Discussion: A member of the audience asked what policy changes have been made as a result of the availability of the above data. Cascarano said that, for example, after the first wave of data, Phoenix lobbied the State legislators, who earmarked $8.5 million for drug use prevention and treatment and pretrial drug-testing programs. Availability of the DUF data also resulted in the search by the current administration for funding to battle the drug and crime problems. It costs $50,000 to fund the collection of DUF data in one city for 1 year. In response to a query on why drug offenses are not separated from others, Cascarano said that he has such data in tabular format. Anglin said that there are problems with differential enforcement among cities.

Joe Gfroerer, NIDA, spoke on the Drug Abuse Warning Network (DAWN), which is undergoing a major change. It is changing to a probability sample design, so that representative estimates can be produced. DAWN has been presenting raw data and using consistent channels for trend analysis, because hospitals are moving in and out of the system. The new sample currently being implemented is a probability sample in 21 metropolitan areas, each an independent sample for which an estimate will be produced. There will be a national panel with its representative sample to be combined with the 21 metropolitan areas to produce national estimates.

The sample design is based on the American Hospital Association data file and weighted to those levels. In terms of statistical modeling, prevalence estimation based on DAWN data has shown a great improvement. Rates can now be calculated, legitimate comparisons can be made among metropolitan areas, and rate trends over time can be observed. The number of hospitals is being reduced somewhat from about 750 to 600, because, in some of the larger cities with larger samples, precision can be maintained by using fewer hospitals. This major transition will

be completed by the end of 1989, and the studies of some cities will be completed even sooner.

The complete changeover to the new system will start with 1990 data as scheduled now, and at that point all DAWN reports will contain projected estimates reformatted to show various comparisons and data items. There will, however, be overlap of the old and new systems. The overlap data will be put through a statistical model to map the new sample onto the old in order to produce trend data going back to the early years of DAWN.

Discussion: In response to a question on whether the breakdown on drugs will be changed, Gfroerer said it would not, but that data may not be observed in such fine detail. Anglin asked if the modeling will successfully bridge the transition period. Gfroerer said that, because early DAWN information will be combined with the new, it is expected that past reality will be successfully projected. He added that no mortality data are being used.

Dan Tweed, Duke University, spoke on the need for mental health services. He said that, until recently, he was with the Mental Health Systems Evaluation Project at the University of Denver, involved in a Colorado social health survey that was designed to evaluate existing attempts at using social indicators to estimate the prevalence of mental health problems in an area. The basis of the Colorado study was a large sample of 4,745 noninstitutionalized adults in 48 areas. Though the study was designed to produce Statewide estimates, the intent was to produce area estimates. The sample per area was 100 cases. "Caseness" was viewed in a number of ways: in terms of the presence of diagnosable psychiatric disorders, the presence of dysfunction not explainable by health or economic problems, or the presence of stress or demoralization as measured by the Center for Epidemiologic Studies Depression Scale. These can be seen as the dimensions of a case and can be combined in a number of ways. There were five models that existed in the literature that were crude attempts to make small area estimates of the prevalence of diagnosable disorders. Most of them were defined in a diffuse, generic manner, and one cannot necessarily extrapolate a technique based on a definition of caseness in one study to that based on another.

The Colorado study found that modeling success varies according to the model and the definition of caseness. The models explained 30 to 60 percent of between-area variance, which was not bad, because most of the between-area variance was unreliable as a result of the variance of the sampling estimates within areas. There were two kinds of estimates that could be compared: the direct estimate and the models based on social indicators and parameters in the optimized versions of these models that were selected given the sample. Tweed said that he often has more faith in some indirect estimates than in some of the direct,

especially when the extremes are considered. Models have the ability to exclude some of the unreliability of the data.

Two models were attractive. One was the synthetic model, with the variables age, sex, marital status, and race, that was calibrated using data from a national survey and the Center for Epidemiologic Studies to define mental health caseness. It performed well across different definitions of mental health caseness. The other was a regression model that worked even better, with 3 rather than 72 parameters. It contained only two variables: the number of divorced or separated males and the number of one-person households. This illustrates the fact that, often, relatively unsophisticated models can work reasonably well.

Discussion: Anglin asked whether it is preferable to aim for simplicity and practicality. Tweed said that, for a given model, there was an idea that the areas modeled vary according to the prevalence of problems and that there are reasons for the variation. Some of the reasons could be determined in terms of social indicators; a profile could be constructed. Two areas can produce different predictions for the need for mental health services. Working backward and looking at the profiles, one can determine a high-need area and the conditions contributing to risk. The number of variables is not necessarily the issue. Cowan said that there is a certain cost to having broader models, e.g., the cost of the time involved in dealing with 72 rather than 3 variables. In answer to a question, Tweed said that family status correlated with mental health and drug variables; socioeconomic status indicators correlated with mental health; age and mobility correlated with the drug variable.

Dr. Holzer spoke on working on an ecological basis versus an individual basis and the combining of both kinds of information in one data set. He said that there can be a problem in working as Tweed has, since a change of unit ecologically changes all the estimation parameters. He said that, when he has worked with that sort of data set, ecological studies have not been able to analyze an economically mixed area very well. As a result, he has shifted toward looking at synthetic, individually based approaches.

His goals were to introduce the Epidemiologic Catchment Area (ECA) project and to give an example of the uses of the resulting estimations. ECA was originally planned to consist of 10 sites but expanded to 500. There was a community part and an institutional part, and it was designed to be longitudinal over the course of a year. The Diagnostic Interview Schedule (DIS) was the instrument used, which focuses on diagnostic criteria as opposed to quantity frequency variability, with which many other substance abuse surveys have dealt. It focused on lifetime coverage, recency, and other variables on social background, utilization, etc.

The first step was to specify the sociodemographic cells and to define categories such as age, sex, race, marital status, and high school graduation. The next step was to smooth the rates, which tend to vary among a large number of cells. One can then use various kinds of estimation to generate artificially, for a small area, the sufficient set of cells that are unique and in each of which there is one person. For each cell, there is an estimate from the smoothing process from which one can estimate the number of cases in each of the cells. The sum gives the estimate at any geographical point for all the people. A sum over various marginals gives an estimate of men versus women, young versus old, etc. Holzer discussed a model of schizophrenia, which is an example of a low-rate phenomenon with more statistical problems than a high-rate phenomenon such as alcoholism.

In order to determine how well synthetic estimates work in a given area, Holzer plans to make blind estimates for the Colorado census tracks. He is also making estimates from some areas of ECA to others, making comparisons with the utilization of hospitals in Texas, and comparing estimates for alcohol with mortality in alcohol-related motor vehicle accidents.

Discussion: Anglin said that the survey approach to prevalence estimation discerns more deviant behavior at smaller frequency, and that ECA suggests very little heroin or cocaine addiction. The watering hole technique (emergency rooms or police stations) produces a high rate of repeated deviant behavior. Holzer said that the survey asks about frequency of emergency room visits. Cowan added that, when pollsters attempt to predict election outcome, a number of questions are asked to determine the likelihood that the people questioned will vote. Manderscheid asked what population uses a particular emergency service? Holzer said that, in multiple purpose surveying, it is possible to use the first screening to determine which people will later be asked the more detailed questions.

II. NEW AND IMPROVED STATISTICAL APPROACHES TO PREVALENCE ESTIMATION

Dr. Jack Homer, UCLA, gave a slide-intensive presentation on system dynamics. He said that the technique has existed for more than 30 years, and that he has utilized it in modeling in the health care area in the public and private sectors for 12 years. His doctoral thesis examined the process by which new medical products are adopted and used by physicians over a period of time. He has recently become involved in the area of the adoption of illegal drugs.

System dynamics is a method for analyzing change and anticipating new trends. The focus is on patterns of change rather than on point estimates. It is an attempt to look at trends in a macro way and to think about how they may change in the future. Rather than performing straight-line forecasting, possible dramatic changes in patterns are sought that can be built into the models. System dynamics is an

approach to computer simulation modeling that is not Monte Carlo simulation. It is also a social science application of feedback control principles.

There are two basic principles: 1) Flows are conserved through accumulation and 2) flows are regulated by feedback from the existing accumulation back to decisions that are made. By including the feedback loops in the system, the claim of system dynamics is that one can understand the patterns of change that have taken place over time and that these patterns can be generated endogenously within the model. In trying to limit the amount of data by which the model is driven, there is a better chance of understanding how patterns might change in the future. The orientation is toward procedure in terms of projection. Prevalence is an accumulation of incidence going in and departure coming out, which has interesting implications about how the data must be related to each other. If there are data on incidence, prevalence, and departure, one can test for their consistency by determining whether the accumulation of incidence minus departure yields prevalence. Therefore, there is a means within system dynamics to gain a check on the consistency of data.

The methodology consists of the following steps:

- Identify issue and gather data
- Identify significant accumulations and feedback loops
- Construct a parsimonious set of equations
- Determine model's ability to reproduce history
- Project the system's behavior under different "what if" conditions

There is a model of the estimations and projections of cocaine use in progress that has a problem with the post-1982 period. The model suggests that, from 1976 to 1979, the dominant feature of cocaine use was the snowball effect, in which one was more likely to become a user as one associated with a greater number of users. From 1980 to 1983, there was accumulating news of the dangers of cocaine, which produced a leveling-off of use.

Discussion: In response to a question from Jim Schmeidler, New York State Division of Substance Abuse Services, Homer said that the introduction of crack is probably responsible for the increase in medical emergencies in the eighties. Data on the spread of crack beginning in 1982 are needed. Existing data suggest that compulsive use of cocaine started to rise in 1983. Gropper suggested that one does not expect morbidity and mortality to lead to increased drug use but that both can precede criminality. Homer said that consumption and

price can explain crime. Dr. John Newmeyer, Haight-Ashbury Free Clinic, expressed concern that the high school dropouts are being missed. Rick Harwood, NAS, suggested that the substitution of drugs and its resulting threshold effect should be considered. Des Jarlais suggested that one of the explanations for the cocaine epidemic is the clampdown on amphetamines in the middle to late seventies. Gropper suggested that the beginning of the AIDS epidemic and the emphasis on decreasing IV drug use could have encouraged IV drug users to switch to intranasal use of cocaine.

Data-Directed Approaches

Dr. Thomas Wickens, UCLA, spoke on multiple capture and synthetic estimation. He said that the system dynamics model is an attractive way of integrating a great deal of data and ideas, which, however, is not the whole answer to the problems of prevalence estimation. It does not furnish procedures for looking at particular sets of data, tracking down missing observations, or "cleaning out" areas lacking necessary information. In order to do this, Wickens has been looking at multiple capture methods and synthetic estimation procedures.

Data from the California Drug Abuse Data System (CALDADS) consisted of a series of reports from referrals to treatment and thus were records of entry to and departure from treatment. These records had sufficient identifiers to track the entries and exits over a series. Wickens looked at four 6-month periods from mid-1985 to mid-1987. In each of the four periods, it was determined for each individual whether he had appeared in treatment, scoring one for presence and zero for absence, resulting in a set of data that form a typical multiple capture arrangement. Data of this sort can be reconfigured into an incomplete four-way table. One approach is to fit a probability model to this, but for sets of longitudinal data, there is no reason for assuming a closed population or that certain associations should be present in the model and that others should be absent. Therefore, Wickens turned to some of the standard ecological multiple capture models. The strongest contender for the open population model is the Jolly-Seber model. The assumptions of the model are:

1) The animals behave independently and identically with respect to the capture probability, the survival probability, and the probability of the sampled animal (treatment) returning to the population.

2) Samples are instantaneous and release is made immediately after the sample.

3) The animal's behavior is unaffected by the capture history.

4) There is no temporary emigration from the population.

5) All marked animals can be identified.

There are difficulties with the model. If there are different subpopulations, the first assumption is at risk. Assumption 2 is not true for treatment data insofar as there is a period of time involved, and a person in treatment tends to stay in treatment. Assumption 3 cannot apply because, if the treatment is effective, the animal will leave the population. Assumption 4 cannot be very well satisfied inasmuch as people often leave and then return to treatment. Assumption 5 cannot always be satisfied because of changes in a sample's identifying characteristics.

An attempt has been made to develop a more dynamic model and to graft it onto a standard multiple capture situation. This becomes complicated as nonusers move into a period of using, then into treatment or not, then to death or termination of use. It is impossible to tell the difference between a person who dies and a person who stops using drugs. (Successful treatment is the addict's equivalent of trap death in the animal.)

Wickens said that there has been much talk in his group about the use of semi-Markov models as a representation for the addiction and drug use process. They are time series models in which there is a series of states, and an individual is tracked through transitions between states. In the semi-Markov representation, two factors determine the transition from one state to another: the current state and the length of time an individual has been in that state. The Markov property is that other historical information is irrelevant. If one allows duration of states to have some influence on an individual, the process becomes semi-Markov.

Once an individual has appeared in the process for the first time, it makes sense to follow the rest of the process. Therefore, the balance of the process could well be represented as a function of a simple Markov chain, i.e., a simple transition mechanism among states. A Markov chain, a discrete time representation, rather than a Markov process, a continuous time representation, can be used because of the quantizing of the sampling operation. Therefore, a simple Markov model can represent treatment and nontreatment, and the observed capture and noncapture can be treated as functions of the Markov process.

As always, when one fits a model, one runs into some trouble when dealing with data that are functions of a set of latent states that are impossible to observe. Some of the parameters associated with the transitions are likely not to be fully identifiable.

Discussion: In response to an inquiry from the audience, Wickens said that the people who are going into treatment are being drawn from a

larger population of people who might be sampled for treatment. He said that he is trying to get a feeling for the number of people who potentially could be going into treatment. By looking at the dynamics of people moving in and out, one is able to infer the number of new people from which the sampled population is drawn. The probability of a new person's being accepted in treatment is estimated at about 0.09 based on information on return rates. If these rates apply to the new population, one can infer how large that population can be.

In answer to a question from Shreckengost, Wickens said that, in the Markov chain representation, one could have different transition probabilities at each sample interval. He said that he hopes to represent the parameters by simple polynomials or slowly changing functions. Cowan suggested that it might be interesting to allow changing parameters to excite a later change in a different set of parameters. He said also that putting a limit on the amount of treatment that can be administered may cause problems in the model.

Dr. Cooley spoke on a surrogate method of projecting the size of the AIDS risk groups, with a focus on IV drug users, based on a paper by Bruchmeyer and Gale. Their model represents what happens during the period between infection with the AIDS virus and diagnosis. There are three entities: the number of people infected, a distribution on the incubation period before diagnosis, and the incidence of AIDS cases. A procedure that works backward was developed, starting with the use of the incidence of AIDS cases to establish the prevalence of human immunodeficiency virus (HIV) as it has occurred in times past. In the absence of any other infection, therefore, the number of AIDS cases that will occur in the future can be predicted. The article was published in the *Journal of the American Statistical Association* of June 1988.

Cooley implemented the method and applied it to all AIDS data that involved IV drug use. An adjustment was necessary for the AIDS data reporting lag. Work conducted in New York by Des Jarlais and others provides strong evidence that drug users tend to die of other infectious diseases before they are diagnosed as having AIDS. Not only is this phenomenon very pronounced, but there is an estimate that 2.1 cases of premature death occur for each AIDS case. Therefore, the assumption can be made that IV drug users are degrading their immune systems through the introduction of bacteria by needle sharing. This ultimately, in the presence of HIV, which also degrades the immune system, results in premature death prior to diagnosis of AIDS.

The next step is to predict the extent of this phenomenon of HIV-related non-AIDS death. The Bruchmeyer-Gale procedure is applied to one component of AIDS data assuming one form of the incubation distribution--in this case one obtained from a cohort of English men who have been studied by Anderson and Medley. It has been suggested in the literature that the Weibel distribution, with a median of 8 years, is the best estimate of the form of the incubation period. The

San Francisco cohort satisfies this assumption. It should be noted, however, that only 48 percent of that cohort had progressed to AIDS. Presumably, those with the longer incubation period are undersampled in this process. The influence of AZT could also be a factor. Cooley said that he indeed used a Weibel distribution with a median of 8 years. It is a distribution that incorporates an increasing hazard. Out of this process was obtained the prevalence of those individuals who use drugs, eventually contract AIDS, and are then detected by the CDC.

The Bruchmeyer-Gale method was then applied with a different survival distribution. Two different distributions with two different means were used. First, for progression from infection to death, the Weibel with 8 years was used, with the argument that a shorter median is used when deaths occur before the deaths can result from AIDS. Second, Cooley chose to use an exponential model of survival distribution, with a mean of 6 years, to characterize a survival distribution with a different shape and a different mean. He then aggregated the prevalence components and obtained an estimate of total infection due to IV drug use. The study began with IV drug users from the AIDS data who are at risk for contracting AIDS. Working backward, one can obtain numbers of IV drug users infected with the virus. That portion of the IV-drug-using population that share needles runs the risk of contracting AIDS. As of January 1988, 380,000 IV-drug-use infections are projected, assuming the 2.1 adjustment and an 8-year Weibel distribution.

Discussion: Cooley reiterated the difficulty of modeling the AIDS epidemic with the lack of knowledge of the size of the gay male population. More is known about IV drug use and the behavior of the users. Newmeyer suggested utilizing the method differently among cities. In San Francisco, the IV drug of choice among gays is amphetamines. Des Jarlais said that many of the gay IV drug users are injecting heroin and sharing their equipment with heterosexuals. Cooley agreed that the AIDS epidemic should be modeled city by city. Charles Schade, NIDA, said that a large enough number of cases is needed to avoid instability in the Cooley approach, because it depends critically not on recent data but on the early course of the epidemic and on having sufficient numbers of AIDS cases recorded in 1982 and later. A member of the audience said that there was underreporting of AIDS cases in areas outside New York at the beginning of the epidemic.

Newmeyer suggested three methods of prevalence estimation. First, he suggested testing hair from the floors of barbershops as an indicator of recent drug use. Second, he suggested enlisting the retail suppliers of cocaine as researchers to gather information on how much is snorted and when and where. Third, he described an "unwatering hole" method of arriving at the aggregate use of cocaine in a city. The excretions from urinals or from the sewer systems of a city could be sampled. This would avoid the problems of confidentiality.

NOVEMBER 4, 1988

III. WORKING SESSIONS FOR EACH METHOD

Philip Cooley provided a recap of the previous day's discussions. He added that plans for the future should be discussed as an agenda item.

Dr. George Dunteman, RTI, gave a presentation on capture-recapture and provided handouts. He said that the problem with using treatment data is that inferences can be made only through the people susceptible to treatment. People die or go to jail and do not enter treatment. Therefore, "fudge" factors must be applied to account for the elusive part of the population. He also has concerns that the quality of the data may not justify the use of the more rigorous models. The mandate for his contract is to make prevalence estimates using currently available data. The problem with the capture-recapture model is that it represents only some of the incidence. Some assumptions must be made of the use rate. There is also the problem of arriving at a usable definition of "heroin user." Dunteman uses a definition that encompasses those whose primary drug is heroin and who arrived at treatment as a result of the use of heroin.

He has combined several data bases for information on treatment admission and has arrived at an estimate of 90,000 for the number of client admissions aggregated across the States. He adjusted the estimate up to 102,000 on the basis of other available data.

Discussion: In answer to a question, Dunteman said that TOPS is a program funded under NIDA to collect data on three cohorts of drug users entering federally funded drug abuse programs in 1979, 1980, and 1981 in a few metropolitan areas. Of these data, he used those applying to heroin users. He said that the treatment programs were typical: detoxification, outpatient drug-free, residential, and methadone aid. The data were not collected from a probability sample, but in most cases all the intakes for a period of 3 months were included. The goal was to review the treatment process and the outcomes longitudinally over a period of years, to study the degree of success of various subgroups progressing through the programs, and to compare treatment modalities. Anglin asked if the time coverage of the TOPS data is such that they can be placed in a semi-Markov state arrangement. Dunteman thought that perhaps they could but wondered how representative the treatment histories are with regard to trying to project them. He said that TOPS is a very comprehensive data base.

A member of the audience asked about possible assumptions on the absence of any constraints on the numerator or denominator on page 2 of the handout. Dunteman said that the lambda parameter (average number of treatments per year) for each year would have to be estimated. Lambda varies from community to community. Lambda was estimated by calculating an interarrival time between the TOPS admission and the

previous admission and taking the average. Another estimation of lambda was made by taking the interarrival times for less than 1 year and modeling them using the exponential by taking the ratio of the number of clients with an interarrival time less than one to the total number of clients in the sample. Wickens said that, since Dunteman is working from the distribution of the number of multiple entries, he could look at that distribution to ascertain whether he is catastrophically off on the Poisson distribution assumption. Dunteman said that he cannot get the number of treatments for the last year but can only determine whether a person has received one or more treatments. One way he estimated lambda was to add on the length of the treatment and take the interval from TOPS admission to admission to the previous treatment episode. The lambda used in the exponential function was 0.52, and the lambda obtained using the inverse of the interarrival time was 0.44. The "average" approach does not make any distributional assumptions, whereas the exponential approach makes the assumption that the interarrival times have an exponential distribution. Dunteman said that, if the total number of client admissions and the average number of admissions per client per year are known nationally, one can derive the estimate of the number of treatments in the susceptible population. He said that Woodward has used the incomplete Poisson to estimate the size of the population of criminals involved with illegal drug activities using the two sufficient statistics: the number of arrests in a time period and the number of arrestees. Anglin said that, in capture-recapture, a population needs to be sampled twice and that the individual treatment histories do not matter. The relationship of the sample to the population gives the parameter, but an individual, unique identifier is needed to connect people at time 1 and time 2. In the truncated Poisson, there is a sample whose treatment history is needed. For example, if the number of passengers in cars on a freeway is counted, with a truncated Poisson one tries to find the number of cars with no passengers. Anglin said that he feels that the truncated Poisson needs an intake of questions on treatment history. Mendelson said that few States would have a client tracking system in place for this kind of analysis, but, for a truncated Poisson, a large number of States would ask about prior treatment experience at admission. Brodsky said that the lambda is a rate and that, to ask for history of prior treatment, the underlying duration dividing the sequence of events must be known for the calculation of lambda. He added that, in the CODAP data, the frequency distribution of the length of time in treatment and between treatments is an apparent truncation effect at the minimum and the maximum time.

Schmeidler said that most treatments in New York use methadone and, as a result, are long term, whereas a patient may move in and out of a detoxification program many times in a year. Wickens said that, since inter-entry times are the sum of the treatment time and the time until reentry, the treatment distribution ought to be estimable from other sources, and that an exponential Poisson model might be used for the discharge-to-reentry time that could be convolved with a known

distribution. Newmeyer said that one needs to know if there are two different populations.

Dr. Wickens gave a review and clarification of the discussion of his estimation techniques. He said that the assumptions of the Jolly-Seber model were violated to an extent. He said that any method will apply only to the population from which the multiple capture derives. There can be no extrapolation beyond that population without the use of "fudge" factors. In process models, there is always a danger of ramifying the process by adding states. Hence, the model can deteriorate or the estimated probabilities can have an unacceptably high standard error. Therefore, Wickens prefers to keep the models as simple as possible.

(In a discussion of the FBI data, it was established that there are two data bases, both of which may be susceptible to capture-recapture techniques or to the use of the truncated Poisson. The data bases respectively contain individual histories and information on the population from which the individuals come. The data bases allow linkage across time periods by individual identifier numbers.)

Any treatment history can be separated into three parts: the portion before the first capture, the interval of the first capture, and the portion subsequent to the first capture. The basic notion is to model the three portions separately. The first portion is represented by a series of multiplicative terms. The second portion, the sampling, is represented by a simple Bernoulli variable. The third portion is represented by a simple Markov model. In answer to a question, Wickens said that ϕ_i is not a probability, because the population may be increasing or decreasing at any one time. He added that the size of a population may not change, but the individuals may change. The definition of a user in treatment is critical and depends on the specific data. Wickens has been using CALDADS data, and therefore his definition of a "treatment" is a person in one of the programs reporting to CALDADS, and a "user" is one who is engaging in behavior placing him at risk of being captured by this treatment program.

Discussion: Newmeyer said that there are ongoing changes in the treatment modalities for cocaine users and that this could change the underlying orientation to treatment. In California, there is also an increasing use of pseudonyms. Wickens said that changes will be reflected in inhomogeneities in the parameters and that he hopes to accommodate these changes. Gropper said that there are good estimates of the prevalence of drug positives among arrestees but that he does not know what percentage of drug users are criminally active. The definition of criminal activity is important. Shreckengost said that a study has been made of the relationship between the incidence of three different kinds of crime and the abundance of heroin over a period of 10 years, resulting in a very tight fit.

Synthetic Estimation

Dr. Anglin opened the segment on synthetic estimation by saying that there are two techniques: the extrapolation from one survey data base to a different sample or a larger population and the factor analytic method.

Dr. Cooley introduced the method by saying that, historically, in the heroin area, it has had two components: the index itself and the way the index is linked to prevalence. Constructing the index and assessing how the various components should be incorporated to produce a measure that records changes in prevalence has required some sophistication. The linkage between the index and prevalence is then established and is the point of change between a dimensionless quantity and an absolute quantity that is prevalence. Historically, this is based on best guesses or numbers provided by the States. The construction of the index has utilized far more sophisticated procedures than the actual construction of the anchor points. Cooley feels that synthetic estimation is right for the marriage of several techniques. The only area that has seroprevalence values that are close to reality is the area of drug treatment. NIDA has a 16-city seroprevalence survey. If, in a subset of these cities, one could obtain accurate AIDS data and work backward through the acceptable incubation distributions, HIV prevalence could be developed for the cities, and there would be independent estimates of the IV-drug-using population. This could be linked to the index and could then be used to monitor changes in the index.

Dr. David Hamill, RTI, opened his presentation by outlining the problems to be solved: 1) Choosing prevalence estimates for anchor areas, 2) choosing indicator variables, and 3) choosing the regression model. His group has been using the standard metropolitan statistical areas (SMSAs) as the geographical units, and the anchor cities are Chicago and New York. The quality of the estimates varies from anchor to anchor. In fitting functions, it is nice to have more points, but every added anchor estimate is less reliable than the previous one. The estimates are from the SADAP report.

Hamill started with five possible indicators: emergency room mentions of heroin involvement; medical examiner reports of heroin involvement; treatment admissions where heroin was the primary drug; price of heroin; and purity of heroin. Requirements for the inclusion of indicators are data availability and monotonicity. Indicators must also be monotonically increasing or monotonically decreasing functions of heroin prevalence. Price and purity data are unlikely to satisfy the monotonicity requirement and present difficulties in interpretation. Size of buys and confiscations affect price and purity. Treatment admissions may not satisfy monotonicity. CODAP data on admissions are no longer available. Emergency room and medical examiner data are available from DAWN. Both are probably monotonically

related to heroin prevalence and hence are used in Hamill's application.

Discussion: Anglin said that other plausible variables are arrests or admissions to State hospitals. Hamill added that another possible indicator is the toxicology examination given by medical examiners, i.e., the autopsy becomes the watering hole. Brodsky said that these systems are real over time, and, if the possibility is considered that the locus of prevalence is being tracked over time, the part of the nonmonotonic function that is operating could then be determined. Hamill said that, when a predictor equation is obtained, one cannot take the intercept value to be used as the value for all SMSAs that have no emergency room admissions. He added that it is important to know what kind of users are found in a particular situation, because there is a distribution of behaviors or use patterns, such as the use of a different kind of drug. The simplest assumption is that all users are alike and that there are no changes over time in the drugs used. A second approach is to assume that there is no difference in distributions of types of users across States or time.

Hamill continued to discuss the inclusion of the indicators in the model. He uses two points, which can only be fitted to a straight line. This is one reason that there is a tendency to use linear combinations derived as a single independent variable. One approach has been to use factor or principle components analysis to arrive at weight for the linear combination and to assume that there is an unmeasurable driving variable pushing the other variables. This approach to Hamill's two variables gives a choice of using standardized or unstandardized variables. If two variables are standardized, they result in equal weight. One possible model uses the sum of the two variables. A second approach computes weights based on unstandardized variables, resulting in the heavy weighting of the variable with a large variance. A third approach, the logical combination, is based on the idea of relative risk. Each user in a community has a probability of arriving at an emergency room or at the medical examiner and being reported. The ratio of these two risks can be estimated by the ratio of the events, because they have the same denominator. The ratio of emergency room mentions to medical examiner reports gives an estimate of their relative risk. This ratio can be used as a weight. If the probability of a user arriving at an emergency room is 1 percent, each emergency room report indicates the presence of 100 users. If the probability of the user's dying is 1 in 300, then each medical examiner's report indicates the presence of 300 users. For this risk ratio to be constant over the entire range of prevalence values, there must be similar probabilities of reporting and homogeneity in the distribution of user types, either of which might be untrue. The next question is what kind of function to fit.

Anglin suggested another scenario. The use of a new form of a drug in a population not used to titrating it can result in a change in death rates and emergency room admissions from overdoses without any

increased prevalence. He said there is a conflict between ethnographers and emergency room indicators. There is a pervading belief that the cohort of heroin addicts is aging and that prevalence is declining. The indicators, however, indicate an increase in many areas. Hamill said that the users exhibiting particularly risky behavior tend to drop out of the population, leaving a population that on the average practices less risky behavior.

Dr. Gropper announced that a data center and clearinghouse for drug and crime data has been established at the Bureau of Justice Statistics. There are three functions: centralized acquisitions, storage, and dissemination; future analyses; and coordination among ADAMHA, NIJ, and the criminal justice system.

Rick Harwood, NAS, spoke on a system dynamics model. He said that simulation of the heroin-using population (heroin prevalence) is a wonderful framework for integration. It is an opportunity to formulate a comprehensive theory for identifying the major elements in a system such as criminal justice or treatment in the heroin system. There is an attempt to identify the causal relationships among the major elements and to quantify them. The output of the model is testable by comparison with reality. His group, under an RTI contract, was charged with extending over time a model developed by Shreckengost and Gardner to bring it up to date, to look at the performance of the model, and to extend it conceptually.

This simple model uses the basic data available on a systematic basis for its evaluation. Two data elements are needed per year to generate projections: the size of the susceptible population (the number of individuals aged 14 through 34 years) and the estimate of heroin imports generated over time by the National Narcotics Intelligence Consumers Committee (NNICC). Predictions can therefore be derived from this model for the various elements contained in the validation part of it. The validation elements are the number of drug overdose deaths, the observed purity of heroin that is sold at retail, and the observed price of the heroin sold at retail. NNICC estimates that heroin imports increased about 15 percent between 1982 and 1983. (NNICC generates its estimate of heroin imports by taking prevalence estimates that are generated by synthetic estimates or capture-recapture models.) The model predicted that prevalence should increase 2 percent and that purity should increase. It was observed that purity decreased in 1983. The model predicted a decrease in price, but price remained constant from 1 year to the next. The model predicted an increase in mortality, but DAWN data showed a decrease followed by an increase.

Over a 10-year period, the model was successful in tracking trends in terms of understanding the phenomena and calibrating the coefficients to make predictions to corroborate observed values. The charge, however, was to look at heroin prevalence. The curve for the susceptible population rises gently and then levels off. Prevalence, as predicted by the model, increased from 415,000 to 460,000 in

2¼ years, followed by minimal fluctuation over an 8- to 10-year period. Harwood feels that the actual prevalence is lower by a factor of 2 or 3 but that the model can represent trends in the addict population.

Heroin users appear to modify their consumption of heroin significantly in response to price changes. If price rises by 10 percent, their consumption falls by 16 percent. There has been a policy and public misconception that heroin addicts will not vary in their daily consumption. They are, however, price sensitive.

Extension of the model could be made to consumption by nonaddicts and to cohort effects. Also, in this model, supply is exogenous; it drives the model. Harwood would like to see the model allow the heroin supplier to react to the availability of heroin over time. For policy purposes, components need to be added to the model that could represent the effectiveness of supply reduction. Reaction to AIDS also needs to be incorporated.

Discussion: Gropper said that there is an implication that no increase in purity, a small increase in prevalence, and an increase in imports mean that a typical user increased his consumption by 10 or 11 percent. Harwood agreed. Shreckengost said that prediction and reality often move in opposite directions because of the "floppiness" of the data and the delay in the reporting of the data.

Gropper asked how crime could be modeled as a feedback loop. Harwood feels that crime is the driving force behind the concern about heroin. Future models should incorporate not only criminal activity but also the number of people warehoused in prisons. This has increased significantly in the last 15 years, and many of those imprisoned have histories of drug problems. He said that $8 million is a rough estimate of the street value of heroin consumed in 1 year and that the money to buy it is derived primarily from crime. Shreckengost said that there are indications that perhaps a substantial portion of heroin users are weekend users and hold regular jobs. Harwood reminded the audience that the model is circular and that the number of addicts is predicted based on an estimate of the number of addicts.

Dr. Homer gave a review of his approach to system dynamics. The sequence of events in the process is as follows: Gathering of relevant data; identifying the significant flows and accumulation; formulating a set of equations; comparing the model's behavior with historical evidence; and performing a "what if" analysis. He described the evolution of a deer population as an illustration of how his models are built and the application of the two principles of system dynamics: the accounting or accumulation principle and the feedback principle.

The ecosystem on a plateau in 1900 (an interplay among a few thousand deer, their natural predators, and the grasslands on which they all fed) was stable. There was, however, an increasing reliance on

ranching, and the cattle were being killed by the same predators that killed the deer. After a bounty was put on a fraction of the predators around 1907, there was a decrease in their number. The natural balance was disturbed, allowing the deer population to increase. By 1917, there were signs that the grasslands were reduced to a dangerous point. The deer population continued to rise until 1923, when suddenly it began to decline as a result of starvation. They had destroyed the grasslands. Homer will model this scenario with a simple system dynamics model that may or may not work.

The deer population is seen as an accumulation. In system dynamics, it increases because of births and decreases because of deaths: $DP_t = DP_{t-dt} + dt(\text{births} - \text{deaths})$. As dt goes to zero, deer population $= \int (\text{births} - \text{deaths})$. The birth and death rates will affect the numbers of births and deaths per year. There are both natural and predator-caused deaths taking place. The incidence rate (number of births per year) will equal the birth rate times the population. Deaths will equal the population times the natural death rate. The food supply will also be included in the system. Predator kills are a source of death and an exogenous, driving function. If the deer population becomes sparse, it becomes harder for a predator to find a deer. The explosion in the deer population results from a decrease in the number of predator kills. Initially, births and deaths are equal, there is little net change, and equilibrium exists in the deer population. There is a positive loop, a self-sustaining cycle, and there can be an exponential increase in population if there is no counterbalancing outflow. Deaths equal predator kills plus natural deaths, which must be specified.

Another aspect of system dynamics is the ability to specify nonlinear functions, which are a real part of the system in which events may be stable and then triggered by new factors. The amount of food per deer is an important determinant of the health of the deer. Nonlinearity exists in the system, because it does not matter how much food is available beyond some minimum daily requirement. Only when food per deer drops beyond some critical point will there be an effect on deaths. Every assumption must be buttressed by a careful argument. Macroassumptions should be built from the microbehavioral data available, thus fostering greater confidence in the model. This model cannot, however, anticipate a radically new kind of behavior. Food supply is being decimated, and this is not represented in the model, which assumes a constant food supply. The model, however, can be helpful in generating policy involving predator reintroduction, deer harvesting, or fertilizing.

Discussion: Brodsky suggested using a monitoring system at the transaction level to determine the reliability of the nonlinear function. He also said that the problem with the drug abuse issue is that man has made discoveries about drugs that have changed the psychotropic functioning of day-to-day life of human beings. Anglin observed that even the simple deer system takes 50 years to evolve

through all its ramifications. Harwood suggested modeling fruit flies. Gropper asked if a nondriving factor that indicates the size of the population could be included in the system. Homer said that indicators could be hung on the model or that one could use the Richardson and Sterman approach to the estimation of petroleum reserves. The estimation process could be built into the model.

Homer said that an interesting approach would be to take the model's output and put it through a decision-analytic evaluation and compare policies on this basis.

Brodsky observed that there is probably a greater morphological similarity between the structure and operation of the human brain and the structure and operation of human society than between the structure of statistical systems and their decision outcomes.

Dr. Cooley concluded the meeting by suggesting that plans be made for a possible monograph based on this meeting and a future meeting, summarizing points put to practical use in the refinements of current models. After an observation by Brodsky that face-to-face rather than written communication is superior, Anglin suggested that a meeting 2 months before the end of contracts would be useful. He hopes that the product of a future meeting might be a joint monograph composed of three sections: general issues in prevalence estimation; specific applications to drug abuse; and placement of the subject in context.