L. Degenhardt, V. Rendle,
W. Hall, S. Gilmour & M. Law

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Louisa Degenhardt, Valerie Rendle,

Wayne Hall, Stuart Gilmour and Matthew Law

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EXECUTIVE SUMMARY

Problems related to heroin use, such as dependence, blood borne virus transmission, premature death from overdose and crime, negatively affect the community in ways that are disproportionate to the relatively small proportion of Australian adults who are dependent on heroin. An important question to ask (and answer) is therefore: how many people use heroin? Such an exercise was undertaken in 2000, when Hall and colleagues estimated the population prevalence of opioid dependence using 1997/1998 data.

In recent years, however, we have seen significant changes in the heroin market in Australia. Early in 2001, anecdotal reports were received of a sharp reduction in the availability of heroin. These reports were initially confirmed by research in convenience samples (Day et al., 2003; Weatherburn, Jones, Freeman, & Makkai, 2001), and later confirmed in the monitoring systems that had documented the increasing heroin availability during the previous five years (Darke, Topp, Kaye, & Hall, 2002; Topp, Kaye, Bruno, Longo, Williams, O'Reilly, Fry, Rose, Williams et al., 2002). A common issue for consideration has been the extent to which changes in the availability of heroin may have impacted upon the number of persons using the drug. This report seeks to examine which methods for estimating the number of heroin users are most appropriate to use when the numbers of heroin users may be rapidly changing in response to marked changes in availability of their drug of choice.

Achieving this aim is not simple. Making estimates of a hidden population, such as heroin users, is difficult for a range of reasons in the best of circumstances. Added to these difficulties are complications introduced by marked changes in drug supply.

Given the illegal and stigmatised nature of heroin use, it is not a simple task to estimate the number of dependent heroin users in Australia. There are no widely accepted "gold standard" methods for estimating the size of this "hidden population". The favoured strategy is to apply a variety of different estimation methods of varying validity to different data sources, looking for convergence in the estimates. We carried out an evaluation of data sources used to produce estimates of the number of heroin users, and of methods that might be able to measure the size of this population during relatively short periods (i.e. annually).

Aims

The aims of the current study were to examine methods with which to estimate the number of regular heroin users in NSW (for discussion of Australian estimates, please see Degenhardt et al., 2004). In particular, we wished to consider:

1. Are some methods less sensitive than others to changes in the supply and use of heroin (and potentially the number of regular heroin users)?;
2. Are there problems with the use of some estimation methods in the context of rapid suspected changes in the size of a hidden population?
3. Do different sources of data provide information about different subsets of the group of regular heroin users?

The estimates of the number of the number of regular heroin users are presented in detail in Degenhardt et al (2004). In considering these questions, we have examined the estimates of NSW regular heroin users over the period 1997-2002 derived from different sources and methods.

Results

Estimates were generated from secondary analyses of existing databases. We made estimates of the number of *current regular heroin users*. The number of opioid dependent persons in total is likely to include the number of persons maintained upon opioid pharmacotherapy as well as our estimates of the number of regular heroin users. The data sources that were used in the current study included:

1. national data on the number of opioid induced deaths per year compiled by the Australian Bureau of Statistics;
2. data on ambulance attendances at suspected drug overdoses provided by the NSW ambulance service;
3. the NSW Health Department's heroin pharmacotherapy client database provided by the Pharmaceutical Services Branch (PSB);
4. data on arrests for drug offences provided by the NSW Police Service; and
5. data provided by the Alcohol and Drug Information Service (ADIS) on calls received related to heroin use.

Three indirect estimation methods were used to make annual estimates of the number of active, regular heroin users with the following estimation methods:

(1) **Multiplier methods** using data on the number of opioid overdose fatalities, entrants to opioid pharmacotherapy, arrests and ambulance callouts to suspected opioid overdoses;
(2) **Capture-recapture estimates** based on methadone and police arrest data; and
(3) **Back-projection methods** using data on fatal opioid overdose and first time entrants to methadone maintenance to estimate the incidence and prevalence of heroin dependence.

Results

Clear increases in the scale of harms related to heroin use were documented in the latter half of the 1990s, with sharp reductions from 2001. These changes were relatively consistent across the data sources examined, with the exception of the *total* number of persons in opioid pharmacotherapy, which has steadily increased over time as new heroin dependent persons have entered treatment, and others have remained stabilised on it.

Capture recapture methods tended to "average" changes across time in the indicators of current heroin use, and the resulting estimates did not provide estimates sensitive to the changes observed in indicators of use. Back projection methods, although more sensitive to changes in the indicators used, were limited in their ability to accurately model changes that occurred due to their recency . Back projection methods will probably be able to better model recent trends after a longer period of time has elapsed. In contrast, multiplier methods were able to capture these short term changes. As a result, the range of multipliers developed for use in this study formed the basis of the estimates derived.

There has been a significant drop in the estimated number of current, regular heroin users in NSW (Table A). This drop was sustained in 2002. Detailed estimates of the number in NSW and in Australia, as well as stratification by age and gender, are provided in the companion report (Degenhardt et al., 2004).

Table A: Median estimates and range of the number of current regular heroin users in NSW, 1997-2002

	1997	1998	1999	2000	2001	2002
Median	**35,300**	**48,000**	**48,200**	**43,900**	**22,100**	**19,900**
Lower limit of range	*25,500*	*42,900*	*41,800*	*35,600*	*16,600*	*17,800*
Upper limit of range	*39,200*	*52,400*	*61,100*	*52,300*	*36,500*	*41,900*
Number in pharmacotherapy	11,304	11,987	12,400	13,363	14,381	14,790

These estimates do not necessarily imply a similar reduction in the number of *opioid dependent* people. There has been an increasing number of persons in pharmacotherapy in NSW; in 2002, almost 15 000 persons were in pharmacotherapy for opioid dependence (Table A).

Discussion

In periods where there are dramatic and sudden changes to the extent of drug supply in the community, making estimates of potential changes in the population of users is a difficult process. Methods that use data from a long window period (such as capture recapture), or which require data on longer term trends in drug use and its progression (such as back projection), may be less able to provide estimates that correspond to known changes in trends in existing indicator data. Multiplier methods, because of their relatively straightforward use of these indicator data, may be better suited to indirect estimates of the population in these periods. It will be of use to repeat this estimation exercise in two to three years.

1. INTRODUCTION

Heroin (diacetylmorphine) is produced from the opium poppy, *Papaver somniferum*. Opiates such as morphine, opium and codeine are all natural derivatives of the opium poppy, whereas methadone and pethidine are synthetically produced opioids.

The use of opiate drugs has a long history in Australia (McCoy, 1980a). Concern about the use of heroin began to rise in the 1980s, following an apparent increase in heroin related harms such as overdose deaths. Political concerns about the visibility of heroin use and property crime committed by dependent heroin users led to a Special Premiers' Conference that launched a National Campaign Against Drug Abuse (NCADA), with additional Federal funding for drug programs. Despite increased funding for treatment and harm reduction, the heroin market in Australia – and its related harms - increased. The increase began in the early 1990s, but was particularly marked in the mid 1990s, when national illicit drug monitoring systems were established (Fry & Topp, 2002; Shand, Topp, Darke, Makkai, & Griffiths, 2003).

Data from these monitoring systems indicated that during the mid to late 1990s, heroin was the drug injected most often in Australia (MacDonald, Robotin, & Topp, 2001). In six jurisdictions drug market participants reported that heroin was consistently available (Darke, Hall, & Topp, 2000); the purity of heroin was relatively high; and the price of heroin either remained stable or decreased every year.

Early in 2001, anecdotal reports were received of a sharp reduction in the availability of heroin across Australia. These reports were initially confirmed by research in convenience samples (Day et al., 2003; Weatherburn et al., 2001), and later confirmed in the monitoring systems that had documented the increasing heroin availability during the previous five years (Darke et al., 2002; Topp, Kaye, Bruno, Longo, Williams, O'Reilly, Fry, Rose, Williams et al., 2002). Greater detail on the causes, course and consequences of the reduction in heroin supply will be provided in 2004, with the publication of reports from an 18 month study of the issues by researchers from in NSW, Victoria and South Australia (Degenhardt & Day, 2004; Degenhardt, Day, & Hall, 2004; Dietze et al., 2004; Harrison, Christie, Longo, Pointer, & Ali, 2004). This work clearly documented a

decline in the frequency of heroin use among regular heroin users, and reduced availability of heroin, in 2001 (Topp, Day, & Degenhardt, 2003).

In this way, the period 1997 to 2002 - the period of interest for this report - was characterised by a period of increasing heroin availability in 1997-2000, followed by a sharp and sustained reduction in availability from 2001. This report seeks to examine which methods for estimating the number of heroin users are most appropriate to use when the numbers of heroin users may be rapidly changing in response to marked changes in availability of their drug of choice.

Achieving this aim is not simple. As will be outlined below, making estimates of a hidden population, such as heroin users, is difficult for a range of reasons in the best of circumstances. Added to these difficulties are complications introduced by marked changes in drug supply.

1.1. Populations of heroin users

Before attempting to make estimates of the number of heroin users, it is necessary to ask to the following question: "Which "population" of heroin users are we wanting to estimate the size of?"

Estimates of the size of such populations have been made previously in both Australia and overseas. In most cases, such estimates have been made during a period where it has appeared that the market conditions have either been relatively stable, or changing in a consistent manner.

The estimates produced have variously defined the population of concern as: "opioid dependent users" or "heroin dependent users" (Hall, Ross, Lynskey, Law, & Degenhardt, 2000a; Law, Lynskey, Ross, & Hall, 2001; National Drug Abuse Data System, 1988; Sandland, 1984, 1986), "problem drug users" (European Monitoring Centre for Drugs and Drug Addiction, 1999), or "injecting drug users" (Duque-Portugal, Martin, & Taylor, 1994; Hser, 1993). In a steady state, the difference between a regular or problematic heroin user, and an opioid dependent person, may be of little import.

Such definitional issues may seem semantic. However, in the context of the rapid decline of heroin availability, it seems important to examine this critically. This is because it may not be the case that all heroin users change their patterns of heroin use in the same way if heroin became less available, more expensive and less pure.

1.1.1. Dependent heroin users

Heroin dependence can be defined as the loss of control over heroin use, as indicated by continuing to use heroin in the face of problems that the user knows or believes are caused by its use, including legal difficulties, interpersonal problems and health problems. Dependent heroin users in Australia typically inject heroin daily or near daily (Bell et al., 1995).

Epidemiological research indicates that substantial numbers of heroin dependent persons do not come to the attention of drug treatment services or the legal system. (Anthony, Warner, & Kessler, 1994; Eisenhandler & Drucker, 1993). Some of these dependent users discontinue their heroin use without professional assistance (Biernacki, 1986; Johnson, 1978). However, dependent heroin users who seek treatment and who come to the attention of the legal system may continue to use heroin for decades (Goldstein & Herrera, 1995; Hser, Hoffman, Grella, & Anglin, 2001; Vaillant, 1988; Vaillant, 1973). Among these chronic users, periods of daily heroin use are interrupted by detoxification, drug treatment and incarceration for drug-related offences. That is, at any point in time, some dependent heroin users may not be using heroin on a daily basis.

1.1.2. Regular heroin users

Research that aims to make indirect estimates of the number of heroin users often uses data such as arrests for heroin possession or use, heroin overdose figures, and numbers in treatment for heroin as markers of current "regular", "dependent" or "problematic" heroin use (see section 1.2). In the context of stable or slowly changing market conditions, it may be reasonable to assume that the population of dependent heroin users is broadly similar to the population of regular heroin users; that is, that many or most heroin dependent heroin users will also be regular heroin users (since regular or recurrent heroin use is one feature of dependence).

It is less clear what we might expect when there is an interruption to heroin supply in a community. Will *all* dependent heroin users continue to use heroin on a regular basis? Will they switch to using other drug types? Will they cease heroin use? Further, if some users cease heroin use, would it be a temporary or permanent change in use patterns? In the current report, we attempt to estimate the number of regular heroin users across time, and discuss the findings in the light of other evidence on drug use patterns in NSW.

Indicators that reflect *current, active heroin use* as opposed to dependence may be better able to demonstrate changes over time, especially if it is hypothesised that the number of persons *currently* using the drug may have decreased, even though the numbers of those who are dependent may have only marginally decreased. Such changes may be relevant to policy-makers who are addressing issues related to acute harms related to current use, rather than latent dependence. Indicators that are good reflections of current use are a) fatal overdoses; b) non-fatal heroin overdoses; c) arrests for heroin offences; and d) *registrations* for heroin treatment (such as pharmacotherapy maintenance treatment or PMT).

1.2. Methods of making estimates of the number of heroin users

There are substantial technical difficulties in estimating the number of heroin users in Australia or in any other population. In most developed societies, heroin use is illegal and a stigmatised activity that is practiced in private by consenting adults who prefer others not to know about their behaviour. There are no well-tested and widely accepted "gold standard" methods for producing credible estimates of the number of people who make up the "hidden population" of dependent heroin users (Hartnoll, 1997).

The preferred strategy is to look for convergence in estimates produced by a variety of different methods of estimation (European Monitoring Centre for Drugs and Drug Addiction, 1997, 1999). These methods can be classified into two broad types: direct estimation methods that attempt to estimate the number of heroin users in representative samples of the population; and indirect methods which attempt to use information from known populations of heroin users (such as those who have died of opioid overdoses,

and those who are in treatment or the criminal justice system) to estimate the size of the hidden population of heroin users.

Further, unlike previous estimates of the number of heroin users in Australia (Hall, 1995; Hall, Ross, Lynskey, Law, & Degenhardt, 2000b; Heather & Tebbutt, 1989; National Drug Abuse Data System, 1988), what is unique about the current exercise is that it is attempting to discover whether an abrupt reduction in heroin supply has reduced the number of active dependent users in the population. Potential rapid changes in the number of heroin users means that some methods of estimating the number of users may be less reliable than they would have been in periods of less rapid change, because many of these methods assume either that the heroin dependent population has reached a steady state or that it is expanding at a constant change over the period for which an estimate is to be provided.

1.2.1. Direct estimates: Surveys of drug use

The most direct way to estimate the proportion of people who have engaged in behaviour that affects health is to ask a representative sample of the at risk population whether and how often they have engaged in that behaviour. School surveys detect too few dependent heroin users to be useful because dependent heroin use typically develops after adolescents have left school (Lynskey, White, Hill, Letcher, & Hall, 1999). Household surveys of adults provide better representation of the population at risk but they are likely to underestimate the number of heroin users in the Australian population for a number of reasons.

First, household surveys of drug use are likely to under-sample heroin users who are concentrated in a small number of geographic areas, usually those where heroin is most readily available (Griffiths, Farrell, & Howe, 1997). In New South Wales, for example, 35% of overdose deaths between 1992 and 1996 occurred in two areas of Sydney around major heroin markets, namely Kings Cross and Cabramatta (Darke, Ross, Zador, & Sunjic, 2000). A representative sample of the Australian population will include very few persons who are resident in these areas.

Second, heroin users' lifestyles make them less likely to live in conventional households, and less likely to participate because of unavailability or reluctance to be interviewed.

Heroin dependent persons are accordingly likely to be over-represented among the 35% to 50% of eligible respondents who decline to participate in NDS Surveys (Makkai & McAllister, 1998).

Third, even when heroin users are selected in a sample and agree to be interviewed, their heroin use is likely to be under-reported because it is an illegal and stigmatised behaviour.

Fourth, these surveys provide at best a crude indication of *dependent* or even *regular* heroin use. In most surveys, respondents are asked whether they have ever used heroin and the frequency of heroin use in the past year. Rarely is any attempt made to estimate daily heroin use or to assess symptoms of heroin dependence.

Fifth, heroin use is rarely reported in household surveys. Small numbers of persons reporting use make the estimate less reliable, and detailed estimates of age and gender breakdown almost impossible to do in a valid way.

It is worth noting that recent work has attempted to make more sophisticated use of survey data in modelling population trends in heroin use since the 1970s (Kaya et al., 2004); however this is likely to be ill-equipped to account for dramatic, short term changes in market conditions.

1.2.2. Indirect estimates: Multiplier methods

A simple way to estimate the number of regular heroin users in the population is to multiply the number of known heroin users in some accessible population (e.g. persons who have died from an opioid overdose) by a factor that reflects the probability a regular heroin user will be a member of that subpopulation (e.g. the proportion of heroin users who overdose in a given year) (Frischer, 1998; Kraus et al., 2003). The multiplier method is easy to understand and requires very little data. Further, it begins with a count of the number of persons who one can be reasonably confident are regular heroin users (e.g. persons dying from opioid overdoses) (Hall et al., 2000b).

The method nonetheless has its limitations (Frischer, 1998). First, multiplier methods presuppose that we know the probability that a regular heroin user will be in the sample.

This may be estimated from a) information collected on a subsection of the population of heroin users (e.g. a cohort of heroin users) (Frischer, 1998); or b) the implied probability calculated from other estimates of the total number of heroin users (Hall, 1995). Second, the probability may not remain constant over time, and may not be the same in different countries or regions (Frischer, 1998; Hall et al., 2000a). Third, the multiplier method assumes that the number of heroin users in the sample is known (e.g. the number of persons dying from opioid overdoses), and is therefore dependent upon the accuracy of recording and identification practices, which themselves may change over time (Frischer, Hickman , Kraus, Mariani, & Wiessing, 2001; Kraus et al., 2003).

Despite these limitations, multiplier estimates based on mortality (Frischer, 1998; Hartnoll, 1997; Hartnoll, Lewis, Mitcheson, & Bryer, 1997) and treatment data (Hall et al., 2000b) have often produced estimates that have been consistent with estimates produced by other methods, such as capture-recapture methods. They also have the advantage that they produce methods that reflect the immediacy of the data on which they are based and so are able to reflect rapid changes in the number of heroin users.

1.2.3. Indirect estimates: Capture-recapture methods

The capture-recapture method for estimating a population size was developed in population biology where it has been used to estimate the numbers of fish and other animals in wild populations. It requires a minimum of two samples from the population of interest. Members of the first sample are returned to the wild after being "marked" in a way that permits those who are recaptured in a second or subsequent samples to be identified. Analysis of the capture- recapture patterns provides an estimate of the hidden population that has not been captured, and hence allows the total population to be captured (Domingo-Salvany, 1996; Sandland, 1984, 1986). Capture-recapture methods have been used to estimate the number of problem drug users, both using two different data sources that capture problem drug users (Duque-Portugal et al., 1994; Kehoe, Hall, & Mant, 1992) and repeated samples from the same source ((Hall et al., 2000b; Sandland, 1984, 1986) (Refer Appendix C for further details).

In this report, we use the procedures outlined by Sandland to produce separate multiple sample capture-recapture estimates of the number of heroin users in NSW from two data sources, using the analysis from four successive capture periods (Sandland, 1986). The

data used for these analyses were: a) data on arrests for heroin related offences during the eight year period from 1995-2002 and; b) data on entry to PMT 1997 to 2002. Data over four successive capture periods was used to estimate the hidden population. In both of these data sources, captured individuals are typically not immediately released (individuals arrested for heroin offences may serve custodial sentences, whilst individuals registering for pharmacotherapy spend time in a program before discontinuing and being available to re-register). Accordingly, the capture period must be long enough to enable (ideally all) individuals to be released and available for recapture in the following capture period. However, an increase in the capture period results in a fourfold increase in the analysis period (Sandland, 1986) so that a longer capture period can significantly reduce the responsiveness of the analysis to rapid changes in the data source. In this study, we investigated the most appropriate capture period to use for each of the two data sources by examining data on the length of the capture period for each data source and by comparing the effect of using six monthly and annual capture periods. (refer to Appendix C for more a more detailed explanation of the method and its limitations) (Sandland, 1984, 1986).

We assigned a "midpoint" for each estimate, such that if a one-year capture period was used (with four capture periods), the estimate was assigned to the second year of the period; and if a six month capture period was used, the second six months.

1.2.4. Indirect estimates: Back projection methods

The back-projection method, widely used to estimate HIV incidence from AIDS incidence data (see De Angelis et al, 1998 (with discussion)) can be applied to other indicators of regular heroin use, such as the number of fatal opioid overdoses or new entrants to pharmacotherapy treatment, to estimate the past incidence of regular heroin use (Hall et al., 2000a; Law et al., 2001).

The back projection method uses estimates of the rate at which people progress from regular heroin use to either fatal opioid overdose or first entry to PMT to back project the number of people who became regular heroin users in any one year. These back projections are then combined with assumptions about the rate at which people cease heroin use to estimate the number of heroin users in any year (Law et al., 2001) (Refer Appendix D for further details).

Aims

The aims of the current study were to examine methods with which to estimate the number of regular heroin users in NSW (for discussion of Australian estimates, please see Degenhardt et al., 2004). In particular, we wished to consider:

1. Are some methods less sensitive than others to changes in the supply and use of heroin (and potentially the number of regular heroin users)?;
2. Are there problems with the use of some estimation methods in the context of rapid suspected changes in the size of a hidden population?
3. Do different sources of data provide information about different subsets of the group of regular heroin users?

The estimates of the number of the number of regular heroin users are presented in detail in Degenhardt et al (2004).

In considering these questions, we have examined the estimates of NSW regular heroin users over the period 1997-2002 derived from different sources and methods.

2. METHOD

The data sources that were used in the current study included:

1. national data on the number of opioid induced deaths per year compiled by the Australian Bureau of Statistics;
2. data on ambulance attendances at suspected drug overdoses provided by the NSW ambulance service;
3. the NSW Health Department's heroin pharmacotherapy client database provided by the Pharmaceutical Services Branch (PSB);
4. data on arrests for drug offences provided by the NSW Police Service; and
5. data provided by the Alcohol and Drug Information Service (ADIS) on calls received related to heroin use.

Population estimates were obtained from the ABS estimates of the resident population in the mid point of each calendar year.

The above data sources were examined for trends in numbers, gender and age distribution. The study focussed on data pertaining to individuals aged 15-54 years. The age range was selected on the basis of previous analyses of illicit drug mortality (English et al., 1995) and trends in fatal opioid overdoses in Australia (Degenhardt & Barker, 2003b), which suggest that most heroin use and fatal opioid overdoses occur among adults within these age groups. The use of a focussed age range also eliminated other drug related incidents associated with the elderly.

Using the above data sources, a number of annual estimates of the number of regular heroin users (aged 15-54) in NSW were made for each of the 6 years, in the period 1997 to 2002. The specific methods used are set out below. The estimates produced by the different methods were considered in the context of the uncharacteristic changes in heroin use associated with the heroin shortage in 2001.

2.1. Opioid induced deaths

Data were obtained from the Australian Bureau of Statistics (ABS) for each Australian State on gender and age at death for fatal opioid overdoses (including heroin, opium, methadone and codeine) among Australian adults aged 15-54 years, between 1964 and 2002 inclusive (refer Appendix A for details of the ABS classifications used).

2.1.1. Trends

Trends in the levels of fatal opioid overdoses were examined over the period 1980 to 2002. As the opioids overdose time series provides high quality information about fatal opioid overdoses over a longer time period than other sources of data used in this study, the data was also used to compare the pattern of overdose deaths in the period 1997-2002 (the period of the current study) with patterns observed over the period 1980 to 2002.

2.1.2. Multiplier estimate

A multiplier estimate of the number of regular heroin users was obtained for NSW, using the number of fatal opioid overdoses and a multiplier of 112.5 (refer Appendix B).

2.1.3. Back projection estimate

The annual number of fatal opioid overdoses in Australia for individuals aged 15-54, for the period 1964 to 2002 was used to estimate the number of regular heroin users in Australia by the back-projection method (Hall et al., 2000b; Law et al., 2001; Sandland, 1986). The Australian, rather than NSW figures were used as the number of NSW fatal overdoses, particularly in the early years, was small. Detailed assumptions are provided in Appendix D.

The resulting overall rates of progression from commencing regular heroin injecting to overdose deaths based on these assumptions are shown in Appendix D. These rates of overdose deaths were assumed to be constant throughout the period 1960 to 2002. Estimates for NSW for the period 1997-2002 were derived by assuming that they formed

44.2% of total Australian regular users, the average ratio of NSW to Australian fatal overdoses for the period 1997-2002 (Degenhardt, Rendle, Hall, Gilmour, & Law, 2004).

2.2. Ambulance calls to suspected heroin overdoses

The Ambulance Service of NSW provided data on cases where an ambulance attended a person with whom the poisonings protocol was used and naloxone administered ("naloxone ambulance call outs"). This study used information on the date of each ambulance attendance for the period from the 1st January 1997 to the 30th December 2002 (see Appendix A for further details).

2.2.1. Multiplier methods

Ambulance data was used in conjunction with a multiplier of 10.1 derived from the Hall et al (2000) estimate of dependent heroin users (see Appendix B for further details), to provide a multiplier estimate of the number of regular heroin users in NSW.

2.3. Heroin arrests

Data were obtained from the NSW Police Service on the following heroin-related arrests in NSW between 1995 and 2002: possession, use/administration, possession of a drug utensil, other drug offence, supply of drug/plant, and importing a drug/plant. Each record in the database represents a new offence and an individual may be charged with several offences. Similarly, several people may be charged for the same incident. However, each arrestee had a unique identifier, which enabled us to remove double counting of individuals within as given time period. The variables used were: type of offence (as set out above), date of offence, and age and gender of the offender (refer Degenhardt et al (2004) for further details).

To ensure consistency of data, birth dates were compared across all offence records for an individual, over the period 1995-2002, and where the difference in stated birth dates was greater than one year, the birth date data was not used. In addition there was no birth date recorded for a number of individuals. Similarly for a number of individuals, sex was not recorded (see Degenhardt et al (2004)). Some missing age and sex data occurred

in this data, and although these trends need to be interpreted with some caution, there was no evidence to suggest any bias in these cases.

2.3.1. Multiplier estimate

The arrest data was used in conjunction with a multiplier of 20.8 derived from the Hall et al 2000) estimate of dependent heroin users (see Appendix B), to provide a multiplier estimate of the number of regular heroin users in NSW.

2.3.2. Capture-recapture methods

Arrest data was used as the basis for a capture-recapture study using similar methods to those outlined in Appendix C. To investigate the effect of using different capture periods (see Appendix C), two different analyses were undertaken using capture periods of six and twelve months. In the analysis using six month capture periods, data on individuals who were arrested for heroin offences during 1997-2002 was used to form five, two year blocks of data, starting 1997-1998 and finishing 2001-2002. In the analysis using annual capture periods, data on arrests for heroin related offences during the years 1996-2002 was used to form four, four-year blocks of data, starting 1996-1999 and finishing 1999-2002. Further details of input data are provided in Appendix C. A number of arrest records did not have valid age data (see Degenhardt et al (2004)), so that it was not possible to exclude individuals who did not fall in the 15-54 age group; based on the distribution of ages for the records that have valid age data, approximately 1% of records fell outside the 15-54 age group for all or part of the capture periods.

To further understand the effect of using capture periods of different lengths, sentencing data for primary opioid offences was examined (see Appendix C).

2.4. Pharmacotherapy maintenance treatment

We were given access to a subset of the Pharmacotherapy (methadone and buprenorphine) Patient Management Database maintained by the Pharmaceutical Services Branch (PSB) of the New South Wales Health Department (PSB database) for the period 1987 to June 2003. The PSB database is used by the NSW Health Department to monitor dispensing of pharmacotherapy (methadone and buprenorphine) in New South Wales. The data it contains are derived from forms that are completed: when a medical practitioner applies for an authority to prescribe pharmacotherapy to a client, when a course of pharmacotherapy maintenance is terminated, or when a client is transferred to another program.

Records were de-identified by the PSB to maintain client confidentiality, however, individuals were uniquely identified by an arbitrary number assigned by the PSB. The variables used were: date of birth, sex, leaving code (to identify those that did not commence treatment) and the date of treatment entry/exit and number of treatment to identify first time users. All valid records included age and sex data.

2.4.1. Trends

The trends in the total number of clients in PMT treatment for NSW as at 30 June, the annual number of PMT registrations made and the annual number of PMT first time entrants for the period 1997 to 2002 were examined. Data was obtained from the PSB database. Clients counted as being in treatment as at 30 June were those who had started an episode of treatment on or before 30 June of the relevant year which had not been terminated on or before 30 June of the relevant year. Clients with a leaving code that indicated that they had not commenced treatment were excluded. Re-registrations for clients who were re-registering for PMT within 7 days of leaving a previous PMT program were not included, as it was considered that these individuals were effectively in continuous treatment.

2.4.2. Multiplier estimates

The number of individuals registered for PMT as at June 30, has previously been used as the basis for a multiplier estimate of the number of regular heroin users (Hall et al., 2000b). However, contrary to other indicators of the number of regular heroin users, which suggest that the number of heroin users was higher in 2000 compared to 2001 and 2002 (see results), the number of individuals in PMT in NSW as at June 30 has continued to increase. The continued increase in total PMT registrations is likely to reflect the inclusion of individuals who enter and continue with methadone treatment programs but may not be longer current, regular heroin users. In the current case, the appropriate multiplier to apply to total PMT registrations is likely to change (decline) each year. In the absence of a continuing cohort study of heroin users, this makes it difficult to obtain estimates of the multiplier; however, data from the NSW IDRS are consistent with this, with a higher proportion of those reporting regular heroin use also reporting being in methadone treatment (Roxburgh, Breen & Degenhardt, 2004). It is unclear what the appropriate multiplier might be, however, in the absence of data from less sentinel heroin users than those in the IDRS.

The number of PMT *registrations* (both new and re-registrations) is probably a better reflection of regular heroin users in any given year (see results) and has been used as the basis for a multiplier estimate of regular heroin users (see results). In the absence of reliable and appropriate multipliers, the PMT annual registration data was used in conjunction with a multiplier of 7.6 derived from the Hall et al (2000) estimate of dependent heroin users (see Appendix B), to provide a multiplier estimate of the number of regular heroin users in NSW.

2.4.3. Capture-recapture methods

PMT data was used as the basis for a capture-recapture study using a similar method to that used for heroin arrest data and as described in Appendix C. To investigate the effect of using different capture periods (see Appendix C), two different analyses were undertaken using capture periods of six and twelve months. In the analysis using six month capture periods, data on individuals who registered for PMT programs during the years 1997–2002 was used to form five two-year blocks of data, starting 1997-1998 and finishing 2001-2002. Similarly, in the analysis using annual capture periods, the data on

individuals entering PMT programs during the years 1996-2002 was used to form three, four year blocks of data, starting 1996-1999 and finishing 1999-2002.

To further understand the effect of using different length capture periods, distribution of the time that individuals registering in programs over the period 1997-2002 was examined (see Appendix C).

2.4.4. Back projection methods

The number of new entrants to PMT in NSW for each year during 1970 to 2002 was also used to estimate the number of regular heroin users in NSW using the back-projection method (Law et al., 2001) (refer Appendix D for further details).

Two back projection analyses were undertaken, the first using data for 1970-2000, which excluded the years with the uncharacteristic decline pattern and the second for 1970-2002, which included the years with the uncharacteristic decline pattern.

2.5. ADIS calls about heroin use

The Alcohol and Drug Information Service (ADIS) is a 24-hour telephone information and counselling service in NSW. ADIS staff complete a 'call register form' for each call that their service receives. ADIS provided a copy of the data on all heroin-related calls received from January 1997 to December 2002.

This data had a number of limitations. There are no unique identifiers so the same person may have called several times but this was true across all years and there is no reason to believe that the pattern of multiple calls by the same individual would have changed over the period. Nevertheless the ADIS data differs in this respect from the other data sources examined in this study. Some of the increase in calls in the first years of the service (1992) may also be partially attributable to an increased awareness of ADIS among the public, although this is less likely to occur from the late 1990s. Further the ADIS call data does not typically include demographic data, although this limitation does not affect the validity of the number of calls received.

In view of these specific limitations of the ADIS call data this data source has not been used in previous estimates of the number of NSW regular heroin users (Hall et al, 2000). This study investigated whether the ADIS heroin call data (specifically, call data where heroin was the first drug discussed) would provide an additional source of data for multiplier estimates of regular heroin users by comparing the pattern of the number ADIS calls with the median of the multiplier estimates of regular heroin users.

2.6. Comparison of data sources

The data sources described above provide different ways of accessing and measuring subsets of heroin users. To investigate the information provided by the different data sources, they were compared by examining the following: levels relative to 1999, the year in which a number of indicators peaked; age; and gender. Further details of the demographic trends and methods are given in Degenhardt et al (2004).

2.7. Estimates produced

The estimates of the number of NSW regular heroin users produced by each of the three different methods (multiplier estimates, capture recapture estimates and back projection estimates) were compared with other estimates produced. A median estimate of the four multiplier estimates was calculated. The median multiplier estimate was compared with the median estimate using all appropriate estimates. The various methods and data sources were evaluated to determine the most appropriate methods and data sources to use to estimate the number of NSW regular heroin users in periods of rapid change, as experienced in 1997-2002.

Following an examination of the results of different methods, it was decided to base the primary estimate of the number of regular NSW heroin users on the multiplier method, and to use the estimates from capture-recapture and back projection analyses to confirm the multiplier estimates. Accordingly, the estimate of regular heroin users aged 15-54 in NSW for each of the years 1997-2002 was calculated as the median of the multiplier estimates of regular heroin users aged 15-54.

3. RESULTS

In this section we have reviewed trends in two sources of data, fatal opioid overdoses and PMT. Opioid overdose data is relatively consistently collected according to stringent criteria and provides a long term indicator of trends in heroin usage. Trends in PMT data are discussed because different aspects of the data have different trends and associated characteristics. Detailed trends in other data sources are reviewed in Degenhardt et al (2004).

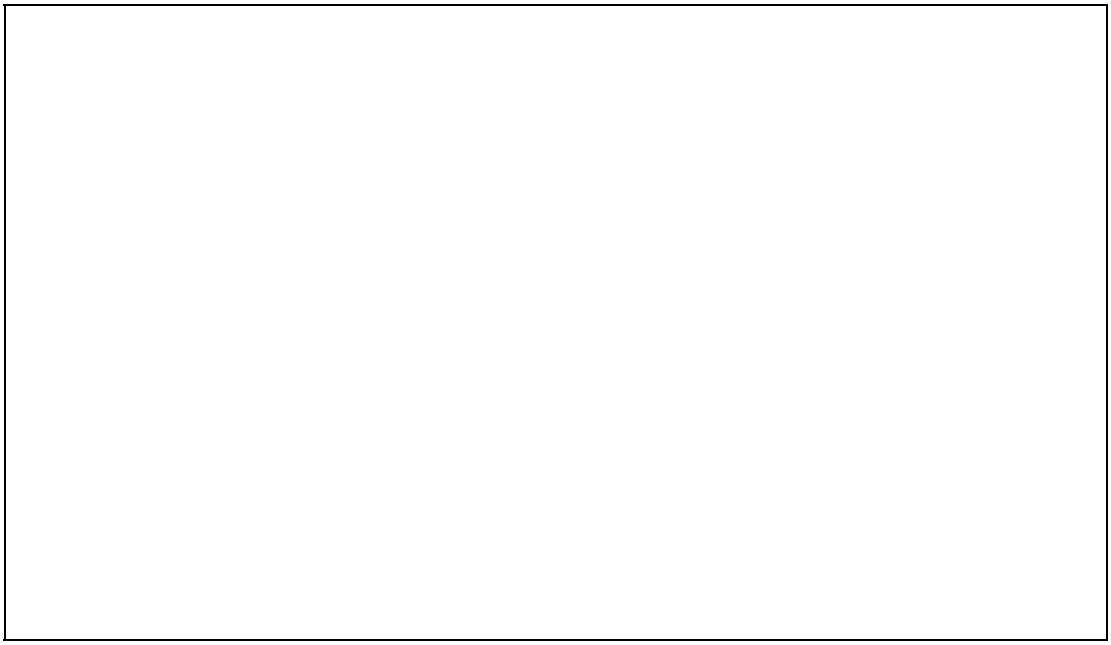
3.1.1. Opioid induced deaths

The number of deaths attributed to opioids among NSW adults aged 15-54 years increased from 35 in 1980 to a peak of 481 in 1999, declining to 158 in 2002 (Figure 1). A similar pattern occurred in the number of Australian opioids deaths for adults aged 15-54, which increased from 56 in 1980 to a peak of 1116 in 1999 declining to 364 in 2002. Similarly, the rate (per million adults aged 15-54) increased 11-fold for NSW and 15-fold for Australia in the period 1980 to 1999. By 2002, the rate had dropped to 32% of the 1999 value for both NSW and Australia[1] (Degenhardt & Barker, 2003a).

The period 1997-2002 showed an uncharacteristic pattern of change in the number of NSW overdose deaths, with a period of uncharacteristic of increase (1997-1999) followed by a period of uncharacteristic decrease (2000-2002). There were both high levels of change in individual years and consecutively over a three-year period. The annual increase in NSW overdose deaths of 36% in 1998 was the highest annual increase since 1988 (59%). Further, in the three-year period 1997 to 1999 there was an 85% increase in the rate of NSW overdose deaths compared to the level in 1996. An increase of this magnitude had not occurred since 1983 and 1984, where three year increases of 198% and 106% had occurred off a relatively small base of overdose deaths 21 in 1980.

[1] The use of definitions of opioid overdose from the ICD-10 classification system for the causes of death in 1997 led to a 12% increase in the estimated number of fatal opioid overdoses compared estimates generated under the ICD-9 system. This increase was included in the rise in fatal opioid overdoses shown for 1997.

Figure 1: Number of fatal opioid overdoses among persons aged 15-54 years, 1980-2002, for NSW and the rest of Australia



The annual decreases in NSW opioid overdose deaths of 27% and 49% that occurred in 2000 and 2001 respectively were the highest that occurred over the period 1980-2002. Similarly, the consecutive three years of decline in 2000-2002 resulted in a decrease in overall opioid overdose deaths of 67% relative to the 1999 level which was the highest decrease that occurred over a three year period between 1980 and 2002. Thus the period 1997-2002 included both uncharacteristically large annual and three year increases and decreases in the level of opioid deaths. These changes are related to the increasing availability of heroin in the mid to late 1990s and the reduction of availability in 2001 (Gibson et al., 2003).

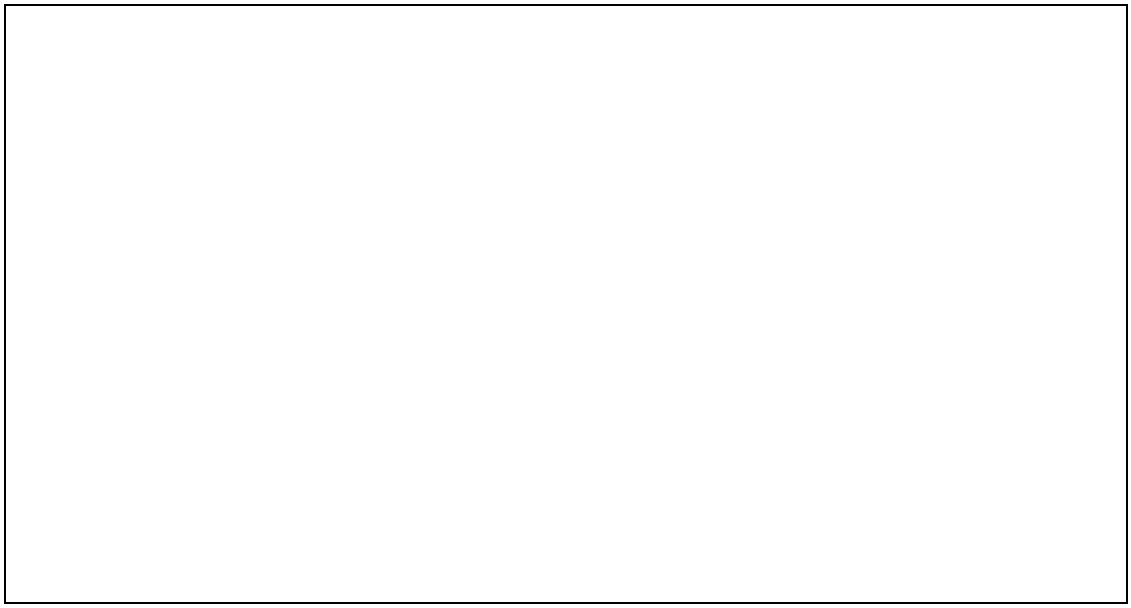
Further details of trends in NSW and Australian overdose deaths including demographic trends are provided in Degenhardt et al (2004).

3.1.2. Pharmacotherapy maintenance treatment

The total number of individuals registered for pharmacotherapy as at June 30 showed a steady pattern of increase over the period 1997-2002. This pattern is in contrast to the pattern of fatal opioid overdoses, arrests and calls about heroin. Individuals receiving PMT receiving treatment includes individuals who commenced programs in previous

years and although may still be heroin dependent may not be regular heroin users (see Section 1.1), reflecting the cumulative number of individuals who have developed heroin dependence *at some point previously*, rather than current regular heroin users.

Figure 2: NSW trends in the number of individuals registered for pharmacotherapy as at June 30, annual registrations made and new entrants for the period 1997-2002



The total number of individuals registering for treatment comprises re-registrations and the number of new entrants. Both re-registrations and new entrants showed a similar pattern of increase during 1997-2000; new registrations declined in 2001, whereas re-registrations were less affected. Throughout the period 1997-2002, the proportion of registrations represented by re-registrations increased from 52% in 1997 to 62% in 2002.

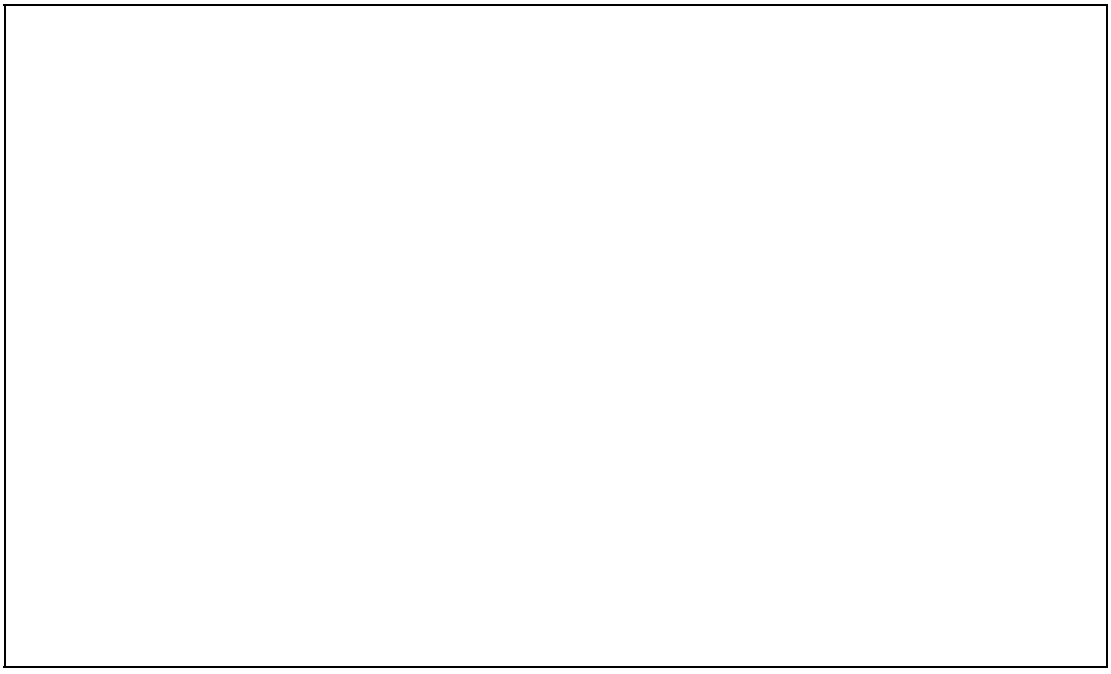
The total number of registrations is likely to be the most representative of regular heroin users, as individuals registering for PMT treatment presumably need to demonstrate a current heroin problem at the time of registration, in contrast to individuals who have remained in programs for some years. The total number of registrations probably includes longer-term users (re-registrations), and those who may have commenced heroin use more recently (first time entrants).

3.2. Comparison of trends across data sources

Fatal opioid overdoses, heroin arrests and naloxone ambulance call outs showed a similar pattern of increase and decrease over the study period (Figure 3). All had increases above the 1997 level in 1998 and 1999 (although naloxone ambulance call outs showed a slight decrease in 1999 relative to 1998), and all showed a substantial decreases in 2000 and 2001. In 2002 there was less similarity between these sources with fatal opioid overdoses and naloxone ambulance call outs showing a further small decrease whilst there was an increase in the number of heroin ambulance call outs.

The data sources PMT registrations and PMT first time entrants showed a similar pattern to each other in that they both increased in 1998 to 2000, showed a decrease in 2001, and then increased in 2002 (Figure 3). Although these two data sources show a general pattern of increase followed by a decline, the decline is lagged compared to the other sources (above) and is less prolonged, lasting for only one year.

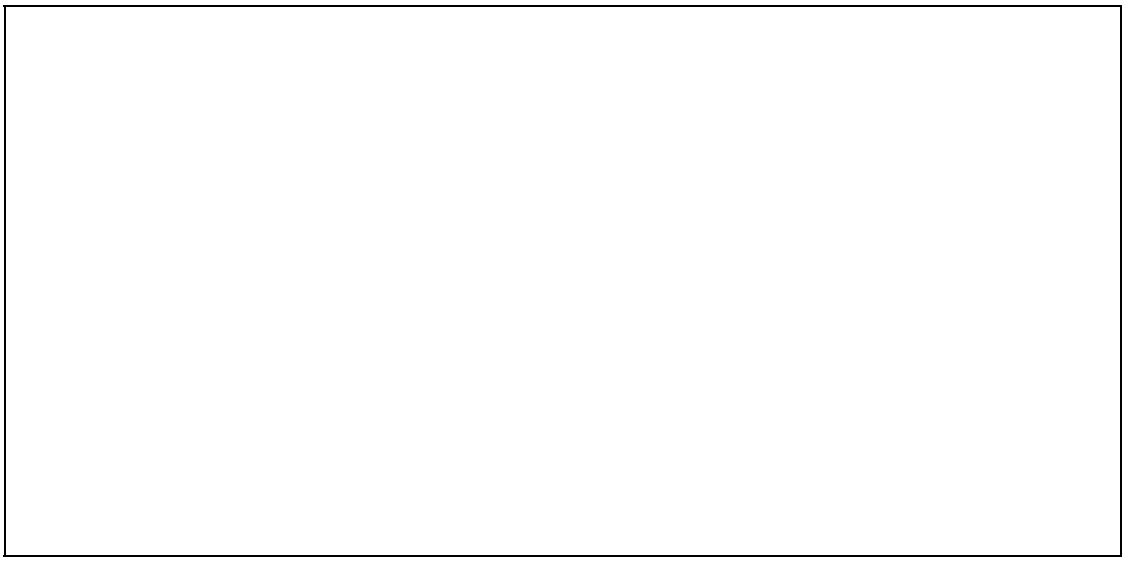
Figure 3: Trends in different heroin related data expressed relative to base 1999



All data sources showed an increase in average age over the period 1997-2002, with the average age of fatal opioid overdoses and heroin arrests increasing the greatest (11% over the period) and PMT first time registrants and PMT registrations the least (2% and 4% respectively; Figure 4). Across the period 1997-2002, the range in average age was

approximately 7 years, with typically PMT registrations having the highest average age and PMT first time registrants the lowest average age. The increase in average age reflects, at least in part, the ageing of existing users. The low average age and low increase in average age for PMT first time registrants may reflect the fact that this data source measures recent initiates to regular heroin use and as such does not include an ageing cohort of users. It also indicates that the age distribution at which individuals first register for PMT is relatively stable (see Appendix E).

Figure 4: Average age of individuals by data source compared with the average age of the NSW population among those aged 15-54 years, 1997-2002



The differences in average ages and rates of change across the different data sources suggest that the data sources are providing information about different (if overlapping) subsets of regular heroin users.

Figure 5: Percentage of males in data groups for years 1997 to 2002

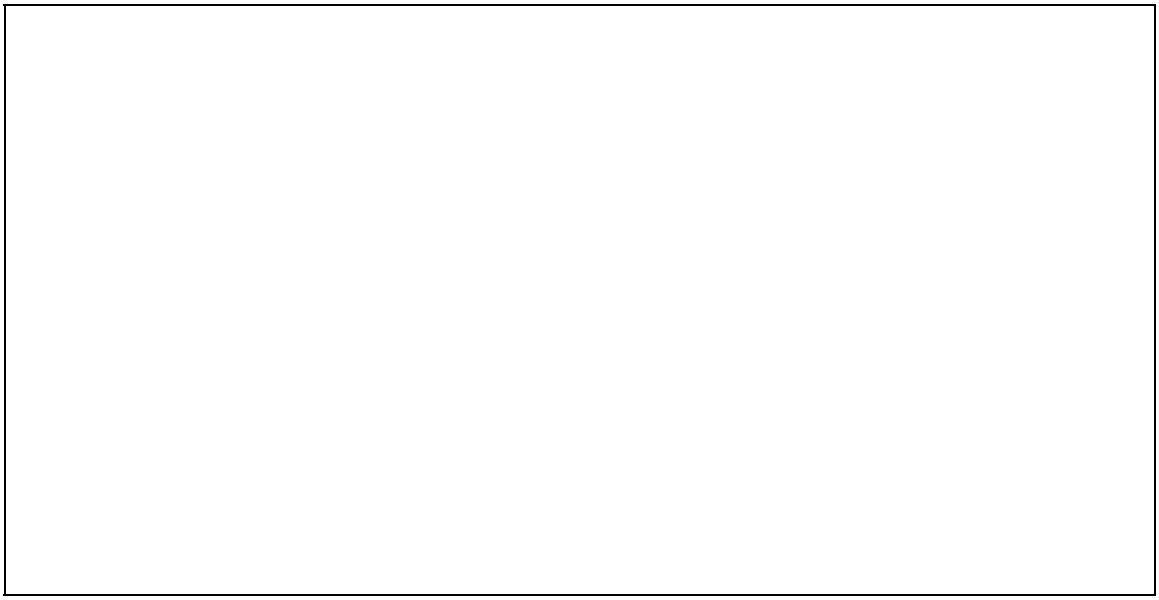


Figure 5 shows that males were most highly represented among persons who were arrested for heroin offences and among those who died due to opioid use. All data sources had higher proportions of males than the average for the NSW population.

In all data sources males outnumbered females although there was considerable variation in the proportion of males in different data sources. Fatal opioid overdoses and heroin arrests had the highest proportion of males (averaging 80% and 79% respectively) whilst PMT registrations and PMT first time registrants had the lowest (averaging 66%) and naloxone ambulance call outs was also low averaging 68%. In the period 1997-2002 the proportion of males was relatively stable in a particular data set although for all data sets the proportion of males decreased in 2001, the nadir of the heroin shortage.

3.2.1. Comparison of data sources

The four data sources described above were selected as they provide different ways of being able to directly look at the population of heroin users. The rapid change in the heroin market in the period 1997-2002 (Degenhardt & Day, 2004) provides an opportunity to critically examine these data sources in a different environment to that of a market with relatively consistent change rates e.g. constant growth (1980-1998).

Changes in the three data sources fatal opioid deaths, heroin arrests and naloxone ambulance call outs were similar and consistent with known changes in the availability of heroin (Breen et al., 2003; Topp, Kaye, Bruno, Longo, Williams, O'Reilly, Fry, Rose, & Darke, 2002). This suggests that all of these data sources reflect the effect of heroin availability on usage and harms.

Is each data source representative of the set of NSW regular heroin users? If each data source is in fact representing the complete set of heroin users we would expect that the demographic characteristics of each data source to represent the demographics of the set of regular heroin users and hence to be similar across the data sources. However, the different demographic profiles across the data sources suggest that they are likely to be providing a representation of different but probably overlapping groups of regular heroin users.

The remaining data source (PMT registrations and the subset of PMT first time registrants) showed less similarity to the other data sources. Although both showed a decrease following the heroin shortage, this was lagged by a year and less prolonged. There were also demographic differences. First, the proportion of females is higher. This may indicate that female regular heroin users are disproportionately more likely to register for PMT, or alternatively that females are under represented in the other data sources, particularly arrest and fatal overdose data. Second, the average age of individuals registering for PMT was higher. It is unclear how this may compare to the "whole" population of regular heroin users, but it seems reasonable to expect that this group may be older than average because of the time lag between onset of regular heroin use and the decision to enter treatment.

Table 1: Comparison of average demographic characteristics of different data sources for the period 1997-2002

Data source	Average male proportion %	Average age	Percent change in average age 1997-2002
Fatal opioid overdoses	80	33	11
Ambulance call outs	68	31	6
Heroin Arrests	79	28	11
PMT registrations	66	34	4
PMT first time entrants	66	27	2

Although there is some variation amongst data sources, two pertinent questions arise: "Do the individual data source provide an accurate estimate of the number of regular heroin users?" and "Is it possible to estimate the demographic distribution of the population of regular heroin users?" The first question will be addressed when individual indirect methods are evaluated. The second question is addressed below.

Demographic breakdowns

Although these data sources may provide good estimates of the total number of regular heroin users, it is difficult to choose one source for making demographic splits. Given that demographic profiles vary across the data sources, and in the absence of any information that suggests that one data source is more representative than another, we have chosen to take the median of the different data sources to estimate the demographic characteristics of regular heroin users[2]. Degenhardt et al (2004) set out the results of the demographic splits of the estimates of NSW (and Australian) regular heroin users.

[2] In this situation the demographic breakdown of PMT new users is excluded as it clearly refers to a younger subset; all PMT registrations have been used here.

Table 2: Median age distribution (% of total 15-54) across the data sources by ten-year age groups

	1997	1998	1999	2000	2001	2002
15-24						
Median %	30.7	29.1	30.5	30.1	28.2	25.6
Range	26.7-49.1	21.0-43.7	18.7-45.7	19.2-40.5	14.1-39.9	11.4-33.8
25-34						
Median %	37.9	41.3	39.7	40.0	40.1	39.8
Range	34.1-44.2	36.4-43.8	35.7-42.9	34.1-43.5	37.4-42.9	37.8-43.0
35-44						
Median %	22.3	23.2	22.9	22.0	23.9	25.7
Range	13.7-30.6	16.2-31.9	15.7-32.0	15.7-37.2	17.6-35.0	20.1-33.5
45-54						
Median %	4.8	4.7	4.8	6.1	6.4	8.9
Range	2.9-7.2	3.3-7.1	2.9-10.4	4.0-9.5	4.9-11.0	5.4-15.2

Median percentages have been prorated so that they sum to 100%

3.2.2. Evaluation of data sources

Table 3 summarises the characteristics of the different data sources. Detailed discussion of the sources may be found in Appendix A.

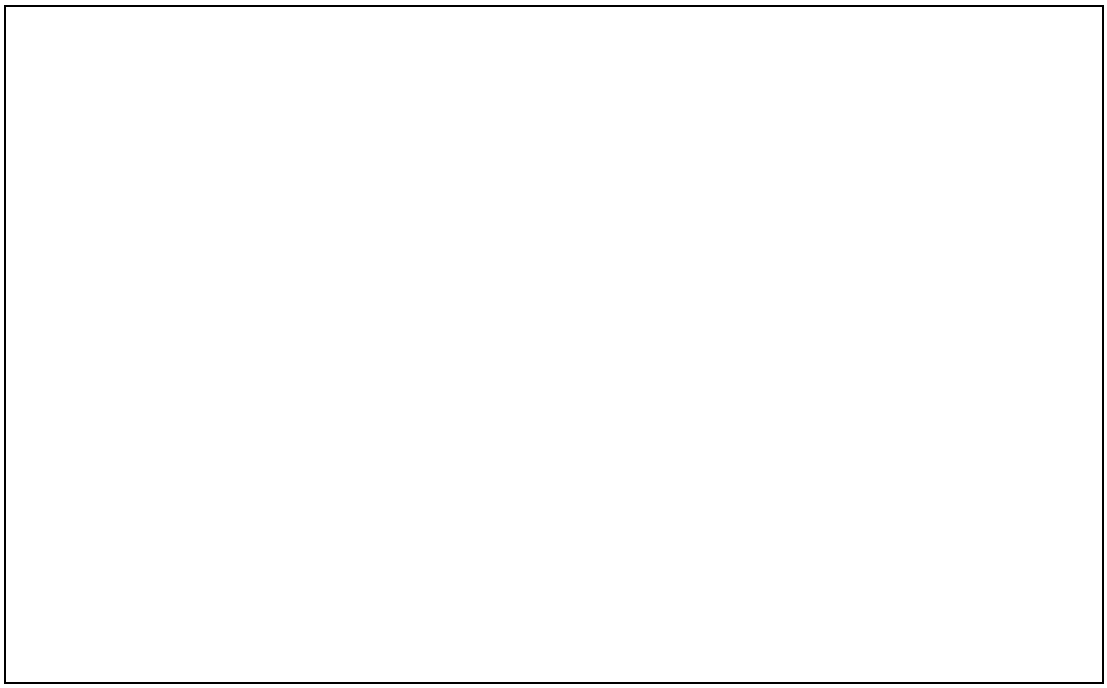
Table 3: Summary of characteristics of data sources

Data source	Description of predominant group characteristics	Data Quality	Timeliness of data	Estimation methods
Opioid induced deaths	Opioid dependent, most male, average age 33 years	Consistent data, with full demographic data.	Time lag of 12 months	Multiplier; Back projection
Ambulance callouts	Higher proportion of females than other data sets	No individual identifiers (so potential for duplicates) Some missing demographics, but improving	Data may be obtained within three months of end of calendar year	Multiplier
Heroin arrests	Persons arrested for heroin offences were the youngest of the four groups; higher proportion of males	Individual identifiers, some demographic data missing	Data may be obtained within three months of end of calendar year	Multiplier; capture-recapture
Pharmacotherapy maintenance treatment	Opioid dependent; females more highly represented among this group; older average age	Individual identifiers; good demographic data recorded	Data may be obtained within three months of end of calendar year	Multiplier; back projection

3.3. Multiplier methods

Figure 6 sets out the estimates of NSW regular heroin users derived from different sources, together with the median of the estimates. Detailed calculations are provided in Appendix B. There was good agreement between the various multiplier estimates which reflected the similarity between the patterns of change in the individual data sources (Figure 3 and Table B8, Appendix B).

Figure 6: Multiplier estimates of regular heroin users in NSW by year, 1997 to 2002

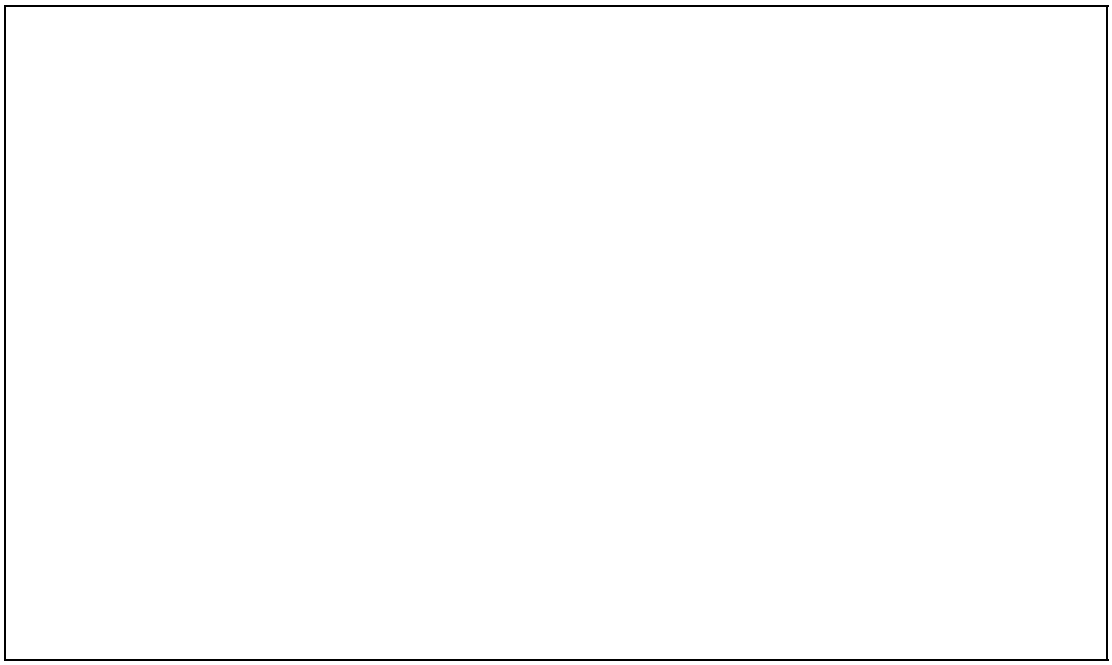


3.4. Capture-recapture methods

Analysis of sentencing data for 2002 indicated that around 90% of individuals who faced court for primary opioid offences would have been free within a year of being charged (see Appendix C). Of individuals starting PMT programs in the period 1997-2002, in all but one year (2001), over 60% were in programs that lasted less than one year and over 50% were in programs that lasted less than 6 months (see Appendix C). To ensure that as many persons were "released" after being imprisoned or in treatment as possible, it was decided to use 12 month capture periods.

Figure 7 and Table C 13 in Appendix C set out the different capture recapture estimates of NSW regular heroin users (see Appendix C for further details). What can be seen in the graph below is that the estimates produced by 12 month capture periods provide slightly higher estimates than the 6 month capture periods do. The estimates are also less likely to change over time than the multiplier estimates (see section 3.3).

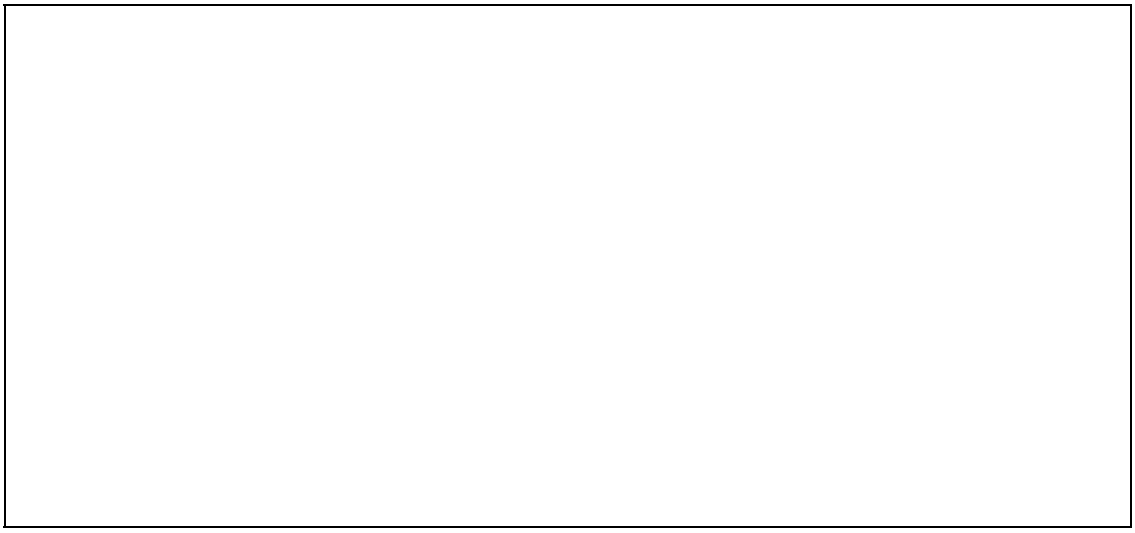
Figure 7: Comparison of capture recapture estimates of the number of regular heroin users in NSW, using different data sources and capture periods



3.5. Back projection methods

Predictions of fatal opioid overdoses for the period 1964-2000, and of new entrants to PMT for the periods 1970–2000 and 1970-2002 showed reasonable agreement with observed data (see Appendix D, Tables D2 and D5) and hence were used to produce estimates of regular heroin users. In contrast, predictions of fatal opioid overdoses 1964-2002 did not show reasonable agreement with observed data post 1996 (see Appendix D, Figure D.2) and therefore are not presented. Figure 8 and Table D2, Appendix D set out back projection estimates of NSW regular heroin users for the period 1997-2002.

Figure 8: Estimates of regular heroin users in NSW derived from back projection methods, 1997-2002



Only one of the two estimates of regular heroin users based on new entrants to PMT has been used in the summary of estimates as the data for the shorter period was included in the longer period, and estimates were in good agreement over the time period to 2000. The estimate of regular heroin users based on PMT new entrants 1970-2002 has been used in the summary estimate (see Section 3.6 below) as it gives almost as good a fit to observed numbers of entrants to PMT, except possibly for the year 2000, (see Appendix D, Figure D5), and provides estimates over the entire period 1997-2002. Appendix D gives details of the back projection details.

3.6. Summary of estimates

Table 4 shows the resulting estimates produced by the three different estimation methods. As can be seen, no estimates were available for 2001 and 2002 using capture-recapture methods and only one back projection method provided 2001 and 2002 estimates. The multiplier methods produced estimates that increased and decreased across time, in accordance with the trends in the data sources from which they were derived.

Comparison of the multiplier median estimate and with the total median estimate suggested that for 1997-2000, the years in which all three methods produced estimates, there was very good accordance between the two estimates (Table 4, Figure 9). For 2001 and 2002, the medians of the total and multiplier estimates also agreed well, which was not surprising given that multipliers comprised nearly all of the estimates produced for these years. It should be noted that the absence of the capture-recapture and back projection estimates for 2001 and 2002 may lead to a lower median estimate, possibly around 4% lower, when extrapolating from the previous four years.

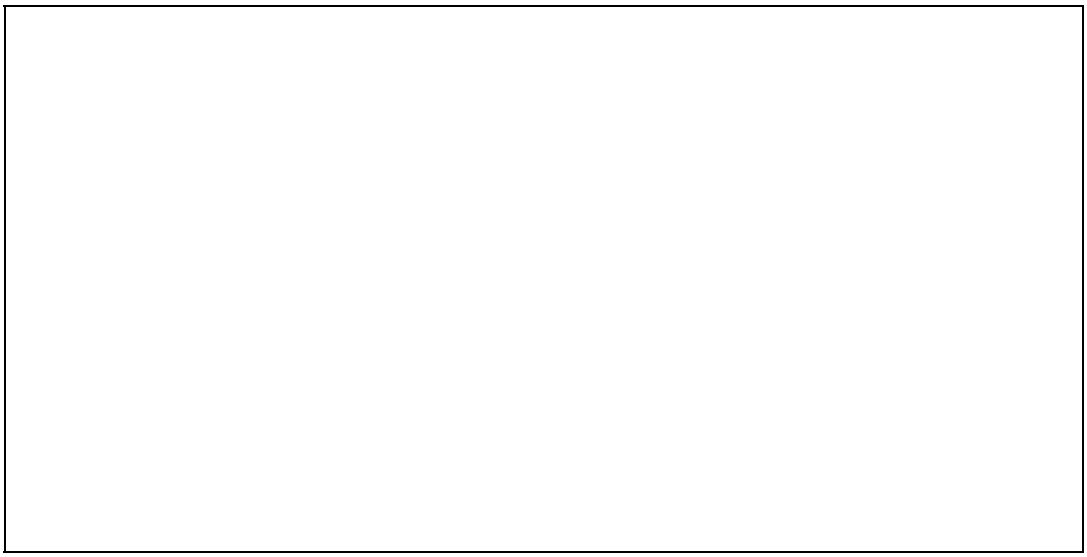
Table 4: Estimates produced by the different indirect methods

	1997	1998	1999	2000	2001	2002
Multiplier estimates						
Opioid overdose deaths	37,500	50,900	54,100	39,300	19,900	17,800
Ambulance call outs	33,000	45,000	42,200	35,600	16,600	18,400
Heroin arrests	25,500	52,400	61,100	52,300	24,200	21,300
PMT registrations	39,200	42,900	41,800	48,500	36,500	41,900
Capture recapture[1]						
PMT Annual	51,600	48,900	47,400	46,500	n/a	n/a
Arrests Annual	55,500	51,300	59,100	49,500	n/a	n/a
Back projection[2]						
Opioid overdose deaths 2000	34,100	38,200	42,200	45,800	n/a	n/a
PMT 2002	40,600	42,200	43,100	43,300	43,100	42,900
Median	**38,350**	**46,950**	**45,250**	**46,150**	**24,200**	**21,300**
Multiplier median	35,250	47,950	48,150	43,900	22,050	19,850

1. Estimates based on annual capture recapture periods have been selected – refer discussion section 3.8
2. Refer discussion section 3.8 for selection of back projection estimates to include

n/a = estimate not available

Figure 9: Comparison of median total and multiplier estimates



3.7. Estimates of imputed multipliers

The multipliers used in this study were based on multipliers estimated from the Hall et al (2000) study (Naloxone ambulance call outs, Heroin arrests and PMT registrations) and other studies (Fatal opioid overdoses). Using the current median annual estimates of regular heroin users for the period 1997-2002, imputed multipliers were calculated for each of the data sources for each of the six years and these annual imputed multipliers were averaged to give an overall imputed multiplier for the period 1997-2002. The (average) imputed multipliers are set out in Table 4 together with the multipliers used in the study.

The ADIS call data was not used in the estimate of regular heroin users in the current study. However, we have calculated the imputed multiplier from this study for use in future estimates of regular heroin users (7.9).

3.8. Evaluation of indirect methods

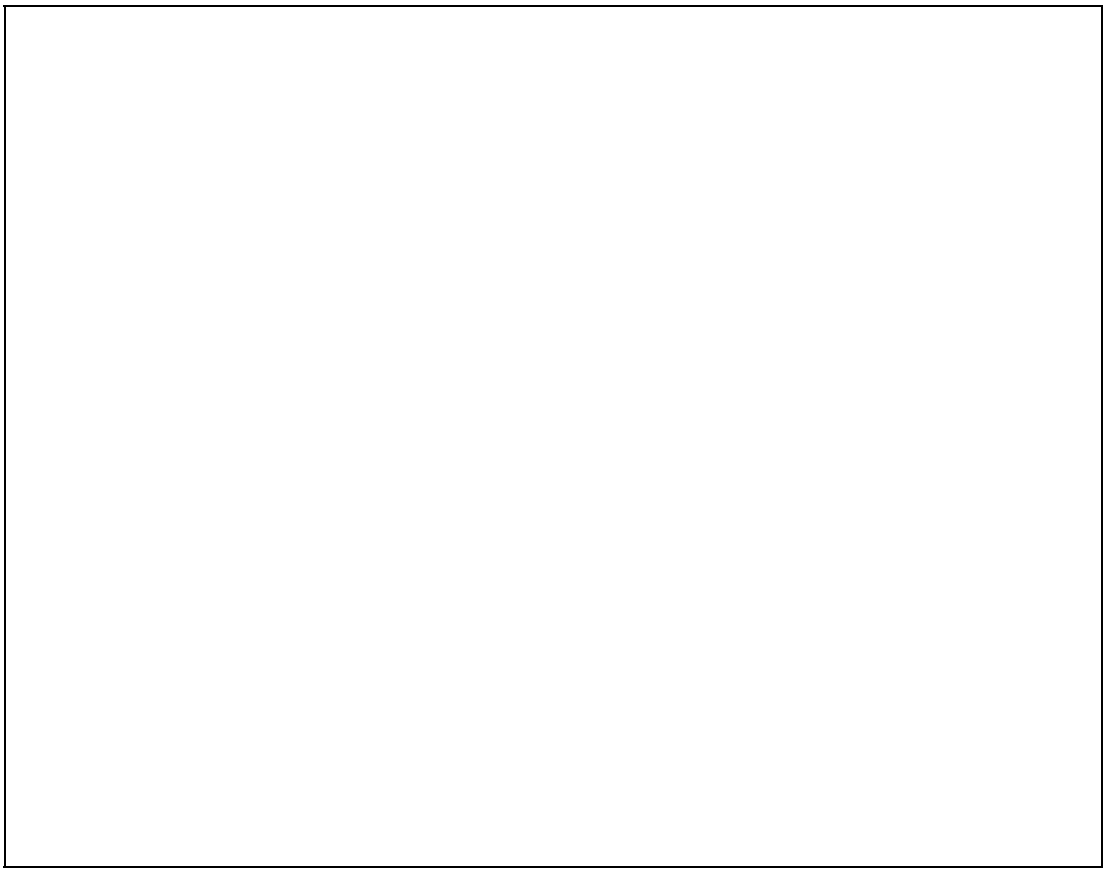
The usual context of estimation exercises of number of users is one in which there is a static or (perhaps) an increasing population. Methods such as capture-recapture assume this is the case. Historically, estimates in Australia have been of the same ilk. This implicit assumption was supported by analysis of opioid overdose data (which was the only data source for which a long series was available), which showed some annual variation, but on the whole a general upward trend.

In the present study, we were estimating the number of users in the context of a known change in the heroin market, namely, a dramatic decrease in supply after a period of increasing availability. Indicator data (fatal overdose data, naloxone ambulance call outs, arrests for heroin offences, and calls to ADIS) all suggested that there has been a relatively large increase followed by uncharacteristic rapid decline. This gave us the opportunity to look more closely at what the different methods measure (i.e. estimates for short periods of time, or longer-term trends that involve smoothing short term fluctuations), and so develop our understanding of the methods.

It is also necessary to consider the most appropriate methods to use in times of rapid change. Overall although there was a wide range in the individual estimates in any one

year, there was reasonably close agreement between the median multiplier estimate and the overall median estimate. Individual estimates were similar for at least one year: no estimate was completely out of the range of the other estimates for the entire period 1997-2002. Estimates produced using the same method tended to have similar characteristics, that is, estimates produced by the multiplier method tended to be the lowest and to have the greatest percentage changes, while the capture recapture method produced the highest and the flattest estimates.

Figure 10: Estimates of regular heroin users from different methods and data sources and median multiplier estimate



The multiplier method of estimating regular heroin users has the advantage that it is easy to undertake, the method is transparent in that one fatal overdose is assumed to suggest 112 regular users, and can be quickly updated as more recent data becomes available. The disadvantage is that the method is very sensitive to the choice of multiplier (i.e. a 10 per cent change in the multiplier translates directly into 10 per cent change in estimate of the number of regular heroin users.), so multipliers need to be applicable to local data. In addition multipliers may change in response to other factors, for example a decline in

heroin purity could be expected to reduce the number of fatal heroin overdoses thereby increasing the multiplier (see section 1.2.2).

In this study, four different multiplier estimates of regular heroin users have been made. In evaluating these estimates, it is necessary to first look at whether it is appropriate to derive multiplier estimates from these data sources. All four data sources have a direct and immediate relationship to current, and most likely regular, heroin users (Appendix A), with changes in the numbers in the data sources representing changes in the numbers of at least a subset of heroin users. This suggests that all four data sources are appropriate for the multiplier method. Three of the multipliers used were estimated from a previous local estimate (Hall et al, 2000), which reduced the risks of applying inappropriate multipliers. The fourth multiplier (for fatal opioid overdoses), was derived from other data but agreed well with the local imputed multiplier based on the Hall et al (2000) study. The four multiplier estimates therefore appeared to be based on reasonable data and to have reasonable and appropriate multipliers.

The question is then "how should these individual multiplier estimates be used to produce a composite estimate of NSW regular heroin users?" Although three of the data sources showed similar trends (section 3.2), the different demographic composition suggests that they represent different subgroups of regular heroin users. Therefore it is important to combine all four estimates to produce a composite estimate.

Although data sources represent different subgroups of the group of regular heroin users, provided changes in the number of the subgroup mirror those of the overall group, then the multiplier estimate is likely to be good estimate of the underlying group of regular heroin users even if some regular heroin users are not represented by any group.

The above analysis has assumed the different multipliers applied to the data sets have remained constant over time, an assumption that may not be correct. For example, the drop in purity of heroin at street level that was noted in 2001 (Roxburgh, Degenhardt, Breen, & Barker, 2003a) might have meant that the risk of overdosing on heroin was reduced (hence leading to a change in the actual multiplier for overdose). However, some users might have substituted or added other drugs that might have then increased the risk

of multiple drug overdose where heroin was also involved (such as benzodiazepines or methadone). Evidence suggested that such drug substitution occurred in Victoria, Tasmania and the Northern Territory (Breen et al., 2003). Furthermore, the change in purity was unlikely to have the effect of reducing treatment numbers and arrests (i.e. if it confounded the trends in overdose, this confounding effect was unlikely to occur for the other data sources). A reduction in heroin purity is unlikely to explain the reduction in the number of heroin arrests, since purity of heroin does not affect the likelihood of being arrested. Furthermore, a reduction in heroin purity might have spurred some users to *enter* heroin treatment, potentially having the opposite effect upon treatment numbers.

It seems unlikely that any factor or factors could have affected these different sources of data similarly. Because a range of data has been used in making these indirect estimates, we can have greater confidence in results produced, because confounding is less likely to have occurred.

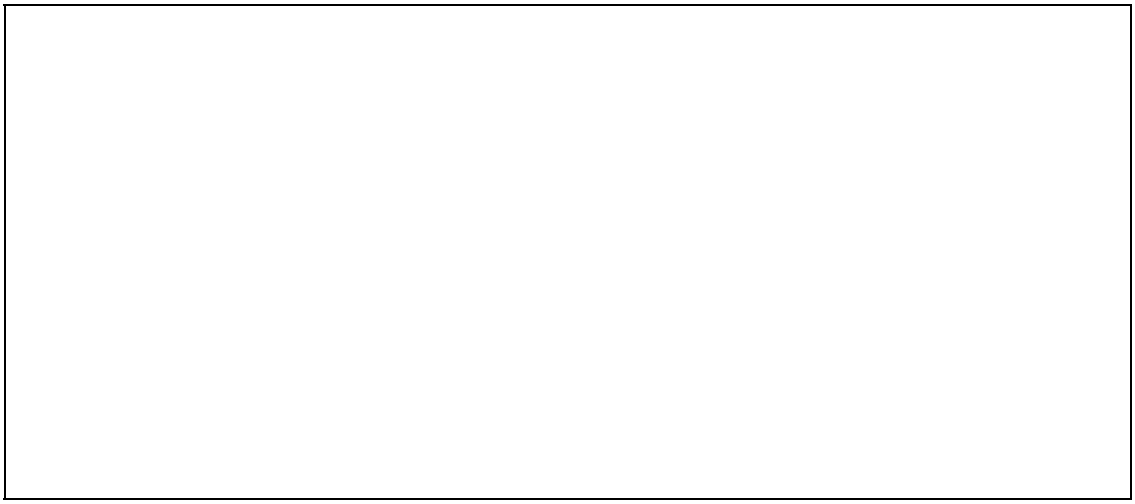
3.8.1. Evaluation of ADIS data as source for multiplier estimate

The number of heroin calls to ADIS showed a similar pattern to the number of regular heroin users as estimated by the median of the multiplier estimates (see Figure 11). This close agreement between the pattern of the median multiplier estimate and the calls to ADIS provided additional validation of the indirect estimates produced in the current study, as well as suggesting that ADIS data may serve as an additional source of information about trends in heroin use

The close agreement between the estimates of regular heroin users and that derived from ADIS calls suggests that the ADIS data provides a good representation of regular heroin users. In addition ADIS calls are strongly and significantly correlated with the data sources (fatal opioid overdoses, naloxone ambulance call outs and heroin arrests). As limited demographic data is available on ADIS callers it is not possible to compare the demographic characteristics of ADIS callers with those of other sources.

In the absence of a prior reason to expect that ADIS data "capture" the same population as other data sources, it may be a source that can be reasonably included in future estimates. This should be considered by those involved in indirect estimation work in the future.

Figure 11: Comparison of the number of current regular heroin users with the number of ADIS calls regarding heroin



3.8.2. Back projection

The back projection method differs from other methods of estimating the number of regular heroin users in that it uses current (ie 1997-2002) and historical data to back project the number of people who commenced regular heroin use in any one year and uses estimates of the rate at which people stop heroin use to make estimates of the numbers of current regular users. The advantage of this method is that it provides a different, independent method of estimating regular heroin users (Law et al, 2001) that reflects long-term behaviour patterns, and allows long-term trends to be estimated. The method has previously provided estimates that have been consistent across data sources and that have also been consistent with estimates derived from other methods (Hall et al, 2000; Law et al, 2001) and these estimates have been substantially replicated by the current study (refer Appendix D, Figures D3 and D7), indicating the stability of the back projection estimates. However these estimates were for the period 1960-1997, that is prior to the rapid decline in use that was associated with the heroin shortage.

The method has a number of limitations that are related to the long time series used in the analysis (see Appendix D). Although the back projection method can be used to estimate long-term trends reliably, the method is less accurate when estimating very rapid changes particularly in the immediate past. Because back-projection, as the name implies, estimates trends in dependent heroin use in the past by projecting backwards from trends

in overdose deaths or entrants to PMT, the immediate recent past is the period over which the estimates are least informative. Furthermore, the back projection method assumes that the rates of progression from starting regular heroin use to fatal overdose and PMT registration, and the rate at which people stop regular heroin use are constant. These assumptions, particularly the constant rate of stopping regular heroin use, would probably not be met during the period of uncharacteristic change in 1997-2002. Although longer term time trends can be evaluated using sensitivity analyses, very rapid changes in numbers stopping regular heroin use, combined with the inherent lack of information about trends in the very recent past, make back-projections estimates over this period less informative.

The back-projection estimates of regular heroin users based on fatal overdose data to 2000 and new entrants to PMT to 2000 and to 2002, are broadly consistent with estimates using other methodologies until the year 2000 (Figure 10). However, back-projection estimates based on new entrants to PMT do not reflect the pattern of increase and subsequent decrease shown in the median multiplier estimates of regular heroin use, although it is notable that back-projection estimates are similar to multiplier methods applied to the similar PMT data during this period. That back-projection analyses based on opioid overdose deaths did not appear to fit the data, and that analyses based on entrants to PMT gave somewhat inconsistent trends during 2001-2002 compared with other methodologies, appears to confirm that back-projection estimates while useful for assessing long-term trends are less informative about rapid changes in the very recent past.

There are also some potential limitations associated with the data sources used in the back projection analysis. The method assumes that the number of fatal opioid overdoses is complete and calculated in a consistent manner throughout the period 1960-2000 (Law et al., 2001). In practice there were 3 revisions to the ICD classification of cause of death in the period which may have resulted in some shifts in the annual number of fatal opioid overdoses (B Barker & L Degenhardt, 2003); further, there may have been misclassifications in the underlying causes of death over time and changes in the rate of misclassification over time (Law et al., 2001). There may also have been changes in the probability of opioid overdose death through for example changes in the frequency of injecting (McKetin, Darke, & Kaye, 2000) or the changes in the purity or availability of

heroin. Further details of limitations of the back projection method as applied to fatal opioid overdoses are given in Appendix D.

3.8.3. Capture-recapture method

The capture-recapture method of estimating the number of regular heroin users has a major advantage over the other methods in that the estimate is derived solely from source data and does not require numerical assumptions derived from other sources such as multipliers or rates of progression (used in back projection estimates). In this way the capture-recapture estimates depend solely on local, current data.

There are some limitations associated with the capture-recapture method. The capture data does not satisfy all the model assumptions (see Appendix C) and the model-building process may result in some estimation error (see discussion Appendix C). It is difficult to understand the effect of these factors on the estimate of regular heroin users. The model itself is difficult for the non-mathematician to understand, and because of the complex interrelationship between capture patterns there is not a direct, obvious relationship between the input data and estimates produced.

The capture-recapture model also has a significant disadvantage in periods of rapid change, in that the model provides an estimate of regular heroin users for the period covered by the four input data periods (see Appendix C) that is for a period of two years (for six monthly data periods) and four years (for annual data periods). In periods of rapid change, estimates over a two or four year period represent some average estimate and cannot reflect details of annual periods. The long analysis period introduces an additional complexity associated with estimates of regular heroin users derived from capture recapture studies that is not found in methods of estimates. Because the estimates span a period of more than one year, the issue becomes how to derive annual estimates when data from a particular year has been included in more than one estimate. In this study, each of the estimates was assigned to just one year, chosen to approximately represent the midpoint of the period. Thus for six monthly capture periods, the estimates were assigned to the first year of the analysis period and for annual capture periods the estimate was assigned to the second of the four years in the analysis period.

Nevertheless, despite these limitations the capture-recapture methods and data sources investigated in this study have yielded estimates that are consistent with estimates from other sources periods of relatively consistent change (Hall et al, 2000). The capture-recapture estimates in the present study have been examined in this framework of potential methodological limitations, particularly the actual length of capture periods compared to those assumed by the model.

Overall the estimates of regular heroin users derived from capture-recapture studies were of similar magnitude to those obtained by other methods, with estimates based on annual capture periods having a closer match than those based on six monthly capture periods, which tended to be lower than other estimates and have a different pattern. Data on the length of capture periods demonstrated that a greater number of individuals would be released and available for recapture using annual capture periods rather than six monthly capture periods. Thus both empirical results and data on actual capture length support the use of annual capture periods. Using capture periods longer than a year may provide a more accurate analysis but this would increase the analysis period unacceptably in periods of rapid change.

There are a number of limitations associated with the annual estimates. As discussed above the individual estimates are for a period of four years, rather than for one year periods for other estimates, and so they reflect all the conditions over this period. Also because four years data is required, making the assumption that the analysis refers to the second year of the analysis means that there are no estimates for the most recent two years.

As well as looking at methodological limitations it is also necessary to evaluate the impact of the input data. Capture-recapture analysis estimates the size of the hidden population that was available for capture but was not captured. That is the population of regular heroin users who could be arrested and the population who could register for PMT. To the extent that there are members of the population of regular heroin users that would not be arrested or would not register for PMT, then the capture-recapture analysis is likely to underestimate the population of regular heroin users. Individuals arrested tend to be young and male (see figures 4 and 5) whereas individuals registering for PMT have a broader demographic range, which suggests that the capture-recapture analysis using

heroin arrests may not reflect some segments of the using population. This is in contrast to multiplier estimates where it is possible to use data from a subgroup of the regular using population provided changes in the numbers in the subgroup mirror changes in the total group of regular users.

In summary, the capture-recapture method has the advantage that it only uses current local data and the capture-recapture estimates using annual capture periods in this study are broadly similar to those produced by other methods. However the limitations associated with the method, including uncertainties about the implications of not meeting some model assumptions, difficulties of a longer analysis period and lack of current estimates, suggest that that capture-recapture analysis is better suited for confirmatory analysis of estimates produced by other methods, rather than as a source of the estimates themselves. This analysis has been undertaken during a period of uncharacteristic change in the main indicators of heroin use, the limitations associated with a longer analysis period are likely to have less impact in periods with constant levels of change where it may be appropriate to use capture-recapture analysis to derive primary estimates.

3.8.4. Final estimates of the number of regular heroin users

Based on the above exercise, the median multiplier estimate was used as the "best estimate". Table 5 shows the resulting numbers. For more detail on NSW and Australian estimates, and on demographic breakdowns, please see Degenhardt and colleagues (2004).

Table 5: Multiplier median estimates and range of the number of regular heroin users in NSW, 1997-2002

	1997	1998	1999	2000	2001	2002
Multiplier median[1]	**35,300**	**48,000**	**48,200**	**43,900**	**22,100**	**19,900**
Lower limit of range	25,500	42,900	41,800	35,600	16,600	17,800
Upper limit of range	39,200	52,400	61,100	52,300	36,500	41,900

[1] The values for the multiplier median are taken from Table 4 and have been rounded.

4. DISCUSSION

The present study has examined methods of estimating the number of regular heroin users when there was a known reduction in the supply of heroin to the drug market. Good evidence suggests that heroin use and harms in the community decreased. Across all of the data examined in this study, marked and sustained decreases occurred in the extent of heroin related harms in the community. The estimates produced by the study suggested that the number of regular heroin users decreased following the reduction in heroin supply, and that this decrease was maintained in 2002.

In the following section, we consider some questions that may be asked of the current findings. These questions largely focus on the following issues: Are the estimates realistic? How could they have been confounded?

4.1. Fewer regular heroin users or less "regular heroin use"?

We need to remember that all of the data used in the current study involves *markers* of heroin use – overdose, arrest, or treatment. One criticism of the current study may be that heroin users reduced the frequency of their heroin use (without ceasing use) such that the probability of being "marked" may have decreased for each user, with no change to the number of regular heroin users per se. In the IDRS, the median days of heroin use among NSW IDU decreased from daily (in 2000) to 158 out of 180 days (in 2001) in the past 6 months (Roxburgh, Degenhardt, & Breen, in press; Topp et al., 2003).This might have meant, for example, that the likelihood of overdosing decreased (due to fewer occasions of heroin use); or that users were buying heroin less often and therefore were less likely to be caught with heroin on their person.

However, this possibility is not consistent with the pattern of ADIS calls of concern about heroin use: the decrease was just as marked for this source of data as it was for overdose and heroin arrests. Presumably, people would still be concerned about heroin use on 158 out of 180 days, as they would be by daily use.

Furthermore, data from the 2002 IDRS suggested that heroin use among IDU sampled for the study returned to the frequency observed prior to the heroin shortage (Roxburgh et al., in press; Roxburgh, Degenhardt, Breen, & Barker, 2003b). In other words, even though a decrease in frequency *was* noted in 2001 among this group, *it was not sustained in the following year*. Hence, a reduction in frequency of heroin use (and therefore a reduced likelihood of being noted in the data sources used in this study) cannot explain the maintenance of low levels in 2002.

From a conceptual level, too, it would seem that if heroin users reduced their likelihood of being "marked" in these datasets, then some persons did not meet "criteria" for being marked in such datasets. It must be remembered that the current estimates refer to the number of regular heroin users, that is, people who inject heroin often enough to put themselves at risk of overdosing, being arrested, or needing to enter treatment. If people reduced their risk of overdosing, being arrested or entering treatment, then they were less likely to meet the criteria for inclusion in these datasets. In other words, the estimated decrease in the number of regular heroin users reflected an actual decrease in regular heroin use by people who probably met criteria for opioid dependence in the period before the heroin shortage when heroin was more readily available.

It should be noted that the number of opioid dependent persons may not have changed in such a clear manner. As will be discussed below, continued increases have occurred in the number of persons enrolled in opioid pharmacotherapy. Such persons are heroin dependent persons still receiving treatment. It seems reasonable to conclude that if we were to hazard estimates of the number of *opioid dependent* persons in total, then we would need to add the estimated number of current, regular heroin users to the number receiving opioid replacement therapy.

4.2. Does a reduction in the number of heroin users imply a reduction in overall drug use?

These reductions in heroin use do not imply, however, that all drug use had decreased. There is good evidence that many heroin users used other drugs (both licit and illicit) when heroin became less available.

In NSW, heroin users particularly seemed to substitute cocaine for heroin, although this change did not appear to be sustained, with evidence of reduced cocaine supply in 2002 (Roxburgh et al., in press). In NSW, there was an increase in the number of younger users seeking treatment for psychostimulants (cocaine and methamphetamine), although the increase in the number of people seeking this form of treatment was less than the decrease in the number of people seeking treatment for heroin (Roxburgh, Degenhardt, Breen, & Barker, 2004). In Western Australia, Victoria and South Australia, clear increases were observed in methamphetamine use among IDU (Breen et al., 2003).

There was also evidence that some more entrenched heroin users may have increased the injection of benzodiazepines in Victoria and Tasmania (Breen et al., 2003). Furthermore, there was evidence that some substituted other opioids for heroin, such as illicit methadone and morphine, particularly in Tasmania and the Northern Territory. In short, among persons who continued to inject drugs (the population from which IDRS samples are drawn), there was good evidence that IDU used other drugs when heroin became less available (Breen et al., 2003).

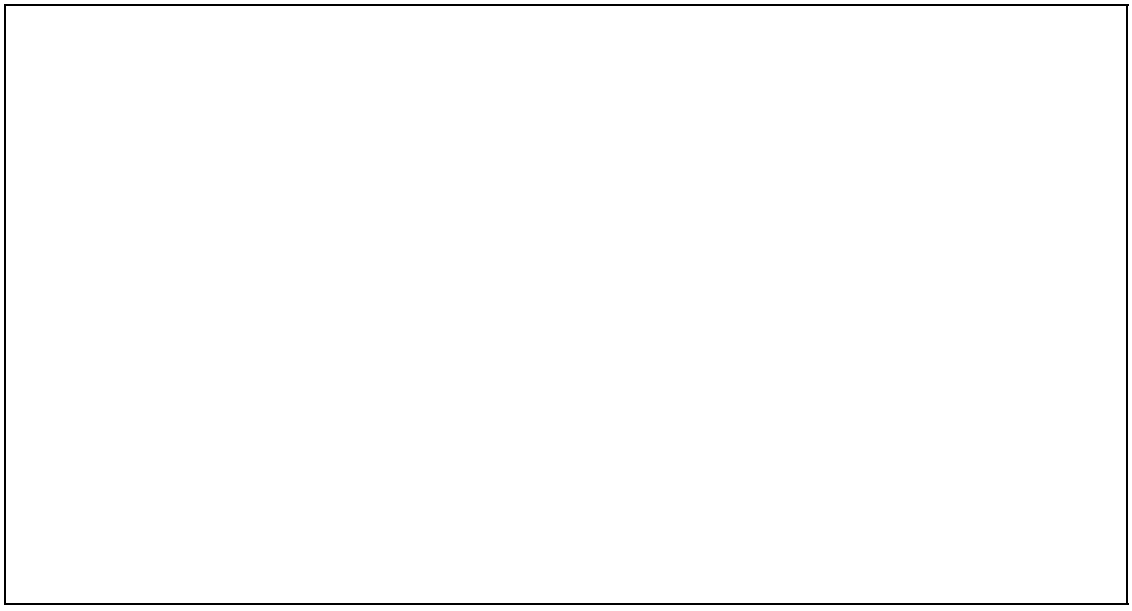
Data on how many injecting heroin users may have *ceased injecting* as a route of administration of any drug is much more limited. Suggestive evidence of a decrease in the extent of injecting drug use in the community may be drawn from data on needles and syringes (NSP) distributed; declines in NSP distribution occurred in both NSW and Victoria. Furthermore, since the reduction in heroin supply there has been a decrease in the number of hepatitis C notifications among younger persons in NSW. This would not have been expected if users had merely reduced the number of injections: it has been estimated that the number of injections would have to reduce by a fairly large margin if hepatitis C were to be reduced at the population level. Hepatitis C in Australia is driven by injecting drug use (Dore, Law, MacDonald, & Kaldor, 2003) and heroin injection in particular (MacDonald et al., 2000), so an unexpected reduction in hepatitis C notifications (compared to models of the epidemic (Law et al., 2003)) is consistent with a decrease in the number of injectors (Day, Degenhardt, Gilmour, & Hall, in press).

4.3. What does this mean for heroin treatment services?

As we have stated previously, the estimates produced in this study are derived from indirect indicators that are likely to reflect *current regular heroin use*. These numbers will therefore fail to include persons are receiving treatment for heroin dependence (such as persons in opioid pharmacotherapy) *and no longer use heroin*.

What was clearly shown earlier in this report is that the total number of persons in opioid pharmacotherapy has continued to increase (see the Figure below). This number comprises persons maintained on this treatment modality, as well as those who have recently entered treatment. One of the interesting findings of this study was that the total number of persons enrolled in opioid replacement therapy continued to increase during the year after the onset of the heroin shortage (see Figure 12 below). This suggests that the pool of *opioid dependent* persons may not have changed in the same way or to the same extent as the pool of *current regular heroin users*. It also suggests that the need for places in opioid pharmacotherapy has not decreased.

Figure 12: Total number in pharmacotherapy in NSW as at June 30, 1997-2002



Making any estimates of the extent to which treatment need is being met is fraught with problems. If we conclude that the estimated number of current, regular heroin users has decreased, then it follows that the proportion of the total pool of heroin dependent people in treatment may have increased following the heroin shortage (since total pharmacotherapy numbers have continued to increase). Nevertheless, the fact remains

that if we assume that the number of regular heroin users is somewhat distinct from the number who remain in opioid pharmacotherapy, then in 2002, up to an additional 20,000 persons may also have been eligible for pharmacotherapy. In summary, there are more persons who may be eligible for treatment than who are currently receiving such treatment. There appears to be no need to reduce the places available for the treatment of heroin dependence in NSW.

4.4. Will these changes be sustained?

The changes we estimate to have occurred were driven by reductions in heroin supply. They were *not* driven by changes in demand for heroin – interviews with injecting drug users and key informants from drug monitoring systems and studies conducted since the heroin shortage have both confirmed that users wanted heroin but were finding it difficult to obtain (Breen et al., 2003; Day et al., 2003). Hence, it seems reasonable to assume that if or when the availability of heroin increases again, the number of persons engaging in regular heroin use is likely to increase over time. Thus, although the heroin shortage has reduced the harms related to heroin use, we should not expect these lower levels of harm to be maintained if or when supply returns *and* heroin use increases.

4.5. Data sources

Analysis of the data sources used in this study suggested that each of the data sources "captured" different subgroups of heroin users. This confirmed the importance of making a range of multiplier estimates in order to ensure that any potential effects of this subgroup sampling do not affect the size of estimates produced.

Overdose data such as that collected by the Australian Bureau of Statistics is an ongoing data collection with strict classification rules and relative consistency of collection, however there is a long time lag before the data are released for any given year. ADIS data on calls of concern about heroin user appeared to follow a similar trend to the other data sources, suggesting that it too was an indicator of the extent of problematic heroin use in the community. Heroin arrest data appeared to be most likely to fluctuate, which might reflect patterns of police activity to some extent. The differences across the

different data sets again pointed to the need for multiple and confirmatory estimates in the future.

4.6. Indirect estimation methods

The results of the current study suggested that methods such as capture recapture and back projection were less able to take into account rapid increases and decreases in the scale of the indirect indicators of heroin use that were used in analyses.

Back projection, as the name implies, estimates trends in dependent heroin use in the past by projecting backwards from trends in overdose deaths or entrants to PMT, so the immediate recent past is the period over which the estimates are least informative. However, it may well be able to accurately model the changes observed in 2001 at a later time.

Capture-recapture will probably *always* involve "averaging" across periods. As a result, short-term changes (if they occur only in one or two years) may *never* be well estimated using this method. Nevertheless, it provides a good way of confirming trends observed using multiplier estimates.

Multiplier estimates, although they do have limitations, may be used for annual updates in the interim. They provided estimates that were in good agreement with the other methods; they could be derived from different data sources. However, it is considered important to conduct confirmatory exercises using the other methods to confirm that the multiplier has not changed due to undetected effects.

Given the findings of the current study, it appears that in a period where there has been a sudden decrease in drug supply in the community, methods of estimating the size of a drug using population that are able to make use of more discrete time periods may be better able to "capture" changes in the extent of drug use. Given the idiosyncrasies of each of the methods (and the potential limitations of multiplier methods) it seems important to conduct estimation exercises with as many data sources and as many methods as possible. Although back projection methods seemed *at present* limited in their ability to model the trends in the data, over the longer term they will probably improve

(Law et al., 2001). Capture-recapture methods will probably be limited in their ability to model short term changes because they involve the use of data over a period that may be too long to capture shorter term changes. Conduct of an exercise similar to this in several years time will provide some data on which to evaluate these possibilities.

In the shorter term, it seems feasible to conduct annual estimates of the number of regular heroin users using a range of multipliers applied to different data sources. These should be referenced to back projection and capture-recapture estimates when they are conducted.

4.7. Conclusions

In periods where there are dramatic and sudden changes to the extent of drug supply in the community, making estimates of potential changes in the population of users is a difficult process. Methods that use data from a long window period (such as capture-recapture), or which require data on longer term trends in drug use and its progression (such as back projection), may be less able to provide estimates that correspond to known changes in trends in existing indicator data. Multiplier methods, because of their relatively straightforward use of these indicator data, may be better suited to indirect estimates of the population in these periods.

It will be of use to repeat this estimation exercise in the future, when these short term changes can be plotted over a longer period.

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APPENDIX A: DATA SOURCES

Fatal opioid overdoses

ABS classifications used

Between 1964 and 1967, fatal opioid overdoses were defined as deaths due to opioid dependence (ICD-7 code 323) and accidental opioid poisoning (ICD-7 codes E870, E872). Between 1968 and 1978 ICD-8 codes for opioid dependence (304.0) and opioid poisoning (E853.0, E853.1) were used. Between 1979 and 1996 fatal opioid overdoses were defined as deaths due to opioid dependence (included in ICD-9 codes E850.0, E850.1) and accidental opioid poisoning (included in ICD-9 codes 304.0 and 304.7). Between 1997 and 2002, fatal opioid overdoses were defined as deaths due to mental and behaviour disorders due to opioids (included in ICD-10 code F11, and code F19 cross classified by T400-T404, T406, and F11) and deaths due to accidental poisoning and exposure to opioids (included in ICD-10 codes X42 and X44 cross classified by T400-T404 and T406). Dual coding of overdose data under ICD-9 and ICD-10, available for 1997 and 1998, indicated that ICD-10 coding resulted in approximately 12% higher estimates of fatal overdoses than under ICD-9 (B. Barker & L. Degenhardt, 2003).

Data on opioid overdose death in the ICD-9 system did not distinguish between licit and illicit fatal opioid overdoses; the introduction of ICD-10 allowed the discrimination of heroin from other opioid drugs, with the finding that most opioid deaths involved heroin.

Ambulance call outs

The percentage of records for which demographic data was provided increased from 45% in 1998 to 86% in 2002 for gender, and from 42% in 1997 to 74% in 2002 for age. Because a substantial proportion of records did not have age data, trends have been based on total callouts, as to limit call outs to the 15-54 age group would have excluded a significant proportion of call outs. Based on the age distribution of call outs for which there *was* data, approximately 3.8% of call outs did not fall within the 15-54 age group in 1996, and 6% in 2002. As no unique individual identifiers were provided, it was not

possible to determine the number of individuals who were attended by the ambulance service or the pattern of attendance to specific individuals.

Evaluation of source data

There are a number of important criteria against which to evaluate using the data sources to estimate the number of dependent heroin users. Firstly, these can be expressed as the data source should be stable, that this the way in which it is defined or measured remains the same so that across time periods like is being compared with like.

Secondly, there should not be any other factors other than the number of regular heroin users that affect the level of the data source. The four data sources have been evaluated according to these criteria.

Fatal opioid overdose data

The fatal opioid overdose data is different to the other sources of data in that it is data provided by the ABS and is intended to be used as an accurate measure of the number of fatal opioid overdoses, in comparison with numbers taken from the other sources of data, where data is collected for a number of reasons. As a result, the ABS data was the database with the fewest errors, and was the one with complete demographic data; furthermore, the criteria for inclusion are well defined.

Nevertheless there have been changes in the classification of opioid related deaths over time, and although criteria are well defined the data is collected from death certificates completed by a large number of individuals who may adopt different classification criteria. Furthermore, changes in the purity and availability of heroin and related polydrug or intermittent use patterns may lead to changes in the rates of fatal overdose.

There is a particular disadvantage associated with the fatal overdose data in that unlike other data sources, annual data for the preceding year is released in December, which means that it is not possible to use fatal overdose data to provide immediate estimates of changes.

Heroin arrests

The number of individuals arrested for heroin offences is obtained from the police COPS database. While the definition of heroin offences is clear, the database has a number of duplicate records of the same arrest and variable completion levels of demographic data. In addition the number of arrests for heroin offences may partly reflect short term policing objectives, and the arrests of heroin dealers is not necessarily the same as the number of heroin users.

Ambulance call outs

It is not clear if the ambulance call-out data includes duplicate records of the same attendance and not all records include demographic data. The criteria of whether the naloxone protocol was used appears unambiguous and stable across time. However, the drug overdose protocol for naloxone ambulance call outs includes all drug overdoses and does not distinguish between the different drugs used by the patient. Naloxone may be administered to other patients who have not responded to other treatment. Limiting records to the proportion represented by the 15-54 age group goes some way to reducing the number of individuals who may have had naloxone administered for non-opioid drugs. Nevertheless the ambulance call out records for the age group 15-54, may include cases where naloxone was administered for non-opioid drugs. We need to assume that this proportion remains small and constant over time.

The proportion of IDU administered naloxone may vary throughout NSW as identification of drug overdose and the need for treatment is based on the ambulance officers' assessment of the patient at the time of treatment/ transport and whether the ambulance officers are authorised to administer naloxone.

The number of overdoses requiring naloxone is likely to be affected by large changes in street heroin purity and availability and related polydrug and intermittent use patterns.

PMT registrations

The number of individuals registering for PMT is derived from the PSB database that tracks all individuals receiving PMT. Although the database does not appear to contain duplicate records, there are several factors that affect the reliability of the data for

example, individuals may register, but not commence programs; identification of these individuals depends on the accurate entry of the leaving code. However provided the ratio of "suspect" registrations to total registrations remains fairly constant this may not affect the estimation of the number of regular heroin users.

The number of clients in PMT may at times be partly determined by the funds allocated to PMT, both at an overall state level and at a more local level rather than the demand, since not all users may be able to access treatment due to changes in treatment places available. Thus the increase in individuals in PMT treatment may at times reflect increases in funding rather than changes to the number of users. It should also be noted that pharmacotherapy treatment options may have changed during the study period with the introduction of buprenorphine in 2001.

APPENDIX B: MULTIPLIER ESTIMATES

Overdose deaths

Multiplier

Estimates of opioid mortality range from 0.5% to up to 3% (with implied multipliers ranging from 200 to 33) ((Frischer, 1998; Frischer et al., 2001; Larson, 1992), with many of the studies being conducted on users in treatment, which may also reduce the mortality rate (Frischer, 1998; Frischer et al., 2001).

The Hall et al (2000) study into NSW (and Australian regular heroin users) applied multipliers of 100 and 125 (based on opioid overdose mortality rates of 1% and 0.8%) to the number of fatal opioid overdoses to derive estimates of the number of regular heroin users. These estimates fell in the range of estimates produced by other means. In the Hall et al (2000) study the implied opioid overdose mortality rate from the median estimate of the number of regular heroin users in NSW was 0.9% based on the ICD-9 classification of deaths which was used in the study, and the implied fatal overdose multiplier was 109 (see Degenhardt et al, 2004). In a longitudinal NSW based study, that followed entrants to a Sydney methadone prior to 1979, the accidental overdose rate for subjects who were not in methadone treatment was 0.9% (Caplehorn et al., 1996) which is within the range used in the Hall et al (2000) study.

In this study, we have used a multiplier of 112.5 to estimate the number of regular heroin users from the number of fatal opioid overdoses. The multiplier of 112.5 is the average of the two multipliers of 100 and 125, previously adopted by the Hall et al (2000) study. We note that the Hall et al (2000) study used figures for fatal opioid overdoses based on the ICD-9 classification, which provides lower estimates of the number of fatal opioid overdoses than the current ICD-10 classification. However we have retained these possibly higher multipliers as first; the opioid overdose mortality rate declined during the period of this study as the heroin shortage affected the availability and purity of heroin (Breen et al., 2003; Degenhardt, Topp, & Day, 2002) and second, the derivation of the mortality rates was based on studies which used varying definitions of fatal opioid overdose.

Table B.1: Derivation of the estimated number of regular heroin users in NSW based on fatal opioid overdoses for individuals aged 15-54

	1997	1998	1999	2000	2001	2002
No of fatal opioid overdoses	333	452	481	349	177	158
Multiplier	112.5	112.5	112.5	112.5	112.5	112.5
Estimated number	37,500	50,900	54,100	39,300	19,900	17,800

Ambulance call out data

Multipliers

There are no direct estimates of the relationship between the number of naloxone ambulance call outs and the number of regular heroin users for NSW. Although self-report data from IDU interviewed as part of the IDRS provides information about the pattern of naloxone administration for this sample, Hall et al (2000) found that using a multiplier derived from these interviews resulted in estimates of dependent heroin users that were considerably lower than those based on fatal overdose and methadone data. Hall et al (2000) suggested that this may have been because the IDRS samples were obtained from around key heroin markets, and that as greater heroin dependence and longer heroin use have been identified as significant predictors of non-fatal overdose (Darke, Ross, & Hall, 1996) that these estimates probably reflected the number of heroin users who are found in the vicinity of major heroin markets. Accordingly ambulance data was used in conjunction with a multiplier of 10.1 derived from the Hall et al (2000) estimate of dependent heroin users to provide a multiplier estimate of the number of regular heroin users in NSW.

Table B.2: Derivation of multiplier to apply to the annual number of ambulance call outs

Number of regular heroin users in NSW[1]	39,000
Average annual number of NSW ambulance call outs to persons aged 15-54 at which naloxone was administered for 1997/98[2] (see table A.5. below)	3,860
Implied multiplier	10.1

1. Median estimate (Hall et al., 2000b).
2. Average of 1997 and 1998.

Table B.3: Estimated number of regular heroin users by year from the number of naloxone ambulance call outs for the period 1997-2002

	1997	1998	1999	2000	2001	2002
No. call outs	3,525	4,658	4,396	3,694	1,793	1,983
% 15-54 yrs	92.6	95.7	95.1	95.3	91.6	91.9
No. 15-54	3,264	4,456	4,182	3,522	1,642	1,822
Multiplier	10.10	10.10	10.10	10.10	10.10	10.10
Estimated number of regular heroin users	33,000	45,000	42,200	35,600	16,600	18,400

Individuals arrested for heroin offences in NSW

Multipliers

Currently there are no direct estimates of the relationship between the annual number of people arrested for heroin offences in NSW and the number of regular heroin users. Hall et al. (2000) estimated a multiplier (4.57) from the number of heroin users interviewed in the IDRS IDU survey who reported that they had been arrested in the previous 12 months for use/possession or dealing/trafficking (McKetin, Darke, Hayes, & Rumbold, 1999), and applied it to the number of people who had been arrested for heroin offences in 1998, to provide an estimate of the number of dependent heroin users in NSW of 11,635. This figure was considerably below the mean estimate from different sources for NSW of 40,000.

The estimate was likely to be an underestimate, because the arrest rate was probably overestimated (and thus the multiplier underestimated) for three reasons. First, the IDRS did not specify the type of drug involved in the arrests and would have included arrests for drug offences other than heroin, such as the much more common offences of possessing and using cannabis. Second, it is unclear how the IDU in the IDRS study defined "arrest". It may be that they are reporting dealings with the police that were not formally recorded. Third, recruitment for the IDRS sample took place in key drug market areas such as Cabramatta and Kings Cross where police activity tends to be high. Finally, the IDU are a sentinel group who are probably more than likely to be arrested than others.

Given the uncertainties associated with a multiplier estimated from the IDRS IDU survey, the arrest data was used in conjunction with a multiplier 20.8 derived from the Hall et al (2000) estimate of dependent heroin users to provide a multiplier estimate of the number of regular heroin users in NSW.

Table B.4: Derivation of multiplier to apply to the annual number of individuals arrested for heroin offences in NSW

Number of regular heroin users in NSW[1]	39,000
Number of individuals arrested at least once in 1997/98 for heroin offence aged 15-44[2]	1,872
Implied multiplier	20.8

1. Median estimate (Hall et al., 2000b)
2. Average of 1997 and 1998 figures

Table B.5: Estimated number of regular heroin users by year from the number of arrested for heroin offences for the period 1997-2002

	1997	1998	1999	2000	2001	2002
No of heroin arrests	1,237	2,546	2,970	2,532	1,174	1,036
Percentage aged 15-54	98.9	99.0	99.0	99.3	99.1	99.0
No arrested 15-54	1,224	2,521	2,940	2,514	1,164	1,026
Multiplier	20.8	20.8	20.8	20.8	20.8	20.8
Estimated regular heroin users	25,500	52,400	61,100	52,300	24,200	21,300

The number of PMT registrations in a year

Table B.6: Derivation of implied multiplier to apply to the number of annual PMT registrations

Number of regular heroin users in NSW[1]	41,000
Number of PMT registrations 1997/98[3] 15-44	5,400
Implied multiplier	7.6

1. Median estimate (Hall et al., 2000b)excluding PMT multiplier estimate.
2. Excludes reregistrations with less than 7 days since end of previous program.
3. Average of 1997 and 1998

Table B.7: Derivation of the estimated number of regular heroin users in NSW based of pharmacotherapy registrations made for individuals aged 15-54

	1997	1998	1999	2000	2001	2002
Number registering for PMT[1]	5,152	5,647	5,498	6,386	4,803	5,514
Multiplier	7.6	7.6	7.6	7.6	7.6	7.6
Number of regular heroin users	39,200	42,900	41,800	48,500	36,500	41,900

1. Registrations taken from figures supplied by NSW Department of Health.

Table B.8: Multiplier estimates of regular heroin users in NSW using different source data for the period 1997 to 2002

	1997	1998	1999	2000	2001	2002
Fatal overdoses x 112.5	37,500	50,900	54,100	39,300	19,900	17,800
Ambulance call outs x 10.1	33,000	45,000	42,200	35,600	16,600	18,400
Heroin arrests x 20.8	25,500	52,400	61,100	52,300	24,200	21,300
PMT reg x 7.6	39,200	42,900	41,800	48,500	36,500	41,900
Mean	33,800	47,800	49,800	43,900	24,300	24,900
Mean per 1000 pop	9.4	13.1	13.6	11.8	6.5	6.6
Median	35,250	47,950	48,150	43,900	22,050	19,850
Median per 1000 pop	9.8	13.2	13.1	11.8	5.9	5.3

APPENDIX C: THE CAPTURE-RECAPTURE METHOD

The capture-recapture method was used to make separate estimates of the number of NSW regular heroin users from two sources of data. Members of the first sample are returned to the wild after being "marked" in a way that permits those who are recaptured in a second sample to be identified (Hall et al, 2000). Sandland (1986) adopted capture-recapture procedures to estimate the number of regular heroin users from arrest data, whilst Hall et al (2000) used similar procedures to estimate the number of regular heroin users from both arrest and PMT data. This study uses similar procedures to those adopted by Hall et al (2000) to make separate estimates of the number of regular heroin users from heroin arrest and PMT data. Details of the procedure adopted are set out below. For a wider discussion of the use of capture-recapture procedures to estimate the number of regular heroin users, see Hall et al (2000).

Data

In this study following Hall et al (2000) data from four successive capture periods was used to estimate the size of the hidden (not captured) population and hence the overall population of NSW regular heroin users. Within each four-period block, the data were recoded to form four summary variables. These variables represented whether or not the individual had been arrested in each of the four periods. Cross-tabulations of these four variables therefore created 16 profiles ranging from those who had been arrested in each of the four periods to those who had not been arrested during the four periods of the study. The frequency of 15 of the 16 patterns can be obtained from the existing data; the capture-recapture analysis estimates the size of the sixteenth (hidden) population. The size of the hidden population is combined with the existing data to provide an estimate of the number of individuals who could be potentially captured (regular heroin users) during the four periods.

Arrest data

Two different analyses were undertaken using capture periods of six and twelve months. In the analysis using annual capture periods, data on arrests for heroin related offences during the years 1995-2002 was used to form 5 four-year blocks of data, starting 1995-1998 and finishing 1999-2002. Within each four-year block, the data were recoded to

form four summary variables that reflected whether an individual had been arrested at least once during a period, as described above. Table C.1 shows the data created using this procedure: for each of the four periods. The data are coded as arrested (1) or not arrested (0) and the final column gives the count data for each possible combination. Thus, it can be seen from the final row that there were 43 people who were arrested for a heroin-related offence in each of the four years 1996, 1997, 1998 and 1999. The top row of Table C.1 represents those people who are regular heroin users (and may therefore potentially be arrested for heroin related offences) but who have not been arrested at any time during the four-year period. This row represents the hidden population that we are attempting to estimate.

Table C.1: Numbers of people arrested for heroin related offences in NSW, in four year periods, during the overall period 1996 -2002

Row No.	YEAR 4	YEAR 3	YEAR 2	YEAR 1	Count			
					1996-99	1997-00	1998-01	1999-02
1	0	0	0	0	???	???	???	???
2	0	0	0	1	1126	860	1856	2370
3	0	0	1	0	798	1789	2105	1890
4	0	0	1	1	124	116	343	319
5	0	1	0	0	1851	2111	1838	809
6	0	1	0	1	89	83	144	99
7	0	1	1	0	117	323	2370	118
8	0	1	1	1	27	49	75	38
9	1	0	0	0	2322	1887	808	724
10	1	0	0	1	84	62	49	78
11	1	0	1	0	82	151	89	92
12	1	0	1	1	20	28	29	32
13	1	1	0	0	350	295	111	48
14	1	1	0	1	43	19	35	19
15	1	1	1	0	50	70	38	28
16	1	1	1	1	19	20	15	15

Note: 1 = arrested; 0 = not arrested

Using six month capture periods, data on individuals who were arrested for heroin offences during the years 1996 – 2002 was used to form six, two year blocks of data, starting 1996-1997 and finishing 2001-2002 as shown in Table C.2.

Table C.2: Numbers of people arrested for heroin related offences in NSW, in four six monthly periods, during the overall period 1997 –2002

Row No.	Period 1	Period 1	Period 3	Period 4	Count				
					1997-1998	1998-1999	1999-2000	2000-2001	2001-2002
1	0	0	0	0	???	???	???	???	???
2	0	0	0	1	1221	1054	988	383	503
3	0	0	1	0	990	1321	1056	574	389
4	0	0	1	1	122	133	84	18	34
5	0	1	0	0	461	1068	1025	1049	403
6	0	1	0	1	43	73	68	24	15
7	0	1	1	0	38	155	99	59	18
8	0	1	1	1	13	22	16	7	4
9	1	0	0	0	525	913	1414	1187	634
10	1	0	0	1	41	61	68	28	30
11	1	0	1	0	36	88	94	52	32
12	1	0	1	1	17	12	15	8	3
13	1	1	0	0	38	103	127	97	27
14	1	1	0	1	13	20	15	5	2
15	1	1	1	0	10	27	26	14	3
16	1	1	1	1	2	4	3	2	3

Note: 1 = arrested; 0 = not arrested

PMT Data

In the analysis using annual capture periods, the data on individuals entering PMT programs during the years 1997-2002 was used to form 3 four year blocks of data, starting 1997-2000 and finishing 1999-2002. Within each four-year block, the data were recoded to form four summary variables that reflected whether an individual had registered for PMT at least once during a period, as described above and shown in Table C.3.

Table C.3: Numbers of people registering for PMT in NSW, in four year periods, during the overall period 1997 -2002

Row Number	Year 1	Year 2	Year 3	Year 4	Count		
					1997-00	1998-01	1999-02
1	0	0	0	0	?	?	?
2	0	0	0	1	3775	2708	3228
3	0	0	1	0	2797	3538	2447
4	0	0	1	1	796	677	638
5	0	1	0	0	2873	2822	3576
6	0	1	0	1	570	390	589
7	0	1	1	0	646	744	583
8	0	1	1	1	279	222	236
9	1	0	0	0	2847	3182	3122
10	1	0	0	1	440	377	427
11	1	0	1	0	415	627	409
12	1	0	1	1	170	142	136
13	1	1	0	0	686	727	878
14	1	1	0	1	199	155	170
15	1	1	1	0	236	304	248
16	1	1	1	1	163	138	112

Note: 1 = registered; 0 = not registered

Similarly in the analysis using six month capture periods, data on individuals who registered for PMT programs during the years 1997 – 2002 was used to form five, two year blocks of data, starting 1997-1998 and finishing 2001-2002.

Table C.4: Numbers of people registering for PMT in NSW, in four six monthly periods, during the overall period 1997 –2002

Row No.	Period 4	Period 3	Period 2	Period 1	Count				
					1997-1998	1998-1999	1999-2000	2000-2001	2001-2002
1	0	0	0	0	???	???	???	???	???
2	0	0	0	1	1887	1976	2009	2297	2091
3	0	0	1	0	1685	1999	1831	2514	1450
4	0	0	1	1	300	353	254	402	202
5	0	1	0	0	1886	2010	2112	1962	2016
6	0	1	0	1	215	250	304	261	216
7	0	1	1	0	263	285	268	258	203
8	0	1	1	1	113	97	81	109	56
9	1	0	0	0	2147	1908	2513	1479	2183
10	1	0	0	1	165	197	248	166	215
11	1	0	1	0	248	244	224	199	160
12	1	0	1	1	61	76	54	58	34
13	1	1	0	0	335	260	359	189	559
14	1	1	0	1	64	54	81	41	68
15	1	1	1	0	108	93	102	68	89
16	1	1	1	1	47	28	46	19	25

Note: 1 = registered; 0 = not registered

Procedure to estimate the hidden population

A loglinear model was used to estimate the number of hidden population, i.e. those with a capture history of 0000, from the numbers of individuals with different capture histories. The procedure described below is that adopted by Sandland (1986) and Hall et al (2000).

The general structure for the model with no interaction terms is

(1)

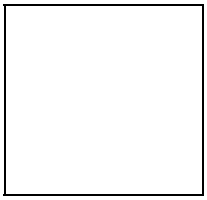
where is the log of the observed population in the ith capture pattern, is the value of the jth year in the ith capture history (either 0 or 1), the are regression coefficients and is the error in the model. The predicted value of the hidden population and its standard error are obtained by calculating the predicted value of when all the are zero. A generalised linear model was fitted to this equation to estimate all the parameters, and the predicted value obtained for the case of capture history 0000 (all the).

For this project the model with all second-order interaction terms was fitted, as were all models with third-order interaction terms and the saturated model (with fourth-order interaction term). AIC and BIC goodness-of-fit statistics for the models relative to the saturated model were obtained. Each model was weighted with the following weight:

(2)

where is the BIC statistic for the j-th model. Thus the saturated model has a weight of 1 and models with better fit statistics than the BIC are given higher weights. As suggested by Hooke and Regal (1995) the final estimate of the hidden population was estimated from weighted mean of the predicted estimates of the hidden population using these weights. The estimate of the total population of regular heroin users was thus the final estimate of the hidden population and the counts in each in of the capture histories.

The standard error of the final estimate of the hidden population is obtained by treating each separate estimated predicted value as a random variable and calculating the weighted standard error:



(3)

where there are n=16 possible models

The standard error estimate calculated from (3) was applied to a normal distribution, because a) the estimate was large and the normal approximation was considered appropriate and b) the degrees of freedom for the weighted mean were not clear (as contributing models had different degrees of freedom).

All modelling was conducted in S-Plus 6.1.

This procedure was applied to the capture history profiles obtained from the NSW arrest data and PMT registration data set out in Tables C.1, C.2 ,C.3, and C.4.

Where a number of analyses included data for a particular year the estimate of regular heroin users for that year was been obtained by averaging the estimates of regular heroin users obtained from all the analyses that included the year in question.

Table C.5: Capture-recapture estimates of the number of regular heroin users for the years 1996-2002 in NSW (annual capture periods)

	1996 to 1999	1997 to 2000	1998 to 2001	1999 to 2002
Regular heroin users estimate	55,485	51,338	59,062	49,489
CI Lower	49,603	45,899	52,873	42,169
CI Upper	62,181	57,553	66,101	58,318

Table C.6: Combined estimate of regular heroin users for the period 1997 to 2002 in NSW, from capture-recapture studies individuals arrested for heroin offences using annual capture periods

Capture-recapture period	1997	1998	1999	2000	2001	2002
1996-1999	55,485					
1997-2000		51,338				
1998-2001			59,062			
1999-2002				49,489		
Combined estimate	**55,485**	**51,338**	**59,062**	**49,489**		

Table C.7: Estimates of the numbers of regular heroin users for the years 1997-2002 in NSW, from capture-recapture studies of individuals arrested for heroin offences using 6-monthly capture periods

	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002
Regular heroin users estimate	37,419	27,847	34,741	41,286	28,720
CI Lower	29,180	23,582	28,168	30,843	19,830
CI Upper	48,309	33,095	43,187	55,717	42,065

Table C.8: Combined estimate of regular heroin users for the period 1997 to 2002 in NSW, from capture-recapture studies individuals arrested for heroin offences using 6-monthly capture periods.

	1997	1998	1999	2000	2001	2002
1997-1998	37,419					
1998-1999		27,847				
1999-2000			34,741			
2000-2001				41,286		
2001-2002					28,720	
Combined estimate	**37,419**	**27,847**	**34,741**	**41,286**	**28,720**	

Pharmacotherapy registrations

Table C.9: Estimates of the numbers of regular heroin users from capture-recapture studies of individuals registering for PMT in NSW, for the years 1996-2002

	1996 to 1999	1997 to 2000	1998 to 2001	1999 to 2002
Estimate of regular Heroin users	51,591	48,835	47,422	46,479
CI Lower	49,142	46,285	44,950	43,848
CI Upper	54,222	51,607	50,110	49,365

Table C.10: Combined estimate of regular heroin users for the period 1997 to 2002 in NSW, from capture-recapture studies of individuals registering for PMT using annual capture periods.

Capture-recapture period	1997	1998	1999	2000	2001	2002
1996-1999	51,591					
1997-2000		48,835				
1998-2001			47,422			
1999-2002				46,479		
Combined estimate	**51,591**	**48,835**	**47,422**	**46,479**		

Table C.11: Estimates of the numbers of regular heroin users from capture-recapture studies of individuals registering for PMT in NSW, using 6 monthly capture periods for the years 1997-2002

	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002
Estimate of regular heroin users	42,400	38,963	44,931	46,728	39,436
CI Lower	38,447	35,398	41,405	42,793	35,787
CI Upper	46,893	43,025	48,859	51,136	43,594

Table C.12: Combined estimate of regular heroin users for the period 1997 to 2002 in NSW, from capture-recapture studies of individuals registering for PMT using 6-monthly capture periods.

Capture-recapture period	1997	1998	1999	**2000**	2001	2002
1997-1998	42,400					
1998-1999		38,963				
1999-2000			44,931			
2000-2001				46,728		
2001-2002					39,436	
Combined estimate	**42,400**	**38,963**	**44,931**	**46,728**	**39,436**	

Table C.13: Estimates of the number of heroin users from capture recapture analysis of PMT registrants and individuals arrested for heroin offences in NSW

	1997	1998	1999	2000	2001	2002
PMT 6mths	42,400	39,000	44,900	46,700	39,400	N/a
PMT Annual	51,600	48,800	47,400	46,500	N/a	N/a
Arrests 6mths	37,400	27,800	34,700	41,300	28,700	N/a
Arrests Annual	55,500	51,300	59,100	49,500	N/a	N/a
Median	**47,000**	**43,900**	**46,200**	**46,600**	**34,100**	**N/a**

Limitations of the capture-recapture analysis

The model allows for:

- individuals to enter or leave the pool of regular heroin users during the four-year analysis period;
- Variations in police effort from year to year and similarly variations in the availability of PMT from period to period; and
- Individuals who are arrested in one year to have a different probability of arrest compared to non arrested individuals in subsequent years and individuals who enrol in PMT in one year to have a different probability of enrolling in subsequent years.

Nevertheless there are several limitations to the estimate of the numbers of regular heroin users derived from using the above model:

- The capture-recapture model assumes *homogeneity of individuals to capture*, that is although there can be different capture histories all individuals have the same probability of experiencing the same capture history (Sandlands, 1986). In practice, the capture probability of individual regular heroin users is likely to be affected by personal factors such as heroin usage patterns, location and previous history.
- The model assumes that capture and release occurs at a single point in time, not over a long period, in order to ensure equal survival rates for all individuals. However approximately 20% of individuals arrested receive full time custodial sentences (see below), whilst individuals registering for PMT undergo treatment. The use of annual capture periods, can partly adjust for this limitation, but some individuals remain in custody or in treatment for longer than a year.

The estimates generated here did not use a specified model-fitting strategy (Cormack, 1989; Lebreton, Burnham, Clobert, & Anderson) as in the absence of *a priori* reasons it was difficult to prefer one model to another (Hall et al, 2000). The inclusion of non-optimal models might have had the effect of biasing the estimate of the hidden population away from the true value.

Data on capture periods

Arrest Sentencing data

NSW sentencing data for the year 2002 was used to provide information about sentencing patterns for heroin offences. Assuming that the overall conviction rates apply to opioid offences, approximately 20% of individuals whose charges were determined by the court received full time custodial sentences. Of these receiving full time custodial sentences, just under half (i.e. 9% of those proceeding to court) received lower court sentences which were on average 5.5 months, and just over half (i.e. 10%) received higher court sentences averaging 31.6 months (based on the sentence lengths for all drug offences). In addition the average delay to reach court for all offences was around 2 months. On these figures, around 90% of individuals who faced court for primary opioid offences would have been free within a year of being charged.

Length of PMT programs

Data on the length of stay in PMT for individuals registering for PMT in the period 1997 to 2002 was examined to provide information about patterns in the length of stay. During 1997-2002, of individuals starting any treatment program, in all but one year (2001), over 60% were in programs that lasted less than one year and over 50% were in programs that lasted less than 6 months so that approximately 10% ceased programs between 6 and 12 months after starting (Table C.14).

Table C.14: Percentage of programs lasting less than 6 and 12 months by program start year for 1997-2002 in NSW

Start year	Percentage less than 6 mths *	Percentage less than 12 mths*
1997	59	69
1998	59	69
1999	57	66
2000	52	62
2001	49	58
2002	56	62

* Estimated by interpolation between quarters

APPENDIX D: THE BACK PROJECTION METHOD OF ESTIMATING REGULAR HEROIN USERS

The back projection method has been widely used to estimate HIV incidence from AIDS incidence data (see De Angelis et al, 1998 (with discussion)). More recently, the method has been used with indicators of regular heroin use, such as, the observed numbers of fatal opioid overdoses and new entrants to pharmacotherapy treatment to estimate the numbers of regular heroin users. Trends in estimates of the prevalence of Australian regular heroin users for the period 1970- 1997 derived from these two data sources were in close agreement, and the point prevalence estimates for current users were similar to those obtained from other sources (Hall et al., 2000a; Law et al., 2001). The method of back-projection used in this report was that suggested by Becker, Watson and Carlin (1991) because it has the advantage that it does not require strong parametric assumptions about the shape of the progression distribution from heroin dependence to fatal overdose; it only assumes that this pattern follows a smooth curve. The analysis assumed that there were negligible numbers of dependent heroin users prior to 1960, an assumption supported by analyses of fatal opioid overdoses (Hall et al, 1999a) and historical analyses of illicit drug use in Australia (D. Manderson, 1993; McCoy, 1980a).

Fatal opioid overdoses

The back projection method uses the number of fatal opioid overdoses in Australia in conjunction with an estimate of the rate at which people progress from regular heroin use to dying of a heroin overdose to estimate the incidence of regular heroin use at any time point. Estimates of the rate at which regular heroin users cease using are combined with the incidence estimate to provide a prevalence estimate (Hall et al., 2000a; Law et al., 2001). Detailed assumptions are

- there were negligible numbers of regular heroin users prior to 1960. This assumption is supported by analyses of fatal opioid overdoses (Hall, Degenhardt, & Lynskey, 1999) and historical analyses of illicit drug use in Australia (A. Manderson, 1993; McCoy, 1980b);

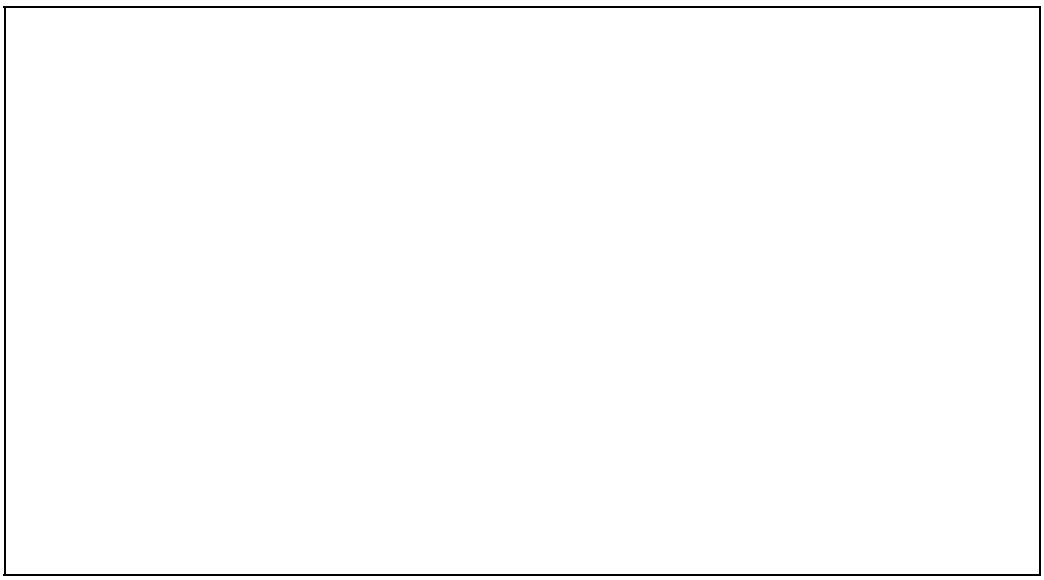
- the annual rate of fatal opioid overdoses is 0.9% of regular heroin users, which is equivalent to the assumption of a fatal opioid multiplier of 112.5 adopted in this study (see Appendix B above) ;
- 5% of regular heroin users stopped regular heroin use each year (English et al., 1995; Thorley, 1981);

An upper limit on the overdose mortality rate among people commencing regular heroin use was obtained by taking an annual rate of fatal opioid overdoses of 0.7% combined with a 3% annual rate of regular heroin users ceasing use. A lower limit was obtained by combining a 1.1% annual rate of fatal opioid overdoses with a 7% annual rate of regular users ceasing use.

Overall rates of progression from regular heroin use to fatal heroin overdose

Figure B1 below, shows the overall rates of progression from commencing heroin use to overdose death derived from the assumption about the annual probability of a regular heroin user having a heroin overdose (see Section 2.1.3).

Figure D.1: Cumulative probability of opioid overdose death from commencement of regular heroin use

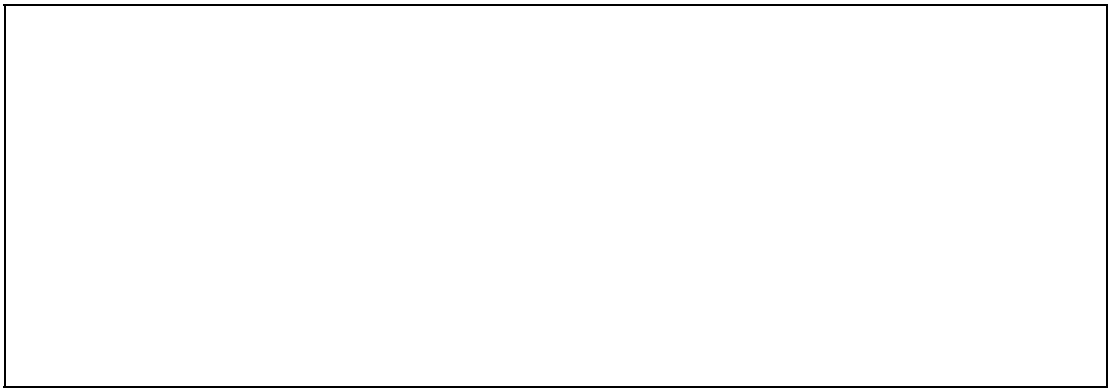


Back projection predications of overdose deaths

Figure B2 sets out the reported number of overdose deaths in Australia (1960-2002) together with the annual overdose deaths predicted by the back projection model fitted to these data, assuming the rate of progression heroin use to fatal overdose distribution

shown in Figure B1 above. In view of the uncharacteristic pattern of decline in the number of overdose deaths in the period 2000 to 2002, two back projections have been undertaken, using data from 1960-2000 and from 1960-2002.

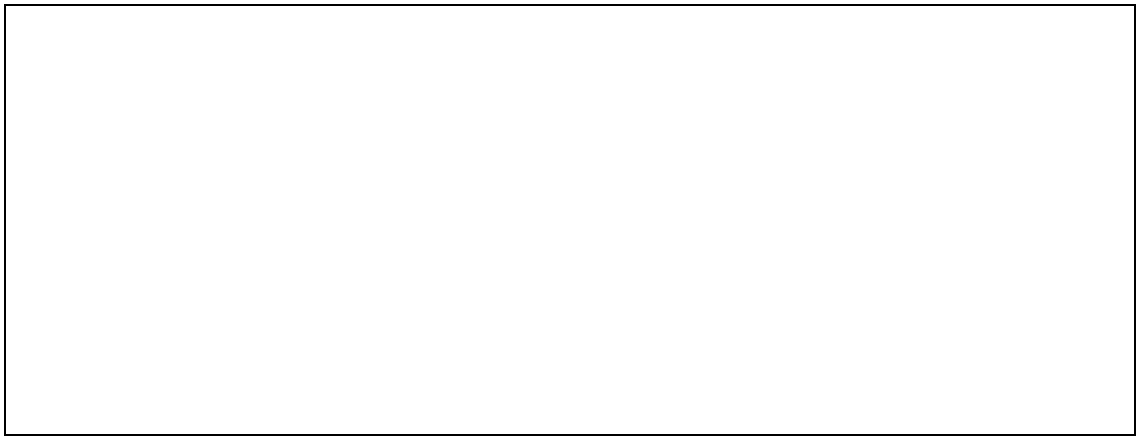
Figure D.2: Reported and fitted annual overdose deaths in Australia 1960-2002



Predictions of annual overdoses show a reasonable fit with reported overdoses until 1996 (consistent with the Law et al (2001) earlier study, however post 1996, the predictions are less able to match the large changes in the number of reported fatal overdoses. With the 1964-2000 data set, the predictions show a trend consistent with reported figures. However when the data period is extended to include 2001 and 2002, that is the period of uncharacteristically 3 years of consecutive decline and in particular 2001 a year of particularly large decline, then the predictions post 1996 fail to fit adequately with the trends observed in the reported data. This suggests that it is more appropriate to use the 1964-2000 data to derive estimates of the number of regular heroin users.

The back projection estimates of the numbers of Australian regular heroin users based on the number of Australian overdose deaths for the period 1960-2000 are shown in Figure D.3 together with the estimates from the previous Law et al (2001) study.

Figure D.3: Back projection estimates of the numbers of Australian regular heroin users compared with Law et al (2001) estimate



There is broad agreement between the current and Law et al (2001) estimates of Australian regular heroin users using the back projection method applied to fatal overdoses.

New entrants to PMT in NSW

The back projection method uses the number of NSW new entrants to PMT in conjunction with an estimate of the rate at which people progress from regular heroin use to PMT to estimate the incidence of regular heroin use at any time point. Estimates of the rate at which regular heroin users cease using are combined with the incidence estimate to provide a prevalence estimate (Hall et al., 2000a; Law et al., 2001).

The following assumptions were made:

- there were negligible numbers of regular heroin users before 1960 (this was also assumed in the back projection estimate of regular heroin users from the numbers of fatal Australian opioid overdoses);
- 50% of regular heroin users who were still using heroin after 6 years of regular heroin use would have entered PMT at some time in 6 years, and 80% of persons who had been regular heroin users for 15 years would have entered PMT at some time in that period. These assumptions are consistent with data from a recent survey of Sydney heroin users (Weatherburn, Lind, & Forsyth, 1999). They were also consistent with data on mean age at entry to methadone treatment, self-reported data from needle and syringe exchange attendees (MacDonald M, NCHECR Sydney, personal communication 1999), and self-reported data from injectors surveyed in the

Australian Study of HIV and Injecting Drug Use (Loxley, Carruthers, & Bevan, 1995);

- Upper and lower limits of rate of entry to methadone were specified as follows. It was assumed that 50% of heroin users entered PMT by 4 years and 8 years respectively, and that 90% and 70% respectively had entered PMT by 15 years;
- 5% (upper and lower limits of 7% and 3%) of regular heroin users ceased heroin use each year and the rate at which they did so was independent of whether or not they entered methadone treatment (Figure B2). The latter assumption is supported by evidence that long term abstinence rates in treated heroin users are the same whether they entered abstinence-oriented drug treatment or methadone maintenance treatment (Maddux & Desmond, 1992) (Maddux & Desmond, 1992); and
- The rates of progression from regular heroin use to entry to pharmacotherapy treatment were constant throughout the period 1970 to 2002.

To accommodate a rapid increase in the numbers entering methadone programs in the mid eighties following and increase in the availability of treatment, the back projection analyses was based on numbers that were smoothed using an 11 year moving average (Law et al., 2001).

Overall rates of progression from regular heroin use to PMT registration

Figure B4 below, shows the overall rates of progression from commencing heroin use to PMT registration derived from the assumptions set out in (see Section 2.4.4).

Figure D.4: Cumulative probability of starting PMT from commencement of regular heroin use

Back projection predications of new entrants to PMT

Figures B5 and B6 set out the reported number of NSW new entrants to PMT (1960-2002), the 11 year smoothed data together with the number of new entrants to PMT predicted by the back projection model fitted to these data, assuming the rate of progression distribution shown above. In view of the uncharacteristic pattern of decline in the number of overdose deaths in the period 2000 to 2002, two back projections have been undertaken, using data from 1960-2000 and from 1960-2002.

Figure D.5: Reported and fitted NSW new entrants to PMT 1960-2002

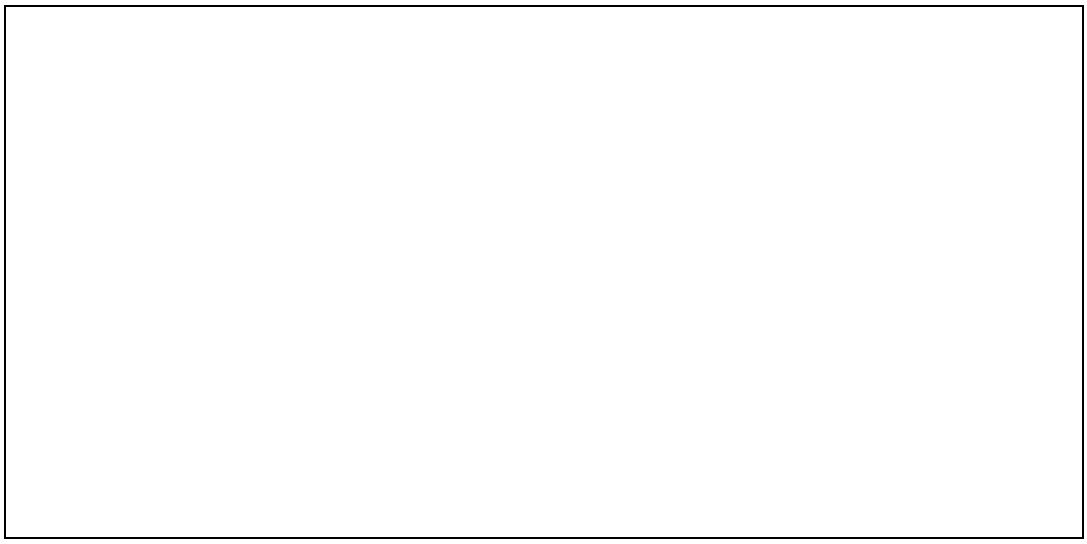
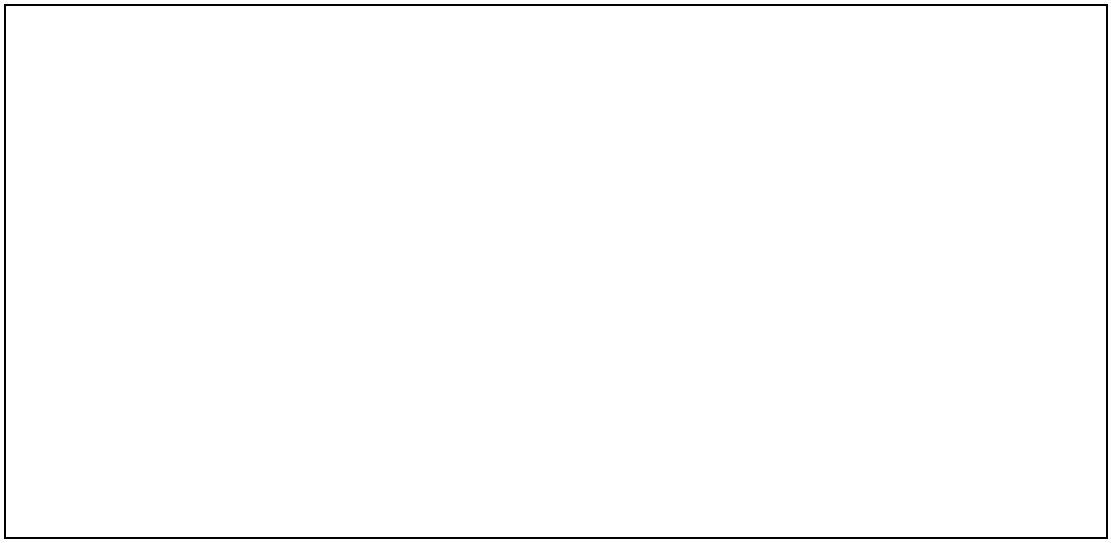


Figure D.6: Detail of Figure D.5: Reported and fitted NSW new entrants to PMT 1993-2002



The back-projection fitting of annual overdoses show a reasonable fit with previous estimates based on reported overdoses (consistent with the Law et al (2001)) for the data set to 2000. Using data set to 2002 the fitted back projections matched the smoothed trends in the reported data, but was not able to match the substantial increase in new PMT entrants in 2000, and the substantial decline in the number of new entrants in 2001.

Back projection estimates of NSW regular heroin users

Figure B7 sets out the back projection estimates of the numbers of NSW regular heroin users based on the number of new entrants to PMT for the periods 1970-2000 and 1970-2002 together with the previous estimate from the Law et al (2001) study.

Figure D.7: Back projection estimates of the numbers of NSW regular heroin users from PMT numbers

There is close agreement between back projection estimates derived from the two data series ending 2000 and 2002 until 1997 at which stage the estimates based on the data set ending 2002 become increasingly lower than the estimates based on the 2000 data set.
There is also close agreement between the back projection estimates of the number of regular heroin users from the three data sets ending 1997, 2000 and 2002, with the 1997 data estimate of 39,200 being 3% lower than the estimates of 40,600 (2000) and 40,400 (2002).

Table D.1: Estimates of regular heroin users in NSW derived from back projection methods, 1997-2002.

	1997	1998	1999	2000	2001	2002
Fatal opioid overdose 2000	34,100	38,200	42,200	45,800		
PMT 2000	40,400	42,500	44,600	46,700		
PMT 2002	40,600	42,200	43,100	43,300	43,100	42,900

Back projection limitations

There are a number of limitations associated with the back projection method (refer Law et al (2001) for detailed discussion). Although the back projection method can be used to estimate long-term trends reliably, the method is less accurate when estimating very rapid

changes particularly in the immediate past. Because back-projection, as the name implies, estimates trends in dependent heroin use in the past by projecting backwards from trends in overdose deaths or entrants to PMT, the immediate recent past is the period over which the estimates are least informative. Furthermore, the back projection method of estimating regular heroin users makes assumptions about rates of progression from starting regular heroin use to fatal overdose and PMT registration and the rate at which regular users cease use. These rates are assumed to be constant although in practice they may vary with individual factors or over time. Law et al (2001) found that assuming an increasing or decreasing rate of progression throughout the period 1960-1997 provided results in long-term trends that were similar to the primary analysis. Nevertheless, very rapid changes in numbers of regular heroin users combined with the relative lack of information about very recent trends, mean that back-projection estimates are less informative about large changes in trends in the recent past.

The back projection method assumes that there is complete and consistent data reporting (Law et al, 2001) however the ICD classification of cause of death has changed three times in the period 1960-2002 and there may be inconsistencies in classification or reporting (Law et al, 2001). Despite these limitations, a previous study has indicated that for data 1970-1997 the two back projection estimates of the number of regular heroin users based on the number of fatal opioid overdoses and the number of new entrants to PMT are reasonably consistent and show reasonable agreement with estimates of the number of heroin users obtained from other methods (Law et al, 2001).