ESTIMATING THE NUMBERS OF HEROIN USERS IN THE ACT

Ann Larson PhD

Feasibility Research into the Controlled Availability of Opioids Stage 2
Working Paper Number 1

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FOREWORD

Gabriele Bammer

Feasibility Research into the Controlled Availability of Opioids

The Feasibility Research into the Controlled Availability of Opioids arose from a request to the National Centre for Epidemiology and Population Health (NCEPH) from the Select Committee on HIV, Illegal Drugs and Prostitution established by the Australian Capital Territory (ACT) Legislative Assembly.

A first stage of research, conducted in collaboration with the Australian Institute of Criminology (AIC), found that a trial to provide opioids, including heroin, to dependent users was feasible in principle. It was recommended that a second stage of feasibility investigations to examine logistic issues be conducted (National Centre for Epidemiology and Population Health, 1991a).

The first stage investigations examined illegal drug use in the ACT, the arguments for and against the controlled availability of opioids as reviewed in the literature, the current Australian political context for a trial, the role of interest groups in social controversies, legal issues, possible options for a trial, ethical issues, attitudes to a trial in the general community and among key interest groups (police, service providers, and illegal drug users and ex–users), and evaluation by a randomised controlled trial (National Centre for Epidemiology and Population Health, 1991b).

In addition, a proposal for a trial was developed as the starting point for the Stage 2 investigations.

The research which needs to be conducted to determine Stage 2 logistic feasibility can be divided into five areas:

- core information (e.g. estimating numbers of users, determining relevant characteristics of ACT–based users, documenting the known information about the psychopharmacological and toxicological effects of opioids)
- information relevant to trial design and evaluation
- information relevant to service provision
- information about relevant legal, law enforcement and criminological matters
- community and key stakeholder acceptability of a specific trial proposal.

Thus, Stage 2 of the feasibility research into the controlled availability of opioids has many components. As significant advances are made in each particular substudy, we plan to publish the results as a working paper, so that the information is available for discussion in the public arena.

Estimating the Numbers of Heroin Users in the ACT

This piece of research on estimating the numbers of heroin users in the ACT is a significant addition to the estimates that were derived in Stage 1 (Stevens et al.,1991). In this working paper Ann Larson discusses the need to carefully define what it is that is being estimated and the advantages and disadvantages of various methods.

During Stage 1 the following estimates were derived:

a) 1000 dependent heroin users from a personal estimate made in 1986 by the Director of the Alcohol and Drug Service at the (then) Woden Valley Hospital.

b) 72 dependent heroin users and 720 heroin users in all from a multiplier based on the number of marijuana users aged between 15 and 30. This was the method favoured by the Cleeland Report (Parliamentary Joint Committee on the National Crime Authority, 1989). This is likely to be an underestimate.

c) 1100 to 1900 dependent heroin users and 3300 to 7600 heroin users in all, using the 'treatment multiplier' derived by Hartnoll and coworkers in the United Kingdom (1985) and based on the number of people in treatment from figures provided by the ACT Drug Indicators Project.

Ann Larson has used more refined techniques to add the following estimates:

d) 464 people who had used heroin at least once in the last 12 months, with a lower bound of –11 and an upper bound of 940. This is based on estimates from the 1988 population survey conducted by the National Campaign Against Drug Abuse.

e) about 1000 people who see their heroin use as a 'problem' (with a standard deviation of around 200). This is derived from list matching techniques (also known as capture–recapture or indicator/dilution) using data from the ACT Drug Indicators Project.

While there are significant problems with each of these techniques, the best of these estimates suggest that there may be around 1000 dependent heroin users in the ACT.

Further refinement of these estimates is now dependent on fieldwork. We have two studies planned and one underway. The study we are currently conducting (in collaboration with the Youth Affairs Network of the ACT) is with users younger than 18 years who are either homeless or at risk of being homeless. From this we will be able to calculate a minimum number of dependent heroin users in this age group. The conduct of the two planned studies is dependent on gaining funding through the normal competitive peer–reviewed channels. One of these studies focusses on users aged 18 or older and one focusses specifically on Aboriginal users. At the very least, we will be able to calculate the minimum number of dependent heroin users in each of these groups. We also plan to use the nomination technique to derive a multiplier, although its value will depend on the sample size and characteristics.

An accurate estimate of the number of heroin users in the ACT is essential for determining the feasibility of a trial. Not only does it indicate whether or not the extent of the problem warrants a trial, but it is also vital for establishing the feasibility of proposed trial evaluation techniques.

The current estimate of around 1000 dependent heroin users suggests that a trial is warranted and that evaluation through a randomised controlled trial is feasible. It would, however, be prudent to develop more refined estimates through fieldwork before finally determining feasibility.

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ESTIMATING THE NUMBERS OF HEROIN USERS IN THE ACT

Ann Larson PhD

Introduction

Knowing the number of heroin users in the ACT is essential for planning, monitoring and evaluating a trial to provide opioids to dependent users in a controlled fashion. Anticipating the number of users who will want to participate in a trial, putting the number of trial participants in the context of the entire heroin–using population, monitoring changes in the ACT's heroin using population, and targeting the various subgroups of the heroin–using population are a few of the many demands for accurate numbers.

This exercise is unique among the sizeable Australian and international literature on estimating the number of heroin users, because the estimates are being derived for a specific purpose. As Peter Reuter (1984, 147) concluded after reviewing the methodologies and data behind widely cited American estimates, "the quality of official data is largely a function of its importance to those who use it. The actual size of the heroin addict population and of drug market incomes is simply not important either to the agencies that prepare the estimates or to any other organized group. Numbers without purpose are numbers without quality." In order to determine whether or not a trial is feasible, the team conducting Stage 2 needs to know how many dependent heroin users there are in the ACT. Furthermore, should the trial proceed, shortcomings of the estimates will be immediately apparent.

This paper discusses the popular and most promising approaches to estimating numbers of heroin users and makes specific suggestions for further work. It is intended to be a practical document and is therefore quite detailed. Estimation techniques and data sources are not only described, but critically examined for their potential for producing valid, reliable, precise estimates. Where data are available, population estimates have been derived. However, general issues regarding estimating the size of hidden populations will be discussed before detailing specific techniques.

Selecting a population

Population estimates must be based on a precise definition of the population to be measured. The entire heroin–using population consists of many intersecting subgroups – some easier to measure than others, some more relevant for certain policy issues than for others. This section discusses the feasibility and desirability of studying various sub–populations which could be of interest.

• ALL PERSONS WHO INJECT ILLICIT DRUGS. The possible spread of HIV through the injecting drug using (IDU) population has engendered reconsideration of illicit drug use policies. If the trial is seen as a partial effort towards curbing the spread of HIV, then it will have to consider what proportion of the total IDU population use heroin and what other drugs heroin users inject.

• ALL PERSONS WHO USE HEROIN. It is now widely understood that many, perhaps most, people who use heroin, use it in a social setting and in a controlled manner; heroin use may not be an overriding factor in their lives. These users rarely approach treatment agencies and do not come into contact with law enforcement agencies. They are, however, heroin users and their injection practices may put them at risk of HIV infection.[1]

For 'all users' to be a meaningful definition, it needs a time reference. People who last used at the Opera House, New Year's Eve, 1979 are not relevant for current drug policy. Practical definitions could be those who have used in the previous twelve months, six months or past week. Short intervals have the advantage of ensuring that one is discussing current users, but may also disqualify regular users who use less frequently and users voluntarily or involuntarily going through a period of abstinence.

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[1] Suggested eligibility criteria for a heroin trial have not been finalized, however nondependent users would probably be ineligible.

•DEPENDENT USERS. Dependence is hard to define so that, coupled with the illegality of heroin use, this population is extremely difficult to measure. For the feasibility research the working definition is that dependent users are "those who are frequent regular users of a drug and who, in the case of heroin, generally use daily and exhibit neuroadaptation to the drug" (Stevens et al., 1991). Data from treatment and law enforcement agencies are frequently used to estimate the size of this population, however it is widely believed that only a subset of dependent heroin users have contact with these institutions at any one time. Surveys of the general population are an inadequate way to measure the proportion of dependent users for a range of reasons which are discussed later. Studies on the size and characteristics of dependent user populations usually enlist the help of known users to learn about the hidden population of users. In Australia, techniques such as participant observation (Dance, 1991), establishing store fronts (Dobinson and Poletti, 1989), samples generated by 'snowballing' (Watson 1991), and 'small world' methodologies (Saunders et al., 1991), have been used successfully to gain an understanding of the characteristics of all dependent users instead of those easily captured through treatment agencies or the police. The section of this paper on the multiplier method discusses how information garnered from a wide cross–section of dependent users can be used to generate estimates of the total number of dependent users.

The problem with these excellent methods is that they require an enormous amount of time and labour. Not all research questions about heroin users require information on the entire population of dependent heroin users. Before proceeding with designing studies which measure the entire group, it is worth considering whether or not it would be sufficient to measure only those users who make themselves known to treatment agencies, law enforcement and other authorities.

•'PROBLEM' USERS. The population of heroin users who define their heroin use as a problem or whom authorities define as having or creating a 'problem' is more amenable to measurement. For example, 'problem' users can be defined as heroin users who have come into contact with the police or hospitals or who seek treatment for their 'problem'. This definition, however, may not be relevant for the trial. At present, it is not clear whether or not a trial would admit persons referred by the courts, although this is one of the issues which Stage 2 will address.

•USERS PARTICIPATING IN TREATMENT PROGRAMS. This population is one of the most feasible to measure because alcohol and other drug services in the ACT kept comprehensive and comparable data in 1988 and 1989 under an ACT Drug Indicators Project. It is also an appropriate population to measure. One objective of a trial is its ability to attract users who would not otherwise seek treatment services. It would be relatively simple to compare the number and characteristics of the current population seeking treatment with those who present themselves for a trial. If the trial attracted more users and/or users with different characteristics it would have met that objective.

Assessing validity and reliability of the estimate

Another issue in estimating numbers of users is validity and reliability. The issue of validity is much the same as selecting the appropriate population. Estimates invariably refer to a specific population and are not valid as an estimate of another population.

Reliability of estimates is another basic criterion of a good estimate. One test of reliability is the repeatability of estimates. Estimates from the same data source for different years should be roughly the same. Reliable estimates are also consistent with expected population size. For example, an estimate of the number of all 'dependent' users should be larger than the estimate of dependent users in treatment. Another test of a reliable estimate is whether it is similar to estimates and guesstimates derived from other sources and with other techniques. Replicating a result with several approaches is known as triangulation and has become almost a tradition in the estimators–of–heroin–users fraternity (eg. Hartnoll et al., 1985; Newmayer, 1988; Drucker and Vermund, 1989).

An estimate can be valid and reliable but not very precise. Similarly, what is an acceptable level of precision for one purpose may not be suitable for another. For example, it should be possible to derive an estimate or series of estimates sufficiently precise to determine the population pool for a trial. However, it may not be possible to derive an estimate which can detect small changes in the size of the dependent user population over time. All estimates should be presented with a confidence interval so that evaluators and managers know before the program begins how much the underlying population would have to change before the change would be evident from the estimate.

Estimation techniques

The remainder of the paper will be a review of techniques which could be used to estimate the number of heroin users in the ACT. Where data are available, the techniques are used to derive estimates. The first method discussed is the population–based household survey. The usefulness of national surveys is considered and possible designs for an ACT survey are explored. The following section addresses a variety of estimation techniques known as capture–recapture. These have been developed by population biologists interested in the size of animal populations but are increasingly being used to estimate 'hidden' groups of people. Using a unique ACT data set, the number of heroin users is estimated with capture–recapture methods. The final section explains the multiplier method and explores various ways of generating the data required.

Direct estimates from population–based surveys

The conventional method of estimating the size of a subgroup is a population based survey in which a representative sample of the entire population is interviewed. The proportion of the respondents falling into that subgroup equals the proportion of the total population which belongs to the subgroup. Household surveys are a tried and true method of measuring groups relevant for social programs: groups such as users of modern contraceptives, unemployed persons, or crime victims.

However, despite their common use for estimating the number of illicit drug users in general and heroin users in particular, major sources of potential bias must be recognised (Johnston, 1989; McAllister et al., 1991). Heroin use is rare and not condoned by the general population. People who have used are assumed to be reluctant to reveal their experience with the drug. Even if respondents are convinced that their responses will be treated confidentially and therefore give honest answers, there is the additional problem of biased samples. Another potential source of bias is that a sizeable proportion of dependent users do not live a lifestyle which makes them easy to capture in household surveys. Many have no fixed address, are institutionalized, live in homes without phones and/or rarely keep appointments. Furthermore, these biases are likely to affect estimates of current users more than estimates of people who have ever used and it is the number of current users which is relevant for effective program design.

Three national surveys have been conducted in recent years to assess Australians' level of alcohol and other drug use and to evaluate the effectiveness of the government's campaign against licit and illicit drug abuse. Commissioned by the National Campaign Against Drug Abuse (NCADA), the 1985, 1988 and 1991 surveys asked a nationally representative sample of adults aged 14 years and over about their use of alcohol, tobacco and illicit drugs including heroin. This paper will review the three surveys' findings on heroin use and discuss the value of using them to estimate the national and ACT heroin–using populations. Lastly, possible designs for a household survey in the ACT which could produce reliable estimates of the heroin–using population are explored. Throughout the discussion the reader should keep in mind not only the technical problems of reliably estimating the proportion of heroin users in the general population – eg. sample sizes and confidence intervals – but also whether a general population survey could be expected to produce valid results on heroin use.

Results from the national surveys

In the 1985 NCADA survey, 45 out of 2791 respondents (1.6 per cent) aged 14 and over reported that they had tried heroin. They were not asked when they had last used. The 1988 NCADA survey found a similar level of ever use of heroin. Only 22 respondents or 1.2 per cent of 1827 persons interviewed said that they had tried heroin. In the recent 1991 NCADA survey the percentage who had ever used heroin was 1.7 out of 2483 respondents.[2] A negligible number of respondents, only 3 (0.2 per cent) in 1988 and 8 (0.3 per cent) in 1991, reported heroin use in the past 12 months. Similar levels of heroin use amongst the general population have been recorded in surveys from the United States (McAllister et al., 1991,123).

Validity

[2] All three NCADA surveys over–sampled respondents under age 20 years but distinguished between their 'random' sample and an 'over–sample' of teenagers. For total population estimates the over–sample was excluded. In 1985 and 1991 residents of smaller states and territories were over–sampled. The numbers and percentages reported in this document are from the unweighted sample. However, weighting had no effect on the percentage reporting they had ever used heroin. On another methodological fine point, all of the surveys had some respondents who did not answer the question on heroin use: 38 respondents in 1985, 8 in 1988 and 4 in 1991. These respondents have been included in the sample. Eliminating them or distributing them equally between the user and nonuser groups does not change the percentage of the sample reporting heroin use.

Several efforts were made to encourage respondents to answer honestly. In 1988 and 1991 respondents used a coded response form to answer questions on licit and illicit drug use. Interviewers did not know the answer the respondent was giving. By giving the respondents confidence that their answers were anonymous, this technique appeared to reduce the number of refusals and resulted in consistent answers.[3]

As with other surveys, there are few ways of detecting the respondents who are deliberately giving false answers. However, the 1988 survey tried by asking respondents if they had used a fictitious drug which they called Quadranines; 16 respondents said they had tried it. Although 12 of those respondents said they had never used heroin, four said they had, which throws doubt on whether they had indeed ever used heroin. If these four are discarded, we are left with only 18 respondents in 1988 reporting that they had ever used heroin and only two who say they last used within the past 12 months. These results can be interpreted in two ways. On the positive side, most (18 out of 22) respondents who said that they had tried heroin gave a credible answer regarding Quadranines. On the other hand, with such small numbers even a minority of unreliable answers can threaten the validity of the results. Then again, both interpretations may be wrong. Polydrug users may not know the name, or the formal name, of every drug they have tried. Respondents with an extensive drug–taking history may genuinely believe that if a drug was common enough to be included on a list in a survey, then they have probably taken it.

Precision

The first question is whether there is a significant difference in the estimates of ever use from the 1985, 1988 and 1991 NCADA surveys. The following calculates the test statistic for a difference in proportions found in 1985 (0.016) and 1988 (0.012). In this exercise we are assuming that a simple random sample of the Australian population was drawn. The estimates are probably much less precise because the sample would have been generated by selecting clusters first.

Difference in proportions:	p(85) - p(88)=	0.004
Pooled standard error:	se(p(85) - p(88))=	0.003630
Test statistic:	(Difference/pooled se)=	1.101851

The test statistic implies that there is no significant difference between the two survey results at the 95 per cent level of confidence.

The same is true of the difference between the 1988 and 1991 surveys:

Difference in proportions:	p(91) - p(88)=	0.005
Pooled standard error:	se(p(91) - p(88))=	0.003756
Test statistic:	(Difference/pooled se)=	1.331030

An alternative way of answering the same question is to calculate the 95 per cent confidence interval around the 1985, 1988 and 1991 survey estimates to see if they overlap. The 95 per cent confidence interval for the 1985 NCADA survey is 0.016 +/- 0.0047 or an upper bound of 0.0207 and a lower bound of 0.0113. The 95 per cent confidence interval for the 1988 NCADA survey estimate of the proportion of ever users in the general population is 0.012 +/- 0.005 or an upper bound of 0.0170 and a lower bound of 0.0070. Finally, the 95 per cent confidence interval for the 1991 survey is 0.017 +/- 0.0051 or an upper bound of 0.0211 and a lower bound of 0.0109. In brief, all three surveys found that ever use of heroin stayed at the same, very low level from 1985 to 1991. This is one confirmation of the ability of household surveys to measure heroin use reliably. Of course, if the prevalence of heroin use has actually changed from 1985 to 1991 then these reliable results will be quite invalid. This cannot be judged from the survey data alone. As will be shown, reliability does not mean that the results can be used to generate precise population estimates. However, it does indicate that household surveys can provide stable measures of the relative magnitude of ever use of various drugs in the general population.

Population Estimates

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[3] In 1988 respondents were actually asked twice about drug use. One method, the coded responses, has already been described. The second method was a standard questionnaire in which the respondent answered the interviewer's questions directly. In 1988 half of the respondents were given the self–administered questionnaire before being asked the same questions by an interviewer and half filled in the self administered questionnaire afterwards. The order did not affect the responses. In 1991 only the self–administered questionnaire was given. The data from 1988 cited here are from the responses to the self-administered questionnaire.

The second question is whether the NCADA survey can be used to estimate the number of heroin users. Since there is little policy relevance in knowing the number of people who are no longer users, this estimate is restricted to people who have used recently. As mentioned above, in the 1988 NCADA survey only three respondents or 0.2 per cent of the sample reported using in the previous 12 months. The 95 per cent confidence interval on that proportion is +/- 0.2 per cent or an upper bound of 0.4 per cent and a lower bound of 0.0 per cent. The 1991 estimate is 0.3 per cent with an upper bound of 0.5 per cent and a lower bound of 0.1 per cent. Although the estimates for the proportion of current users are also stable from survey to survey, the confidence intervals are fairly large – almost twice the size of the point estimate.

According to preliminary estimates by the Australian Bureau of Statistics for 30 June 1991, the Australian population 14 years plus was 13,808,770 (ABS, 1991). Applying the 1988 NCADA proportion of adults who have used heroin in the last 12 months results in an estimated 27,618 users, with a confidence interval of -672 to 55,907.

It may be coincidental, but the estimate of the number of persons who have used heroin in the past 12 months derived from the NCADA survey is quite similar to the estimate produced by the Parliamentary Joint Committee on the National Crime Authority (The Cleeland Report, 1989). The committee based their estimates on a survey of regular marijuana users aged 15–30. The 4.5 per cent of respondents who said they had used heroin in the past twelve months was used as the basis of estimating 33,600 recent heroin users (ca. late 1980s).

Applying the 1988 results to the ACT population also produces a range of estimates which seems unacceptably wide if one actually needed to know how many users there were rather than the proportion of users in the population. Given a 1991 ACT population of age 14 years and over of 232,223 (ABS, 1991), the estimate of ever users would be 2,787 with an upper bound of 3,945 and a lower bound of 1,628. The number of adults who used heroin at least once in the past 12 months would be expected to be 464 with an upper bound of 940 and a lower bound of -11.

Alternative sampling designs for the ACT

In the section above the ACT heroin using population was estimated from proportions based on the national population. National surveys are usually inadequate for local estimates. The ACT is a small area comprising less than two per cent of the Australian population. Even when small states/territories are oversampled, as they were in the 1985 and 1991 NCADA surveys, very few respondents come from the ACT. The 1985 survey had 203 ACT respondents, the 1988 survey only 24 and the 1991 survey had 156.

The ACT, with its higher average income and educational levels, better school retention rates and lower adult unemployment is certainly not like the rest of Australia. On an individual level these factors are related to heroin use; a heroin user is more likely to have not completed school, be unemployed, and to have a low income (McAllister et al., 1991). It could be hypothesized that the proportion of heroin users in the ACT would be equal to the national rate standardized to reflect these differences in the ACT population. For example, among the unemployed the heroin rate in the ACT and the nation as a whole would be assumed to be the same, but the heroin use rates for the employed and unemployed would be weighted by the lower proportion of unemployed adults in the ACT.[4]

Standardizing to estimate ACT rates could be an interesting exercise. However, there are reasons to believe that it may produce inaccurate estimates of the ACT's population of heroin users. The ACT's drug use culture may be quite different from those of rest of Australia resulting in different types of people using heroin. Support for this hypothesis is found in the ACT Schools Survey on drug use among high school students. Despite the ACT's unique schooling system and student population, the ACT schools survey found that ACT students were as likely to have used licit and illicit drugs as New South Wales and South Australian students asked in comparable surveys (ACT Board of Health, 1991).

Clearly, if one's principal interest is in the level of drug use in a particular area, national survey results (standardized or unstandardized) are an inadequate substitute for a household survey of the local area.

The question is, if there were resources available to conduct a local survey, how big a sample would be needed to estimate the number of adults in the ACT who have used heroin in the past 12 months with an accuracy of plus or minus 500 users?[5] To answer this we estimate that a household survey would find that 0.5 per cent of the population reported

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[4] Direct standardization is a useful technique frequently used by demographers. For more information see any demographic methods textbook, such as Pollard, Yusuf and Pollard (1974).

[5] A leading service provider has estimated that there are 1000 dependent heroin users in the ACT (Stevens et al., 1991). Survey results which were not accurate within 500 users in either direction would not be useful.

using heroin in the past 12 months. Five hundred users amounts to 0.2 per cent of the ACT's adult population. In other words, 1.96se(p)=0.2, where se(p) is the standard error of the estimate. In turn,

where p is the percentage to be expected to be estimated and q=1-p. Since 1.96se(p)=0.2,

= 0.2

or

So, substituting the expected percentage 0.5 produces a necessary sample size n

If the estimate had to be within plus or minus 250 users a much larger sample would be required.

Obviously it is not feasible to conduct a study which will give that level of precision; a survey of 19,000 respondents is far too costly to contemplate. Even a survey of almost 5000 respondents is a large undertaking which may be hard to justify, especially since such a survey would uncover only 24 people who had recently used heroin.

An alternative sampling strategy is to interview only the adults aged 20–39 since a large percentage of users fall into this age group. This narrower universe will permit a smaller, more efficient sample. Given the ACT population 14 years and older of 232,223, based on the NCADA survey 0.5 per cent or 1,161 are expected to be current users. The 1991 estimate of the ACT population aged 20-39 years is 110,131. If all of the current users are in this broad age group, then 1.1 per cent of the age group will report current use. The formula for calculating the necessary sample size to estimate the total population of users within plus or minus 500 is

If the estimate had to be within plus or minus 250 users an unfeasibly large sample would still be required, although not as big as the one needed if the entire adult population was to be interviewed.

Restricting the sample to the age groups who are likely to be current users would produce equally reliable results with considerably less time and effort. Nonetheless, one is still left with the problem that in the smaller study only 18 respondents would be expected to report recent use. It would still be necessary to interview about 10,000 adults to get the 100 users which would permit separate analysis of their characteristics.

This is how one would proceed to plan a survey of the ACT — that is, if one did not take the caveats discussed at the beginning of this section seriously and was convinced that household surveys (done properly) can tell us about heroin use.

Indicator/dilution; capture-recapture; list matching

All of these terms refer to similar estimation methods from the disciplines of population biology and demography. A scientist who wants to count fish throws her net out, counts and marks the fish she caught and throws them back. She gives the fish enough time to redistribute themselves before she casts her net again. On the following day she casts her net again and records the number of marked and number of unmarked fish. In other words, the population biologist wants to measure an unknown total population N. All members caught in the initial sample n_1 are marked, hence $m_1=n_1$. The marked members are returned and a second sample of n_2 is taken. In that sample, m_2 individuals are marked, so it is known that they were part of the first sample. Therefore, N is estimated by equating the ratio of the first sample n_1 to the total unknown population to the ratio of marked individuals m_2 in the second sample n_2.

Demographers have been using this method to measure the completeness of censuses and vital registration systems for centuries.[6] After censuses a post enumeration survey is conducted in which the best interviewers re-enumerate an area without reference to the original census forms. The numbers caught in both enumerations and the ones missed by one or the other serve as a means of estimating the probability of being missed on both. Epidemiologists have also recognized the potential of this method for estimating the total number of persons with a certain condition from incomplete lists of such persons (Wittes 1974; Wittes et al., 1974).

There is a small but growing literature on applying capture-recapture methods to estimate hidden populations of drug users from lists of users generated from such sources as arrest records, clients at methadone clinics and/or treatment centres, addict registers, and encounters with drug injecting street-based prostitutes (eg. Hartnoll et al 1985; Drucker and Vermund 1989; Sandland 1986).

Although the simple estimate, N, is conceptually easy to understand, it is not a good estimate unless the samples are large. Small samples and more specifically a small number of marked individual appearing in both samples, produce very biased estimates. Seber (1982) recommends the following unbiased estimator

The first four columns of Table 1 illustrate the importance of using the unbiased population estimate N* rather than N. The table gives various sample sizes (assuming that $n_1=n_2=n$) and recaptured individuals m_2 which would produce an N of 1000. The reader should think of these sample sizes as a range of possible samples which could be drawn from the same population to derive the same estimate of total size. As is evident, the uncorrected estimate exaggerates the size of the total population when samples contain fewer than 100 individuals in total and fewer than 10 individuals in both samples.

Not only are the simple estimates, N, biased when samples are small, small samples and/or few individuals in both samples will result in very imprecise estimates. The importance of estimating populations from samples with at least 10 individuals in common is also clear from the variance of the unbiased estimate N*. Seber calculates the variance in the following manner

Although v* (or) is useful for comparing the precision of various estimates, Seber (1982, 62–4) recommended that this formula for variance not be used to calculate the confidence intervals of N*, particularly when m_2 or m_2/n_2 is small. Instead he advised the use of a Poisson distribution of $N/(n_1 n_2)$ and included a table to assist in calculating the confidence intervals for N when m_2 is less than 50. That table is reproduced here as Appendix Table 1. For every value of m_2 there is a lower and upper bound. To derive the 95 per cent confidence interval for N, multiply each value by the product of the two sample sizes, n_1 and n_2.

If the researcher is fortunate enough to have $m_2 > 50$, then a normal distribution will suffice and the confidence interval of p where $p = m_2/n_2$, can be calculated as

Confidence intervals for the estimated population size are given in Table 1. All but the last row, in which $m_2 = 60$, use the Poisson distribution and are calculated from Appendix Table 1. Clearly researchers planning to apply capture-recapture methods to estimate population size must choose samples carefully to ensure that there are enough members in

[6] Although the method known as "Chandransekan and Deming" was formulated in 1949, Laplace used it in 1783 to estimate the population of France.

common to produce useful results. Estimates based on small samples and/or too few matched individuals can be very misleading and are virtually useless for most purposes.

Table 1: Illustration of key values from a series of hypothetical samples and numbers recaptured with an uncorrected estimated total population of 1000.

m_2	n_1=n_2=n	N	N*		95% Confidence Interval Lower	Upper
2	45	1000	704	330	155	5713
5	71	1000	863	299	325	2586
7	84	1000	902	273	396	2180
10	100	1000	926	239	468	1880
15	122	1000	944	200	543	1652
20	141	1000	960	174	597	1537
40	200	1000	984	121	708	1358
60	245	1000	991	95	819	1283

The capture–recapture method makes several assumptions. Failure to meet any of them severely limits the validity of the final estimate, particularly when the researcher is unaware that the assumptions have been violated.

The first assumption is that the population between the two observations is closed; that is, the underlying population size is constant and there should be no new members added to the population and no members leaving the population while the samples are collected. Assumptions regarding movement out of the population could be violated in a study of heroin users but, if the only change in the population is that some of the members have left, then the capture–recapture estimate will simply be a measure of the original, larger population (Sandland 1984). However, the estimate would be biased if heroin users who have been ‘caught’ in one sample are more likely than other users to leave the population soon afterwards by moving out of the ACT, dying or stopping heroin use. That is, as long as the marked and unmarked individuals are equally likely to leave the population between the time the two samples were taken, the proportion of marked individuals found in the second sample will not be affected and therefore the same estimate will be derived.

Theoretically, differential mortality could produce a bias. Heroin users arrested or attending treatment agencies may be more likely to reduce their use of the drug for a period. Users who have not used for a period may be especially at risk of an overdose if they overestimate their tolerance when they start to use again. This would mean that all users may be equally likely to be part of one sample through being arrested or attending a treatment agency. However, once arrested or in treatment they are less likely to be found in another sample because they are at greater risk of dying in the interim. Nevertheless, in practice, there are very few deaths due to heroin overdose in the ACT. Differential mortality is unlikely to affect the estimates of the total population.

On the other hand, the probability of migrating out of the ACT or abstaining from heroin use is more likely to be different for the treatment agency clients and arrested persons. Once in treatment, clients are probably more geographically stable than other dependent users because of their relationship to the treatment facility. Presumably they are also more likely to give up heroin use altogether. For different reasons, persons facing drug charges may also be more restricted in their movements and more likely to give up illicit drug use in anticipation of court appearances. If users who are not in a sample are more likely to move away then the ratio m_2/n_2 will be inflated because those who have left were not caught in n_1. This will result in an underestimate of the total population size.

Movement into the population of heroin users between the two samples is potentially more serious because there will be individuals in the second sample who could not have been included in the first sample which would result in an overestimate of the population. Clients are geographically mobile. Studies of clients of treatment agencies in the ACT and Sydney have found that about 15 per cent of the client load are users who usually live elsewhere (Stevens et al 1989, 19). In other words there will be some users who moved to the ACT in order to undergo treatment. If movement into the ACT is equivalent to movement out the overall population estimate will not be affected. However testing if this is true is next to impossible. While one could determine the proportion of clients in ACT treatment centres who moved to the ACT in order to undergo treatment, the difficulty comes in measuring the number of ACT users who moved elsewhere. Similarly, users who migrate into the ACT and do not attend treatment centres would also evade detection.

The best way to guard against biases arising from changes in the population and particularly from new users joining the population, is to restrict the study to a relatively brief period. Of course, the period selected also needs to be long enough to allow a sufficient number of individuals to be ‘captured’. Usually researchers have compromised by using lists generated over one year on the assumption (or hope) that the underlying population being estimated does not change much in one year. Surveys of a broad cross–section of users could be used to test if it is reasonable to assume that the population is stable over one year by probing for information regarding migration in and out of the ACT. Information on the frequency of prolonged periods of abstinence and their relationship to treatment and arrests would also help to assess the biases in the capture–recapture model.

Two other related assumptions are that every individual in the population must be equally likely to be sampled in each sample and the two samples must be independent. If being caught once in any way makes a person more likely to be caught a second time, the population will be grossly underestimated. Sandland (1984) demonstrated the enormous discrepancies which can arise when marked individuals have greater 'catchability'. He derived that the best estimate of the total population when marked individuals have a capture probability of (1 + *w*) times that of unmarked individuals is

Note that the first term is the simple version of the capture-recapture formula. When the individuals caught for the first time in the second sample had an equal probability of being captured as the individuals caught in the first sample, $w = 0$ and therefore the entire second term is equal to zero. An illustration of the effects of this bias is given in Table 2. Here n_1=1000, n_2=500 and m_2=50. The simple estimate of N is 10,000 (1000 x 500 / 50). However, depending on the value *w*, the true population N' may be quite different.

Table 2: Size of the estimated population N and the true population N' for various levels of *w*.

w	Simple estimate N	True population N'	*w*	Simple estimate N	True population N'
0.25	10000	12250	-0.25	10000	7750
0.50	10000	14500	-0.50	10000	5500
0.75	10000	16750	-0.75	10000	3250
1.00	10000	19000	-1.00	10000	1000
1.50	10000	23500			
2.00	10000	28000			

Even when the captured individuals are only slightly more likely to be caught again, in this case 25 per cent more likely ($w = 0.25$), the simple estimate of the total population N underestimates the size of the true population, N' because m_2 is larger than it should be under the assumption of equal 'catchability'. When the captured individuals are twice as likely to be caught again ($w = 1$) the simple population estimate is nearly half the size of the true population.

Despite the importance of differences in catchability or the interdependence of samples, in practice samples are rarely completely independent, whether the samples are of fish or clients. Unfortunately, the degree of interdependence is rarely known because that requires knowing what the probability of being caught is for those who were not caught. A study of a broad cross–section of users could possibly provide information on the proportion of users who are likely to be caught once, twice or more than twice. However, without some information from the total population, which of course is unknown, a direct estimate of *w* is unobtainable.

Fortunately, population biologists and epidemiologists have proposed several techniques to test for and correct interdependence of samples. One method is to test for differences in catchability by known traits. If the researcher is aware that different catchability might be a bias, she can take precautions by recording the characteristics which are likely to predict catchability. After all samples have been collected, individuals can be divided into those ultimately recaught and those who were not. If there are significant differences in the characteristics of the groups, the researcher can separate the members of each sample by the relevant characteristics and estimate the total size of subgroups. Bloor et al. (1991) did this in their work on drug–injecting street prostitutes in Glasgow. They found that through their method for sampling prostitutes, drug–injecting prostitutes were more likely to be sampled because they worked more days and longer hours than their nondrug–using peers.

Another technique when samples may not be independent is to use loglinear models to adjust results of three or more samples, two or more of which may be interdependent. In the case of three samples, say lists of users from three sources, a table would be set up as follows:

		Sample 3 Present		Sample 3 Absent	
		Sample 2		Sample 2	
		Present	Absent	Present	Absent
Sample 1	Present	x_{111}	x_{121}	x_{112}	x_{121}
	Absent	x_{211}	x_{221}	x_{212}	x_{222}

The method forces the value of the cell x_{222} which is the number of individuals not in any of the samples to be zero. The best fitting loglinear model with the least number of interaction terms is estimated and the expected value of the missing cell is estimated. The total population estimate equals the expected value of the missing cell plus the number of cases in the other cells. Details of this method along with several examples are given in Chapter 6 of Bishop et al. (1975). Frischer et al. (1991) and Frischer (1992) used the technique to estimate the number of injecting drug users in Glasgow.

Data sources

The ACT is fortunate in that lists of an important subgroup of heroin users with unique identifiers for every individual have been collected by the ACT Drug Indicators Project which was funded by NCADA (Stevens et al., 1989; Quarterly Report, Jan–Mar 1989). By 1988 the project was gathering data from all the major drug treatment and criminal justice agencies in the ACT.[7] The project continued throughout 1989. Every treatment agency was asked to complete a form on every new client. Each client was asked for the first letter of his or her first name and the first two letters from the surname as well as the exact date of birth. Background information was sought on sex, current residence, birthplace, marital status, dependent children, employment and occupation. Clients were also asked about their criminal record, who referred them to the agency, and the drugs they used. The primary problem they were experiencing with drug use which caused them to seek treatment or advice was also noted on the form. Data collected by the police was necessarily briefer. However, it did include most of the background information, details of the current charge and prior criminal record. Only drug charges, mostly use, possession and trafficking, were collected by the Drug Indicators Project.

In other words, the ACT Drug Indicators Project provides information on every person who sought treatment or advice over a period of more than two years from any of about 20 agencies including the government–run methadone clinic, detoxification centres, residential therapeutic communities and organizations providing counselling and information services, such as the Drug Referral and Information Centre (DRIC) and the government-run Alcohol and Drug Services. Similarly, the police data list all arrests on drug charges over this period. It is difficult to imagine a more comprehensive list of heroin users in the community than the lists produced from the ACT Drugs Indicators Project.

Stevens (1991) and Jardine (1991) considered other sources of data on drug users in the ACT and concluded that they involved too few cases or, because of nature of the source, could not collect useful data. Their reviews are useful, particularly from the perspective of trying to identify only heroin users, since they were interested in all illicit drug use. A brief overview of all of these data sources follows.

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[7]Most agencies were reporting to the Drug Indicators Project by September 1987, however most of the analysis in this paper will be restricted to events in 1988 and 1989.

DRUG POISONINGS, CASE REPORTS FROM THE ACCIDENT AND EMERGENCY DEPARTMENTS OF THE ACT HOSPITALS AND DRUG–RELATED CASES TREATED BY THE ACT AMBULANCE SERVICE AND DEATHS REFERRED BY CORONERS FOR DRUG–RELATED TOXICOLOGICAL ANALYSIS. Stevens (1991, 290–1) has a good explanation of why these are not useful data sources. Her most compelling reason is that for the ACT the numbers are too small.

DRUG–CAUSED MORBIDITY. Although in principle this could be a useful data source, it is either not reported completely by the hospitals who are charged with reporting it or users do not end up in hospital very often. In 1986 there were only six opioid–related morbidity cases in the ACT.

HEPATITIS B NOTIFICATIONS. Similarly, in the ACT in 1988, there were only 18 notifications of hepatitis B and only one of these people was identified as an injecting drug user. This data set is also problematic because of the large proportion of people with hepatitis B who are asymptomatic and hence would never be notified.

TELEPHONE ADVISORY SERVICES. By their very nature telephone advisory services do not ask for callers' names and the services have not adopted any other kind of identifiers. However, eight to ten per cent of calls relate to opioids and these callers may be people who avoid other services. If a method could be found to collect information from callers, even if it was only to ask them if they had contacted this service or any other service before, it could form a useful sample for a capture–recapture estimate.

ACT NEEDLE EXCHANGE PROGRAM REPORTS. This is another potentially valuable source of information. The Needle Exchange has developed a scheme whereby clients give a unique identifier (such as a private nickname) which they use at every visit. There is, of course, no requirement that the clients always use the same identifier or that they are receiving needles for themselves alone. Data from the Needle Exchange also have another drawback for estimating the number of heroin users: anecdotal evidence suggests that the majority of their clients are injecting amphetamines and not heroin (Stevens et al., 1989, 52).

The ACT Drug Indicators Project

The ACT Drug Indicators Project measured indicators of illicit drug use. Many of the clients in treatment agencies were seeking help for alcohol related problems but, because of limited resources, the project did not collect data on clients with licit drug problems who reported no illicit drug use in the last month (Stevens et al 1989, 7). Heroin users who attended treatment agencies can be identified in one of two ways. First, clients were asked which drugs caused problems and led them to seek admission. Up to two 'problem' drugs were recorded. Second, all clients were asked what drugs they had used recently (in the last 1 or 3 months, depending on the agency). Therefore, the first and more limited population is the problem users: men and women who said they had come to the agency because of problems arising from their use of heroin and/or methadone. In 1988 233 people contacted treatment agencies and reported heroin or methadone as their presenting problem. In total these individuals made 287 contacts with treatment agencies in 1988. In 1989 there were 254 contacts by 214 heroin and/or methadone users who defined their use as their principle drug problem. The second, broader, definition includes all recent heroin users, regardless of their presenting problem. In 1988 416 new enrolments and 330 persons attending treatment agencies met that criterion; in 1989 there were 479 enrolments by 375 persons.[8]

The most serious potential problem with the Drug Indicators Project data is with matching individuals. False matches, that is, giving two individuals the same identification number, would result in an underestimate of the true population size because there would be too many people who appeared to belong to more than one sample. The project staff believed that the three initials and exact birth date kept this type of error to a minimum. As the 1988 Annual Report stated:

> In every matching system of this type, there will be some degree of error due to incorrect or missing date of birth or changes of name such as aliases. While we have made every effort to reduce these potential errors, we estimate

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[8] For the remainder of the paper heroin and methadone users will be called heroin users. Methadone use and problems with methadone were included because methadone is an opioid and in the Australian context of drug use implies a prior dependence on heroin. The heroin trial is likely to be attractive to dissatified methadone clients. In fact, it was rare for clients to report use and/or a problem with methadone without also mentioning heroin. Out of the entire ACT Drug Indicators data set only 16 people enrolling in a treatment agency reported methadone use but no heroin use compared to 747 enrolments of those reporting heroin use but no methadone use and 223 reporting use of both opioids.

in the early stages of the study, when it was still possible to manually double check the system, that our error rate on matching was at that time less than one per cent (Stevens et al. 1989, 8).[9]

There are two other data quality questions. One is that anecdotal evidence abounds that clients use different names with different agencies. Certainly, if a person chose to hide his or her identity, an accurate match would be impossible. Such falsification would artificially lower the number of individuals appearing in two or more samples and result in a population estimate which was higher than the true population. The extent to which this may have happened cannot be measured here although it would be possible to judge the extent of the practice by asking users in a survey if they ever gave different names.

A related concern is that clients may not be consistent in identifying themselves as heroin users, in presenting with a heroin–related problem or even being arrested for heroin–related offences. Since most heroin users use a number of different drugs it is entirely possible that their problems and their arrest record vary from place to place and time to time. Looking only at variations in reporting within the agency data, out of the 703 persons who reported heroin use, only 57 (8 per cent) appeared another time in the data set and did not report heroin use. Heroin as a presenting problem is reported less consistently: out of 428 persons who appeared in the treatment agency data at least once with heroin as a presenting problem, 76 (18 per cent) appeared other times without heroin as a presenting problem.

Results

Regardless of the potential pitfalls, Table 3 gives the results of a simple estimate of the population based on those who attended any treatment agency and those arrested on heroin charges. The estimates range from about 800 to almost 1200. As one would expect the figures for the heroin using population seeking treatment are slightly bigger than the estimate based on individuals defining heroin use as their presenting problem. All of the estimates resemble the guesstimate of 1000 dependent users in the ACT held by a leading drug and alcohol service provider (Stevens et al., 1991, 10).

The results in Table 3 are interesting but they do not take full advantage of the Drug Indicators Project data. The data set gives more information than a simple dichotomy between clients at treatment agencies and those who have been arrested. The data set also traces individuals through various treatment agencies. It would be a waste not to include these additional opportunities for 'capture'.

Table 3: 2 x 2 estimates of the number of heroin users by matching those in contact with any treatment agency with those arrested for a heroin-related offence.

Population/ Year	n_1	n_2	m_2	N	N*	95% confidence interval Lower	Upper
Heroin/methadone users seeking treatment and/or arrested on a heroin charge							
1988	330	52	14	1226	1169	656	2076
1989	375	44	18	917	890	533	1452
Heroin/methadone users seeking treatment who define their use as a problem and/or arrested on a heroin charge							
1988	233	52	13	932	885	485	1611
1989	214	44	11	856	805	417	1553

Loglinear analysis is required if the treatment agencies are to be divided into several categories or each one treated as a separate list because the design will be more complex than a 2 x 2 table. Loglinear analysis is appropriate as well because the relationship between attendance at any two or more treatment agencies is unlikely to be independent. With loglinear analysis significant interaction terms can be included in the model. However, despite the flexibility of loglinear analysis, it is often not practical to use all of the available lists. Loglinear analysis is very sensitive to cell sizes of zero unless they exist for structural reasons. Many of the treatment agencies included in the Drug Indicators Project served few clients per year and frequently there is no overlap in the clientele of different agencies.

This paper will give a detailed description of the process of deriving estimates of the number of heroin users in the ACT with this method. It will be the number of heroin users in 1988, defined by reported use of heroin or methadone.

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[9] At the early stage of the project, full names and, after a month or so, the first five letters of the surname were recorded on the forms. Staff were able to confirm that the vast majority of matches could be made with only three letters.

The number of contacts and the number of heroin users attending each of the agencies and/or arrested on heroin charges is given in Table 4. Obviously, some of the agencies saw few heroin users in 1988. It was necessary to merge the smallest organizations before proceeding.

Following a method suggested by Wittes and coworkers (1974), the population was estimated from every possible combination of lists using the assumption of independence. Examination of the results would indicate which combinations of lists produced unrealistically high or low estimates. These could have been due to interdependence between the lists or because of unstable estimates due to empty cells. Generally speaking, an unrealistically low estimate indicates people on one list have a tendency to also be on the other list. If the population estimate appears too high then people on one list tend not to be on the other lists.

Table 4: Number of contacts and persons reporting to be heroin users attending various treatment agencies and/or arrested on heroin charges in 1988 (ACT Drug Indicators Project data).

Samples	Contacts	Persons
Treatment Agencies		
Methadone Clinic	60	60
Alcohol and Drug Services (ADS) Detoxification Unit	56	54
Crisis Detoxification Centre (CDC)	160	115
Drug Referral and Information Centre (DRIC)	34	34
Karralika Therapeutic Community	34	34
ADS Community Unit	10	10
Queanbeyan Alcohol and Drug Service	9	9
Toora	20	18
We Help Ourselves (WHOS)	22	22
ACT Probation	9	9
Queanbeyan Probation	2	2
Heroin Arrests	59	52

Table 5 gives the results of this exercise for the 1988 lists of heroin users.[10] It is clear that the models with four or more terms produce total estimates which are far too low, indicating not only interdependence but also too many empty cells. Further merging of lists is necessary if we are to produce stable results. From the excessively large estimates at the bottom of the table it is clear that the 'other' category is interdependent with several other treatment agencies. In other words, if a person attends one small treatment agency, he or she is unlikely to be admitted into another small agency as well.

This process of testing all combinations of variables proceeded for several more steps, systematically merging first Karralika with the 'other' agencies, then the list from the local government detoxification unit and finally experimenting with merging combinations of clients from the Crisis Detoxification Centre (CDC), Drug Referral and Information Centre and 'others'. An effort was made to merge lists which appeared to be interdependent but also to maintain a logic in those which were merged and those remaining unique. There would be no justification, for instance, in merging arrests with any of the treatment centre lists. Similarly, the methadone clinic seemed important enough to warrant keeping separate. The results from the final stage are given in Table 6. The best estimate appears to be around 1250 heroin users for any three-way test using participation in the methadone clinic, heroin-related arrests, and some combination of other agencies and attendance at the Crisis Detoxification Centre and/or DRIC.

Table 5: Estimates of the underlying population of heroin users in 1988 from various combinations of samples from treatment agencies and arrests.

Methadone clinic	*1*	DRIC	*4*
ADS Detoxification Unit	*2*	Karralika	*5*
Crisis Detoxification Centre	*3*	Other agencies	*6*
		Heroin-related arrests	*7*

[10]Loglinear analysis to generate expected values was performed with the HILOGLINEAR procedure in *SPSSX*. Methods of calculating population estimates from loglinear output are given in Bishop (1975).

Model (independent samples)	Population estimate	Model (independent samples)	Population estimate
1,4,5,6,7	229	*3,4,5*	779
1,2,5,6,7	248	*1,3,4,5*	786
2,3,4,5,7	263	*3,4,5*	798
1,2,3,4,5	271	*2,3,4,5*	826
3,4,5,6,7	280	*2,3,7*	1113
2,3,4,5,6	283	*1,5,6*	1136
1,2,3,4,7	288	*2,3,4*	1165
1,2,3,6,7	322	*4,6,7*	1178
2,5,6,7	358	*1,2,3*	1196
2,4,5,6	372	*1,6,7*	1289
1,4,5,6	408	*1,3,4*	1532
4,5,6,7	415	*2,5,6*	1583
3,4,5,6	534	*3,5,6*	1595
1,4,5	627	*4,5,6*	1653
1,5,6,7	704	*3,6,7*	1663
3,5,6,7	735	*2,6,7*	1696
2,4,5	772	*2,3,6*	1792
		5,6,7	2482

Note: The total number of individual heroin users ‘caught’ in 1988 was 368.

Table 6: Estimates of the number of heroin users likely to use treatment agencies or be arrested for heroin offences in 1988, according to the specification of the log linear model.

Methadone clinic	x	x	x		x	x
Crisis Detoxification Centre		x				
DRIC	x			x		
Other treatment agencies						
Heroin arrests	x	x	x	x	x	x
Crisis Detoxification Centre + Others	x		x	x		
DRIC + Others		x			x	
Crisis Detoxification Centre + DRIC + Others						x
Number of empty cells	4	4	0	0	0	0
Population estimate	1491	1464	1234	1282	1234	1251

Note: Chi–square tests indicate there were no significant differences in the expected and actual values for all of the models. In the last four models no additional interaction terms improved the measure of deviance significantly.

Following the same procedures for all heroin users arrested or attending treatment agencies in 1989, the same model appeared to fit the data best. In all cases none of the possible interaction terms were significant. Turning to only those heroin users who reported their heroin use as a problem, the best model was with three independent samples: methadone clinic; CDC, DRIC and other agencies; and heroin arrests. However, grouping the methadone clinic sample with CDC and DRIC and then matching with other treatment agencies and arrests was also a good fitting model which gave almost identical results. These results are given in Table 7. Note that the estimates for each year are reassuringly similar to one another and that there are fewer ‘problem’ users than total users.

Table 7: Best estimates for the number of heroin users in the ACT from Drug Indicators Project data.

Population	Population estimate	Standard deviation
All heroin users seeking treatment and/or arrested on heroin charge 1988	1251	203
All heroin users seeking treatment and/or arrested on heroin charge 1989	1229	188

'Problem' heroin users 1988	1015	187
'Problem' heroin users 1989	973	205

One unresolved problem with the estimates is that some users may be more likely to be 'caught' in more than one sample. The most obvious factors which could lead to differences in 'catchability' are sex and age. It is commonly accepted that female users are less likely to attend treatment clinics and to be arrested. Since we do not know about the entire population of users we cannot judge to what extent women are more likely to stay away from all contact with agencies and law enforcement. However, the Drug Indicators Project data can be used to judge if, once at a treatment agency or arrested, women are likely to have another encounter. The answer to this is no, at least for treatment agencies. Among clients in 1988 reporting use of heroin or methadone, 91 per cent of males attended more than one clinic compared to 90 per cent of females. However, 6 per cent of male heroin users who were new clients in a treatment agency in 1988 were also arrested on heroin charges that year. Only 2 per cent of the female clients were also arrested. Unfortunately, although this difference could affect the results, only two women both attended a treatment agency and were arrested. This is too few to allow a reliable independent analysis of the total number of female users.

In order to examine whether age made a difference in the probability of heroin users appearing in more than one sample, the reported heroin users in 1988 were divided into three age groups: under 25 years, 25–29 years and 30 and over. There was a tendency for the oldest group to be least likely to attend two or more treatment agencies in 1988 (4 per cent as opposed to 13 and 12 per cent for the other two age groups); however, the differences were not statistically significant.

Considerable confidence can be put in the results given in Table 7. However, it must be remembered that this measures the arrest–vulnerable and treatment/advice seeking population of heroin users. This is certainly not all heroin users or even all dependent heroin users.

Multiplier method

As the name implies, this method takes a number that we know and multiplies it by another number (the multiplier) to estimate a total population. A multiplier frequently used to estimate the total number of people using heroin is the overdose death multiplier. The known number of deaths due to heroin overdose is multiplied by 100 or 200. It is argued that every year between 0.5 to 1 per cent of heroin users will die of an overdose. This multiplier was developed in New York City and it is a good example of the weakness of the multipliers. Attempts to apply the deaths–by–overdose multiplier to other populations have been roundly criticised, especially when applied to areas in which crucial factors such as heroin purity, method of administration and the social context of drug use differ from New York City (Sandland 1984; Hartnoll et al. 1985, 203; Parliamentary Joint Committee 1989,42).[11]

Another example of multipliers which have been used uncritically is one proposed by Hartnoll et al. (1985). These British researchers found in a study of clinic attenders that only one out of every six to ten opioid users known to clinic attenders were also attending a clinic. Moreover, for every frequent opioid user known to clinic clients there were two or three acquaintances who were infrequent or intermittent users. These multipliers were used as part of an exercise by the National Drug Abuse Information Centre to estimate the number of heroin users in Australia (National Drug Abuse Information Centre 1988). As the Parliamentary Joint Committee on the National Crime Authority (1989) correctly observed, the number of places in methadone programs has escalated dramatically in recent years. It is unreasonable to expect a single multiplier to remain appropriate as the extent of treatment facilities changes.

In order to be meaningful, multipliers must be developed or verified in the setting in which they are to be used. However, when multipliers are derived from sound research on the group which is the focus of the study, they can be a useful tool.

A complete count of subgroups of the heroin–using population frequently exists. For example, in the ACT and elsewhere, the number of persons attending treatment centres and the number of people who have been arrested or convicted on drug charges are available for 1988 and 1989. These counts are the first requirement for the multiplier method.

When counts of subgroups are available, the next step is to estimate what proportion of the total population of interest belong to the known subgroup. For example, if we have a count of the number of persons arrested on heroin charges in a single year, then we must estimate the proportion of all dependent users (the population we are interested in) who were arrested in that year. Rigorous estimation of this proportion would require interviewing a random sample of the population. Obviously a true random sample is impossible since there is no sampling frame for the population of dependent users. Nevertheless, other sampling methods such as snowball or chain referral sampling and nomination techniques could produce a sample which was sufficiently similar to the actual population of heroin users. Respondents recruited or identified in this manner could be asked if they belong to the subgroup for which there is an accurate count. The final estimate of the total number of dependent heroin users will be the official count of those arrested divided by the proportion of respondents who reported having been arrested.

Multipliers can be a powerful tool for estimating population size, but if this method is to be used it must be planned carefully so the data from the survey can be used in conjuction with the counts of known subgroups. To use a simple example, imagine that the counts come from the records of a single, widely used treatment agency catering to dependent heroin users. The records of this agency could be organized in one of several ways. One, the records may note only clients using the service for the first time. Two, the agencies may keep separate records for every client and note each visit the client made. Third, and most common, the agency may simply record the number of visits without keeping track if the visits were of new or returning clients. Each type of count is actually measuring a different subpopulation and requires different questions from a general sample of users to enable estimates to be generated.

In the first instance the sample survey should ask users if they attended a treatment agency for the first time in the past year. The count of new clients divided by the proportion of new clients in the sample should equal the total population of dependent heroin users. The second case can be dealt with similarly. Respondents should be asked if they attended the agency at least once in the past year. The count divided by the proportion of attenders equals the estimated population size. The final method of recording all visits without distinguishing multiple visits by the same individual is the record keeping system used by most social services. Respondents being interviewed may find it difficult to recall the exact number of visits

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[11] Another reason the death–by–overdose multiplier is rarely used in Australia and would always be impractical for the ACT is that the number of deaths caused by a heroin overdose occuring each year is very small. Yearly fluctuations in deaths would result in considerable changes in the estimated number of users.

during a specific period. If possible the questions should be framed around a short period such as two months, instead of an entire year. The estimate of the population would equal the number of all visits during that interval divided by the ratio of the total number of visits estimated by the respondents and the number of respondents.

Variations of studies using the multiplier method are endless. Each study will have its own strengths and weaknesses depending on the nature of the counts of the subgroup and the representativeness of the sample of the broader population. It should be stressed that there are many sources of biases with all methods to estimate hidden populations. Estimates based on the multiplier method should be confirmed with estimates from other sources and derived by other methods.

Nomination methods

The population which is most relevant for the heroin trial are persons dependent on heroin. Many of the methods described above can measure the size of part of this group – those who come in contact with the police or those who attend treatment agencies. Estimating the other group who have managed to remain hidden from these institutions is much more difficult.

Surveys of users have been attempted in Australia (eg. Australian National AIDS and Injecting Drug Use Study 1991, Watson 1991, Dobinson and Poletti, 1989), however these are time intensive efforts requiring recruiting informants who in turn locate users willing to be interviewed. When researchers need to know a great deal of information from each user, a survey is probably the only way to proceed. However, if the principal object of the study is to estimate the general demographic and drug use–related characteristics of the drug using population then a nomination approach may be more efficient and at least as accurate as a survey based on snowballing and chain referrals.

The nomination technique asks members of a known population familiar with members in an unknown population to give information about their friends. An example of this method was given above. The Hartnoll et al. (1985) study of clinic attenders' acquaintances used a nomination technique. This is not a method for estimating the number of users, however it can be used to estimate multipliers which, in turn, can be used to estimate population size. This technique is not appropriate if the survey will already reach a large proportion of the entire target population.

Blumberg and Dronfield (1976) carried the nomination technique one step further. Their primary interest was in the characteristics of regular users who did not attend clinics. The researchers asked clinic clients in London to give information on one friend also attending the clinic and another two heroin–using friends who did not attend the clinic. They used this particular design in order to compare the characteristics of the clinic–attending friends with the known population of clinic clients, reasoning that if the respondents' clinic attending friends were representative of the entire clinic population than their non–attending friends were likely to be representative of the non–attending heroin–using population. They concluded that aside from a bias towards nominating heavy using individuals, there were no differences between the nominated and actual populations.[12]

Summary and conclusion

This working paper had two purposes. The first objective was to explore methodologies which could be employed to estimate the potential pool of participants in a trial of controlled availability of opioids in the ACT.

Population–based surveys was the first method studied. Surveys to identify current heroin users have a number of potential sources of bias which are widely recognized and which tend to underestimate the proportion of users in the general population. Nevertheless, the three national surveys conducted by NCADA have produced consistent estimates of the proportion of the general population who have used heroin within the past 12 months. The greatest obstacle to using a population based survey to estimate population size is the sample size required to produce estimates which are sufficiently precise for designing and monitoring programs.

Capture–recapture techniques was the second methodology to be considered. Although the technique of estimating a total population from two or more independent samples drawn from the same population has been used in several

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[12] The authors did not consider that respondents may have a tendency to underreport their own use and/or inflate their friends' use levels.

disciplines for two centuries, it is currently enjoying renewed attention. The global threat of HIV infection has forced the attention of researchers and planners on subgroups of the population which practice risk behaviours which they may be reluctant to announce publicly. The size of 'hidden' populations such as high school students who have sex, men who have sex with men, prostitutes, prostitutes' clients, and injecting drug users has become a crucial public health issue. Conventional data sources and methodologies were not always suitable for measuring these populations. When appropriate data exists or can be collected, capture–recapture methods can be a powerful tool in estimating groups which are difficult to reach in other ways.

Use of log–linear modelling in capture–recapture studies means that the samples do not have to be independent. This is an important methodological advance since in practice samples of individuals are rarely independent. A substantial change in the underlying population during the time the data is collected is another potential source of bias which researchers must guard against. Most importantly, the estimates of total population size will only be based on the populations from which the samples are drawn. If certain types of people, such as women, the old or the users who have no problem with their use do not appear in the samples then the estimates will not reflect them.

The multiplier method can be a powerful tool to estimate a total population from data on a subset of the population. However, this method is frequently abused. It is rarely justified to apply multipliers derived in one socio–cultural setting to another setting. Multipliers must be validated before they can be used.

The nomination technique is a promising method for deriving multipliers. Its principal advantage over other surveys of users is that the nomination technique capitalizes on the fact that there is a subgroup of users who are relatively easy to approach and a much larger group who are much more difficult to identify and contact. With the nomination technique one relies on the information provided by the known subgroup to learn about the total population. If the purpose of the research is only to estimate population size, a nomination technique may be the most efficient study design. On the other hand, if the purpose is also to collect in–depth information on other characteristics of the wider, unknown population, the reports of acquaintances may not be sufficient. In that case the researcher will have to collect a systematic snowball sample.[13]

The second objective of the working paper was to generate estimates of the ACT's heroin using population. As part of the Stage 1 feasibility study for the controlled availability of heroin trial conducted by the National Centre for Epidemiology and Population Health in collaboration with Australian Institute of Criminology preliminary efforts were made to estimate the dependent and total heroin using populations of the ACT. Stevens and colleagues used a number of methods which had been used for national estimates and for which they had appropriate data. By applying multipliers, extrapolating from surveys designed for other purposes and collating the 'guesstimates' of service providers they proposed that "it seems reasonable to suggest that in the ACT there are between:

70–2000 dependent users
600–6000 non-dependent users
700–8000 heroin users in total" (Stevens et al., 1991, 10). The estimates presented in this working paper fit within a much narrower range.

If the ACT has a similar proportion of heroin users as the national population then 2,787 residents (95 per cent confidence interval 3,945 to 1,628) have ever used heroin and 464 residents (95 per cent confidence interval of 940 to -11) have used in the past 12 months. However, population based surveys probably underestimate the prevalence of recent heroin use because regular users are less likely to be interviewed and, if interviewed be reluctant to admit current illegal activity. Futhermore there is no way to evaluate if use of heroin in the ACT is as prevalent, more prevalent or less prevalent than nationally.

The capture–recapture estimates based on the ACT Drug Indicators Project data produce higher estimates of current (ca 1988–9) heroin users. They reflect a population which are arrest vulnerable and/or seek treatment/information from ACT treatment agencies. One set of estimates is based on clients who report recent heroin use and/or were arrested on a heroin–related charge and another set is restricted to arrests and heroin users who stated that their heroin use was their principle drug problem. Estimates were produced using the simple 2 x 2 capture–recapture formula and a more complex loglinear model. Both estimates suggest that there was little difference in the size of the populations between 1988 and

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13 The key word here is systematic. Researchers should take great effort to ensure that their snowball–generated sample is as representative as possible. See the seminal work on constructing snowball samples by Biernacki and Waldforf (1981). If carefully planned, the process of generating a snowball sample could generate data useful for estimating the size of the total population. Two approaches have been seen in the literature: as a source for new contacts reaches the limit of his or her contacts the interval between contacts lengthens (Kaplan, Korf and Sterk 1987); as coverage of the entire population improves the number of duplicate referrals to the same person should increase (Bloor et al 1991).

1989. Based on the loglinear models the wider population of heroin users who were arrested or attended treatment agencies was approximately 1250 (plus or minus about 400 persons[14]). The narrower population of what can be termed 'problem users' is about 1000 (plus or minus about 400 persons).

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[14] The confidence interval reported here is double the standard deviations given in Table 7.

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Appendix Table 1: Shortest 95 per cent confidence interval for $N/(n_1n_2)$ based on the Poisson distribution.

m_2	Lower limit	Upper limit	m_2	Lower limit	Upper limit
0	0.0885				
1	0.0720	19.489	26	0.02478	0.0563
2	0.0767	2.821	27	0.02408	0.0539
3	0.0736	1.230	28	0.02342	0.0516
4	0.0690	0.738	29	0.02279	0.0495
5	0.0644	0.513	30	0.02221	0.0475
6	0.0600	0.388	31	0.02165	0.0457
7	0.0561	0.309	32	0.02112	0.0440
8	0.0526	0.256	33	0.02061	0.0425
9	0.0495	0.217	34	0.02014	0.0410
10	0.0467	0.188	35	0.01968	0.0396
11	0.0443	0.165	36	0.01925	0.0384
12	0.0420	0.147	37	0.01883	0.0372
13	0.0400	0.133	38	0.01843	0.0360
14	0.0382	0.121	39	0.01805	0.0350
15	0.0365	0.111	40	0.01769	0.03396
16	0.0350	0.1020	41	0.01733	0.03300
17	0.03362	0.0945	42	0.01700	0.03210
18	0.03233	0.0880	43	0.01668	0.03124
19	0.03114	0.0823	44	0.01636	0.03043
20	0.03004	0.0773	45	0.01606	0.02966
21	0.02901	0.0729	46	0.01578	0.02892
22	0.02806	0.0689	47	0.01550	0.02822
23	0.02716	0.0653	48	0.01523	0.02755
24	0.02632	0.0620	49	0.01498	0.02691
25	0.02552	0.0591	50	0.01475	0.02625

Source: Chapman (1948) cited in Seber (1982).
Note: This table is applicable when $p < 0.1$ or $m_2 < 50$ but serves as an acceptable approximation of the confidence interval when p is larger. To calculate the confidence intervals for N, multiply the lower and upper bounds by n_1n_2.