Estimation of the Size of the Illicit Methamphetamine and MDMA Markets in Canada

A Discussion Paper on Potential Methods and Data Sources

by

Martin Bouchard, PhD

and

Owen Gallupe, MSc

and

Karine Descormiers, MSc

prepared for

Research and National Coordination
Organized Crime Division
Law Enforcement and Policy Branch
Public Safety Canada

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Executive Summary

Background and Objectives

Ever since their relatively recent appearance as drugs of choice among the Canadian population, methamphetamine (meth) and 3,4-methylenedioxy-N-methylamphetamine (MDMA or ecstasy) hydrochloride have been the object of concern for public health and law enforcement agencies. The concern with meth and ecstasy are based on two main issues: (i) the highly addictive nature of these drugs paired with serious health consequences for users (especially for meth), (ii) the identification of Canadian offenders as major players in meth/ecstasy production and exportation. Although various reports suggest that both issues deserve immediate consideration from policy makers and researchers, there is a lack of data on the most basic (yet crucial) issue – the size of the markets.

The purpose of this report is to re-examine the scientific and grey literature on current methods of estimating the size of illegal markets, with an emphasis on the meth/MDMA markets. The first part of this paper reviews the current data available from various surveys on the prevalence of Amphetamine-Type Stimulants (ATS) and MDMA use in Canada. The second section of the report examines recent innovations in the area, with a special emphasis on two families of methods: (i) multiplier methods, which derive an estimate of the population based on a rate of occurrence of an event in the population of interest (e.g. number of overdoses per ATS user); and (ii) capture-recapture methods, which infer the number of users, dealers or producers never arrested based on the patterns of arrests and re-arrests over a fixed time period. The third part of the paper turns to the data requirements for applying these methods to the Canadian meth and ecstasy markets, with an emphasis on estimating the scale of ATS production.

Method

This present report is based on a review of the most recent data available from various research and literatures on the prevalence of ATS and MDMA in Canada. Peer-reviewed articles, including published reports from important longitudinal studies in Canada, as well as surveys and publications available from the following groups were examined:

- United Nations Office of Drugs and Crime
- Centre for Addiction and Mental Health
- Centre for Applied Research in Mental Health and Addiction
- B.C Centre for Excellence in HIV/AIDS

Key Findings

Results from the current data available from various surveys on the prevalence of ATS and MDMA show that although Canada has recently been identified as a primary player in the global amphetamine-type stimulant trade, levels of use remain low in the student and especially in the general population, and are generally on the decline. ATS use is generally higher in specific at-risk populations (e.g. street youths, rave attendees, homosexual populations, etc), with no discernable trends. A review of the literature on trafficking and production found that there is too much uncertainty in regards to the existing data to truly assess the role of Canada in the global ATS trade. There are no established estimates of the size of production and the amount of ATS lab seizures remains low. While Canada ranked 6th in the world in the amount of meth/amphetamine seized in 2007 with 1.54 metric tons, the figure for the previous years was as low as 60kg. Finally, the review found that both methods for estimating the size of ATS market in Canada – multiplier methods and capture-recapture methods have shown more promise in the past in obtaining reliable estimates of illegal populations, including drug dealers and producers.

Conclusions and Recommendations

Several guidelines are provided on how to approach the estimation of the meth/MDNA markets.

- A maximum number of different indicators should be collected and examined for detection of trends. These include: i) meth/MDMA treatment admissions; ii) arrests for meth/MDMA-related offences; iii) meth/MDMA-related overdoses; iv) meth/MDMA purity levels; v) meth/MDMA drug prices; vi) importation of key precursors; and vii) domestic and overseas seizures.

- Estimating the number of drug users is a necessary, but not sufficient starting point. It is not sufficient to determine the size of production because of the position of Canada as a potential exporting country. But a good estimate of the quantity consumed is necessary to assess the size of potential exports (Bouchard, 2008a).

- The number of dealers should (loosely) follow the number of users. For example, an increase in capture-recapture estimates of the number of retail dealers should normally be accompanied by a similar trend in the number of drug users.

- In the context of domestic production, the population of producers, dealers and users may not grow in parallel. While the number of dealers should loosely follow the number of users, the same cannot be said of the number of producers which, in the presence of an exportation market, can follow different trends entirely.

- Triangulation of estimates from different methods is essential. No one method is reliable enough to be used without proper checks for validity, which should include alternative estimates derived from different methods.

List of Abbreviations

AADAC= Alberta Alcohol and Drug Abuse Commission
ADAM= Arrestee Drug Abuse Monitoring
AFM = Addictions Foundation of Manitoba
AHSAMH= Alberta Health Services Addiction and Mental Health
ATS= Amphetamine-Type Stimulants
BCAHS = BC Adolescent Health Survey
BCCS= BC. Coroners Service
CADUMS= Canadian Alcohol and Drug Use Monitoring Survey
CAMH= Centre for Addiction and Mental Health
CAS= Canadian Addiction Survey
DATIS=Drug and Alcohol Treatment Information System
DUMA= Drug Use Monitoring in Australia
E-SYS = Enhanced Surveillance of Canadian Street Youth
HBSC = Health Behaviour in School-Aged Children study
IDMS = Illicit Drug Monitoring System
INCB= International Narcotics Control Board
LGBTQ= Lesbian/Gay/Bisexual/Transgender/Questioning
MASY = Methamphetamine Study of Youth
MDMA= 3,4-methylenedioxy-N-methylamphetamine hydrochloride (Ecstasy)
MIP= Module d'Informations Policieres
MSIYS = Marginalized and Street-Involved Youth Survey
MSIYS2 = Marginalized and Street-Involved Youth Survey
NBSDUS = New Brunswick Student Drug Use Survey
NLSDUS = Newfoundland and Labrador Student Drug Use Survey
NSSDUS = Nova Scotia Student Drug Use Survey
NZNHDS = New Zealand National Household Drug Survey
ONDCP= Office of National Drug Control Policy
OSDUHS = Ontario Drug Use and Health Survey
PHAC= Public Health Agency of Canada
RCMP= Royal Canadian Mounted Police
SAMHSA= Substance Abuse and Mental Health Services Administration
SN = Sex Now
SUCRP = Substance Use in a Canadian Rave Population
TAYES = The Alberta Youth Experience Survey
UNODC= United Nations Office on Drugs and Crime
VIDUS = Vancouver Injection Drug Users Study

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1 Background

Ever since their relatively recent appearance as drugs of choice among the Canadian population (Nordeste, 2004; United Nations Office on Drugs and Crime (UNODC), 2009), methamphetamine (meth) and MDMA (ecstasy) have been the object of concern for public health and law enforcement agencies. The concern with meth and ecstasy touches on two main issues: a) the highly addictive nature of these drugs paired with serious health consequences for users (especially for meth, see Weisheit, 2008); and b) the identification of Canadian offenders as major players in meth/ecstasy production and exportation (UNODC, 2009).

While various reports suggest that both issues deserve immediate consideration from policy makers and researchers, there is a lack of data on the most basic (yet crucial) issue – the size of the markets. There are two major challenges that need to be overcome before the nature and size of these markets can be properly understood. First, most surveys do not cover the populations which are most likely to be heavy users, such as street-based populations, sex trade workers, rave scene enthusiasts, or offenders in general (Nordeste, 2004). As a result, it becomes difficult to assess whether the decrease in use reflected in recent general and high school population surveys (Ontario Drug Use and Health Survey (OSDUHS), 2009) truly reflect a general trend among the population of heavy users. Second, the data on production and exportation are too limited to be able to confidently discuss the prevalence of Canadian-produced meth and ecstasy in other countries. The number of detected lab cases remains small (typically less than 20 annually, Royal Canadian Mounted Police (RCMP), 2008) despite claims of widespread domestic production and exportation (UNODC, 2009). In comparison, production in the US appears to be much more extensive, at least as far as raw numbers are concerned. For example, US authorities reported 12,964 meth lab seizures between 2004 and 2007, although a seriously declining trend in seizures has also been observed during that time period (UNODC, 2009; Weisheit and Wells, 2008).

These challenges in assessing the true size of the problem are not a peculiarity of the meth or ecstasy markets. It is a general challenge with crime in general and with any hidden populations, including offending and drug using populations. Fortunately, recent advances in prevalence research have shown that such challenges can be overcome with the use of proper statistical methods. In particular, capture-recapture methods have been shown to provide valid and robust estimates of various populations of interest here, including drug users (e.g. Calkins and Atkan, 2000; Choi and Comiskey, 2003), prostitutes (Rossmo, 1990) and their clients (Roberts and Brewer, 2006), drug dealers (Bouchard and Tremblay, 2005) and cannabis growers (Bouchard, 2007). Originally developed in biology to estimate the size of animal populations (Schwartz and Seber, 1999), minor modifications of the original methods (e.g. Zelterman, 1988) have been shown to accommodate patterns in human behaviour (Bouchard, 2007). These methods build on the relative importance of a recurring pattern in an observed population (e.g. re-entry into treatment, re-arrest) to infer the proportion of this population that is active, but unobserved in the data.

The objective of the current project is to produce a discussion paper that will review the scientific and grey literature on current methods to estimate the size of illegal markets, with an emphasis on the meth/MDMA markets. The review will focus on recent innovations in the area, with a special emphasis on the utility of capture-recapture methods in estimating the size of hidden populations. The second part of the paper will turn to the potential for applying these methods to the Canadian meth and ecstasy markets, with a concern for estimating the prevalence of users, dealers, producers, and laboratories. The second part will also focus on some of the outcomes of such estimation exercises – including the estimation of the size of production, or the amount available for consumption. Recent studies on the cannabis market in Canada show that a combination of the capture-recapture methodology with detailed case studies of cannabis cultivation operations can be used to estimate the total amount of cannabis used, produced and exported in Canada (Bouchard, 2008a). This approach also contributes to our knowledge of the role of criminal organizations in controlling the industry (Tremblay, Bouchard, and Petit, 2009). The paper will discuss how such methods can be applied to the meth and MDMA markets, with a focus on the existing data collection methods that could serve such purposes, or those that should be implemented. Finally, this work will form the basis for a discussion of the potential prevention and suppression strategies of the meth and MDMA markets in Canada.

2 A Review of ATS Use, Trafficking and Production in Canada

2.1 Consumption

The first step when thinking about illicit markets is their size – in terms of the number of producers, suppliers, and drug users. While estimates for the former two categories may be harder to come by, there are some data available on the prevalence of ATS and MDMA use. Such data are available through various surveys of specific populations. Surveys are a suitable starting point to think about the size of the market to the extent that: a) such surveys are valid indicators of the populations they aim to estimate; and b) there is a survey that can successfully capture all segments of the user population. But there are validity issues to any type of survey, and even combining all existing surveys may not capture all elements of the population – especially the elusive population of heavy users.

A review of the most recent data available on ATS and MDMA use in Canada has been conducted (see Appendix A for details on the literature search). Results are based around three subpopulations: a) general; b) student; and c) "at-risk" populations (defined as those shown to have higher rates of ATS use than other populations, e.g., street populations, rave attendees, and Lesbian/Gay/Bisexual/Transgender/Questioning (LGBTQ)). National population surveys are relied upon to examine rates in the first subpopulation. For students, both general (e.g. Health Behaviour in School-Ages Children Study (HBSC)) and province-specific surveys (e.g., OSDUHS) were examined. Finally, published reports of important longitudinal studies in Canada were reviewed to provide results for at-risk populations.

Results show that while Canada has recently been identified as a primary player in the amphetamine-type stimulant (ATS) market (International Narcotics Control Board (INCB), 2010; UNODC, 2009), levels of use remain low in the student and especially in the general populations, and are generally on the decline. ATS use is higher in specific at-risk populations.

2.1.1 General Population

While ecstasy was incorporated as a separate category in the general population survey many years ago, patterns in methamphetamine use could not be analyzed outside of the general category for ATS like speed before the 2008 version of the Canadian Alcohol and Drug Use Monitoring Survey (CADUMS, 2008). For that reason, these surveys are not a good indicator of meth use but, with the usual caveats taken into account, they can be used to estimate the prevalence of ecstasy use.

Using a random sample of nearly 17,000 Canadians age 15 and older in 2008, the Canadian Alcohol and Drug Use Monitoring Survey found past year prevalence rates of 0.2% for methamphetamine, 1.1% for “speed” and 1.4% for ecstasy (CADUMS, 2008). These numbers are up very slightly from the 2004 Canadian Addiction Survey (CAS) (Adlaf, Begin, and Sawka, 2005) which found that 0.8% had used speed and 1.1% had used ecstasy at least once in the past year. The 2004 CAS found that 6.4% of the population had used speed and 4.1% had used ecstasy in their lifetime.

Projecting these numbers on the Canadian population as a whole, a rate of 0.2% means that there would be over 50,000 Canadians aged 15 or over who would have used methamphetamines at least once in the past year. A 1% prevalence rate for speed or ecstasy means that over 250,000 individuals use those substances annually. Having a good idea of absolute numbers is important to assess the validity of other estimates, including estimates of the number of producers and suppliers of these drugs. But it is also known that these numbers seriously underestimate the total prevalence of users. The question is, by how much? Perhaps capture-recapture methods can help answer that question. Bouchard and Tremblay (2005) used a combination of capture-recapture estimates of the number of dealers of cocaine, crack, and heroin in Quebec in 1998 and a ratio of users-per-dealer derived from law enforcement surveillance investigations to estimate the prevalence of users of those drugs. Here is what they found for cocaine:

> For example, Table 1 reports a [capture-recapture] prevalence figure of 18,626 cocaine dealers in Quebec in 1998. Police investigative files suggest that an

> average cocaine dealer has about 28 customers. Adjusting for part-time cocaine dealers and assuming total replacement, this ratio is brought down to 10.8. We then multiply the number of dealers (18,626) by this adjusted ratio (10.8), and obtain an estimated population of 201,161 cocaine users (rather than the 95,524 self-reported cocaine users found in Quebec's substance abuse survey) (Bouchard and Tremblay, 2005: 744).

Using the same strategy, they estimate the population of heroin (9,381) and crack users (17,300). Note that those estimates were consistent with alternative sources, and that not a single person was surveyed to derive these estimates. From this exercise it was also learned that general population surveys underestimate the prevalence of cocaine users by a factor of 2. A similar strategy could be used to estimate the prevalence of ATS users. Note that the size of the ratio is proportional to the harmfulness of the drug: the more harmful the drug, the larger the under-reporting ratio. It follows that such a ratio is assumed to be minimal to zero for widely used/tolerated drugs like cannabis, and larger for heroin. Drugs like cocaine, crystal meth, and ecstasy are likely to be found in between these extremes.

2.1.2 Student Population

Table 1 presents annual prevalence rates for student populations in most provinces. The data was extracted from a few major surveys around the country, including the OSDUHS which has been conducted for more than two decades. Rates of meth and crystal meth use among adolescent students is generally low compared to cannabis (under 2.5% used in the past year, see Table 1), although it is higher than rates found for the general populations. Over the course of the past decade, rates of meth and crystal meth use have been decreasing. In all regions, ecstasy is the most heavily used ATS, ranging between 7.2% (past year) in Newfoundland and Labrador and 3.2% in Ontario at the most recent measurements. Most regions have witnessed modest increases in ecstasy use over the past decade. Estimates of amphetamine use range from 2% to 5.3% (using both past year and lifetime measures). The most substantial changes over the past decade are in amphetamine use. The most notable of these changes are the decreased prevalence rates in New

Brunswick and Nova Scotia. Interestingly, there are few substantial gender differences in ATS use.

2.1.3 At-risk Populations

Despite a variety of recall periods, the findings of studies examining ATS use among at-risk populations report much higher overall rates than student or general population studies (table 2). Non-Aboriginal street youth appear to have the highest rates, though the ATS use of Aboriginal street youth is not far off. Interestingly, street-based drug injectors have substantially lower ATS use rates than other street populations, though this could be a product of the sampling strategy that focussed on injectors who are more likely to use substances other than ATS. The rates of use among the LGBTQ population appear to be higher than the general population but lower than the street population. The Sex Now (SN) survey (Trussler, 2007) shows that crystal meth use has been declining since the early 2000s among gay men. Rave attendees appear to have the highest rates of ATS use.

Although these surveys of at-risk populations are informative on the extent of consumption for specific subgroups of at-risk individuals, it is much harder to make inferences about prevalence from these numbers. Not only is it sometimes impossible to determine the boundaries from one population to the next or the extent of overlap between them, but the problem of the denominator is even greater – how many users over how many susceptibles? Such is the logic of capture-recapture estimates: given the patterns found in the known population (numerator), how many total users should be found (denominator)?

Note that an important missing sub-population is the criminal population. Surveys like the Arrestee Drug Abuse Monitoring (ADAM) program were found to be extremely important in estimating illicit drug use prevalence and incidence among heavy users in countries where it has been implemented (Bennett and Holloway, 2008; Bouchard, 2008b). In constant operation for over 10 years now, the Drug Use Monitoring in Australia (DUMA) program is perhaps the best example of the group (Gaffney et al., 2010). Because they are conducted quarterly (instead of annually), such programs are key to detecting trends and changes in drug markets, including the emergence of new drugs. A group of researchers led by Dr. Chris Wilkins at Massey University recently received a grant to implement the program in New Zealand. It is imperative that Canada follows suit. An important complement to such surveys is to rely on capture-recapture estimates of arrest data.

Table 1. Adolescent student ATS use in Canada

Region	Substance	Source	Grade level	Prevalence % (year)	Male %	Female %	Trend (total)
Alberta[a]	Meth (speed)	TAYES	7-12	0.5 (2008)	0.5	0.4	5.3% used "club drugs" in 2002 (AADAC, 2003)
	E	TAYES	7-12	3.7 (2008)	3.7	3.8	
	Crystal meth	TAYES	7-12	0.4 (2008)	0.6	0.3	
BC[b]	Amphet	BCAHS	7-12	2 (2008)			2003-2008: 4% to 2%
Manitoba[a]	E	AFM	7-12	4 (2007)	3.5	4.4	2003-2007: 2% to 4%
	Crystal meth	AFM	7-12	0.5 (2007)	0.5	0.5	2003-2007: 3% to 0.5%
New Brunswick[a]	Meth	NBSDUS	7, 9,10,12	2.5 (2007)			
	E	NBSDUS	7, 9,10,12	4.4 (2007)			2002-2007: 4.0% to 4.4%
	Amphet	NBSDUS	7, 9,10,12	2.4 (2007)			2002-2007: 10.9% to 2.4%
Nova Scotia[a]	Meth	NSSDUS	7, 9,10,12	1.6 (2007)			
	E	NSSDUS	7, 9,10,12	6.9 (2007)			2002-2007: 4.5% to 6.9%
	Amphet	NSSDUS	7, 9,10,12	3.6 (2007)			2002-2007: 9.5% to 3.6%
Ontario[a]	Speed	OSDUHS[c]	7-12	1.4 (2009)	1.8	1.0	1999-2009[d]: 5.0% to 1.4%
	E	OSDUHS[c]	7-12	3.2 (2009)	3.1	3.2	2000-2009[d]: 6.0% to 3.2%
	Crystal meth	OSDUHS[c]	7-12	0.5 (2009)	0.6	0.5	1999-2009[d]: 1.4% to 0.5%
Newfoundland and Labrador[a]	Meth	NLSDUS	7, 9,10,12	2.4 (2007)			
	E	NLSDUS	7, 9,10,12	7.2 (2007)			2003-2007: 2% to 7.2%
	Amphet	NLSDUS	7, 9,10,12	3.2 (2007)			
Canada[b,e]	E	HBSC	9, 10	5.5 (2006)	5.0	5.9	1998-2000: Boys – no change; Girls – 3% to 5.9%
	Amphet	HBSC	9, 10	5.3 (2006)	4.0	6.5	1998-2006: Gr 10 boys – 9% to 4.0%; Gr 10 girls – 9.0% to 6.5% (King, Boyce, and King, 1999)

HBSC = Health Behaviour in School-Aged Children study (Boyce, King, and Roche, 2008); OSDUHS = Ontario Drug Use and Health Survey (Adlaf, Begin, and Sawka, 2005); TAYES = The Alberta Youth Experience Survey (AHSAMH, 2009); BCAHS = BC Adolescent Health Survey (Smith et al., 2009)
AFM = Addictions Foundation of Manitoba (Friesen, Lemaire, and Patton, 2008); NBSDUS = New Brunswick Student Drug Use Survey (Balram et al., 2007);
NSSDUS = Nova Scotia Student Drug Use Survey (Poulin and McDonald, 2007); NLSDUS = Newfoundland and Labrador Student Drug Use Survey (Ryan and Poulin, 2007); [a]Past year use; [b]Life time use; [c]OSDUHS categories consist of a) "speed", b) ecstasy, and c) crystal methamphetamine; [d]Prevalence rates peaked around the late 1990s. Longer term trends using a restricted sample show that current prevalence rates are very similar to pre-peak rates; [e]Calculated from the values published in Boyce, King, and Roche (2008).

Table 2. ATS use among at-risk populations in Canada

Population	Region	Substance	Source	Prevalence % (year)	Trend (total)
Street youth	Canada	E	E-SYS[a]	5.1 (2003)	1999-2003: 1.2% to 5.1%
	Canada	Crystal meth	E-SYS[a]	9.5 (2005)	1999-2005: 2.3% to 9.5%
	Vancouver	Crystal meth	MASY[b]	67 (2003)	
	BC	Amphet	MSIYS[b,c]	50 (2000)	
	BC	E	MSIYS2[d]	25 (2006)	
	BC	Crystal meth	MSIYS2[d]	14 (2006)	
	BC	Amphet	MSIYS2[d]	11 (2006)	
Aboriginal street youth	BC	E	MSIYS2[d]	22 (2006)	
	BC	Crystal meth	MSIYS2[d]	12 (2006)	
	BC	Amphet	MSIYS2[d]	8 (2006)	
Street injectors	Vancouver	Crystal meth	VIDUS[e]	6.7 (2004)	1997-2004: 2.5% to 6.7%
LGBTQ	Vancouver	Crystal meth	MASY[b]	24 (2003)	
	Vancouver/ Victoria	E	MASY[b]	26.7[f] (2003)	
	Vancouver/ Victoria	Crystal meth	MASY[b]	26.7[f] (2003)	
	BC	Crystal meth	SN[g]	6 (2007)	2002-2007: 11% to 6%
Ravers	Montreal	Amphet	SUCRP[d]	64.9 (2002-3)	
	Montreal	E	SUCRP[d]	53.2 (2002-3)	

E-SYS = Enhanced Surveillance of Canadian Street Youth (PHAC, 2006, 2009)
MASY = Methamphetamine Study of Youth (Lampinen, McGhee, and Martin, 2006; Martin, Lampinen, and McGhee, 2006)
VIDUS = Vancouver Injection Drug Users Study (Fairbairn et al., 2007)
MSIYS = Marginalized and Street-Involved Youth Survey, 2000 (Murphy et al., 2001)
MSIYS2 = Marginalized and Street-Involved Youth Survey, 2006 (Smith et al., 2007)
LGBTQ = Lesbian/Gay/Bisexual/ Transgender/Questioning
SN = Sex Now (Trussler, 2007)
SUCRP = Substance Use in a Canadian Rave Population (Gross et al., 2002)
[a]Past three months use
[b]Lifetime use
[c]Calculated from the values published in Murphy et al. (2001)
[d]Past month use
[e]Past six months use
[f]Small sample (n=4 reporting ecstasy and crystal meth use)
[g]Past year use

2.2 Market Patterns

Capture-recapture methods rely on data sources showing a pattern of occurrence and re-occurrence (recreating the classic "catch and release" experiments in animal studies) in a population. Medical (entry/re-entry into treatment) and criminal records (arrests/re-arrests) were found to be suitable data sources to estimate not just the number of users, but also the number of dealers and producers of illegal drugs (Bouchard and Tremblay, 2005; Bouchard, 2007). Other statistical techniques, like the multiplier method, rely on a key indicator (e.g. number of fatal overdoses) and information on the rate at which this indicator appears in the population of interest (Law et al., 2006). For example, information on the number of overdoses for methamphetamines and the rate at which meth users overdose could be used to estimate the prevalence of meth use. While data on the number of overdoses can be reliably obtained from Coroner's reports, a reliable rate of overdose per user is much less easy to obtain, and depends on local factors such as methods of drug intake and variations in purity.

Known data on the meth/MDMA markets in regards to treatment, overdoses, purity, and drug prices are reviewed below.

2.2.1 Treatment

Statistics from Ontario (Drug and Alcohol Treatment Information System (DATIS), 2009) show that of the 107,744 substance abuse treatment admissions in 2008/09, 1.6% reported problematic amphetamine use, 2.7% reported problematic ecstasy use, and 1.3% reported problematic crystal meth use[1]. Amphetamine use is down slightly from 2.3% in 2004/05, while ecstasy is virtually unchanged (2.5% in 2004/05). Where crystal meth was almost non-existent in 2004/05 (2 cases), it now comprises a small but substantial proportion of treatment cases (n=1373).

This information is quite important, especially in light of the declining trends reported in general and adolescent population surveys in the previous section. Heavy users – the most important for estimates of total consumption – are most likely to be found in at-risk populations and in such

[1] Problematic substance use is based on client self-reports of the substance(s) that they are seeking treatment for (DATIS, March 24, 2010, personal communication). An individual may report more than one substance.

treatment samples. Because trends in heavy use do not necessarily follow trends in recreational/lighter use (compare the last column in Table 1 and Table 2), making an examination of these users becomes even more important.

Callaghan and MacDonald (2009) examined the Canadian Institute for Health Information's Hospital Morbidity Database which contains information on discharge statistics for inpatient events across Canada (excludes emergency departments, day procedures, and psychiatric facilities). They found that hospital separation rates (discharge for any reason including death, signing out, and regular discharge) for episodes in which amphetamines were involved were low compared to other substances, but that they increased by nearly 600% from 1996 to 2005. In 1996, 2 separations per 100,000 population per year were recorded. This increased to 11 in 2005. These rates are low compared to rates for alcohol (which ranged between 182 and 227 over the same time period) and cocaine (22 to 45).

In the US, 7.5% of treatment admissions were for primary use of methamphetamines in 2007 (Substance Abuse and Mental Health Services Administration (SAMHSA), 2009). This was up from 3.3% a decade earlier. Only 0.3% of admissions were primarily for "other amphetamines" (including ecstasy), down from 0.9% in 1997. While the Canadian and American data tell somewhat different stories, it appears that ATS use results in a greater proportion of treatment admissions in the US than it does in Canada, though ecstasy plays a larger role in Canada than it does in the US.

An estimated 4.6% of drug-related emergency department visits in the US in 2006 involved methamphetamine (SAMHSA, 2008). This is higher than for amphetamines (1.8%) or ecstasy (1.0%). However, estimated ecstasy visits increased by 64% from 2004 to 2006.

2.2.2 Overdose

Coroner's data from BC shows that meth overdose deaths ranged between zero and five per year between 2000 and 2004 (BC Coroners Service (BCCS), 2005). However, deaths in which meth was present in toxicology tests (whether or not it played a role in the death) range from three in

2000 climbing to a high of 33 in 2004. In comparison, there were 64 deaths associated with heroin, and 94 with cocaine, during the same year (BCCS, 2005).
Extracting and reviewing all Coroners' reports of overdose deaths caused by illicit drugs for 2001-2005, Wood et al. (2009) reproduced the five-year trend in meth-related overdoses. They found a significant increase in meth overdose deaths in BC between 2001 and 2005. In 2001, there were two deaths; in 2005, there were 16. Of the 36 meth overdose deaths over this time period, almost half were attributable to administering meth through injection. Fairbairn et al. (2008) found crystal meth use to be a predictor of non-fatal overdose in a population in which polysubstance use is common.

It appears that the overdose death multiplier method has not been used to estimate the number of methamphetamine users anywhere in the world. Recently, Australian researchers used a multiplier of 112.5 (the mid-point between two previously suggested multipliers of 100 and 125) to estimate the number of heroin users in Australia (Degenhardt, 2004). Using 112.5 as the multiplier appeared to produce estimates for the prevalence of heroin use close to the numbers reported in other studies (Bouchard, 2008c).

2.2.3 Purity

It is apparent that ATS purity varies widely. For example, the UNODC (2009) reports purity percentages in Canada ranging from 3% to 100% for methamphetamine and 6% to 97% for ecstasy in 2007. Parrott (2004) examined literature from the US, Europe, and Australia related to ecstasy purity and found that "(t)he ecstasy purity problem was predominantly a phenomenon of the mid to late 1990s, when many tablets contained substances other than MDMA. Before and since then, the proportion of ecstasy tablets containing MDMA has been very high" (p 234). However, Tanner-Smith (2006), based on a sample of anonymously submitted ecstasy tablets collected in the US between 1999 and 2005, found that purity decreased over that period. Overall, she reports that 39% consisted of MDMA only while 15% contained MDMA and other substances. The greatest proportion (46%) contained no MDMA. She also found that size (height and width) of the tablet was inversely related to purity. Taller and wider tablets were more likely to contain no MDMA. Meanwhile, Fries et al. (2008) found modest improvements in purity between 1981 and 2007 such that the most recent estimates place purity percentages around 60-70%.

There is evidence that suggests purity rates can be influenced by external factors in complicated ways. For example, Cunningham, Liu, and Callaghan (2009) found that precursor and essential chemical regulations can reduce methamphetamine purity levels but may also increase overall purity levels supposedly by pushing small-scale, poor quality producers out of the market. In theory, purity levels are important considerations when estimating the size of the market in quantities of drugs produced: one would prefer to estimate the amount of meth/MDMA produced, not of adulterants. In practice, purity levels may become secondary in the estimation process. What matters first and foremost is to estimate the quantity produced as will be bought and used by consumers. These considerations are discussed further in section 3 below.

2.2.4 Price

Examining trends in drug prices is important to understand market size dynamics. All else equal, decreasing price trends could indicate a period of increasing supply (and vice-versa). Fries et al. (2008) shows a general trend towards decreasing meth prices in the US between 1981 and 2007. The UNODC (2009) reports that typical meth prices in Canada are about $100 USD per gram and $22086.50 USD per kilogram. Typical ecstasy prices are $20.70 USD per tablet and $5135.30 USD per thousand tablets. RAND, using a meth purity estimate of 70% (ONDCP, 2007), calculated meth prices at $107 USD per gram in Canada for 2005 (Kilmer and Pacula, 2009).

2.3 Trafficking and Production

Drawing on a new method for estimating production from the number of users, the 2009 World Drug Report estimated worldwide meth/amphetamine production between 230 and 640 metric tons (mt). The range for ecstasy is 63-128 mt. An important underlying assumption behind the new method is that a valid estimate of the total number of users (15.8M and 11.6M, respectively) and of the mean quantity consumed annually by an average user exists (12g and 5.5g, respectively). A total of 53 mt of meth/amphetamine has been seized in 2007, producing a global seizure rate between 7 and 19%. The seizure rate for ecstasy is found to be between 6 and 12%. These figures loosely match the detection rates (11%) found in a recent study drawing on capture-recapture methods to estimate the size of cannabis production in Quebec, Canada (Bouchard, 2008a).

Another assumption is that of a system in equilibrium: quantity produced = quantity demanded. This assumption is important in the Canadian context because it is not likely to be directly applicable. In the 2009 World Drug Report, Canada is represented as a major exporter of methamphetamine and ecstasy to countries like the USA, Japan, and Australia (see also RCMP, 2007). The claims also include estimates of the proportion of meth and ecstasy produced domestically vs. the proportion exported overseas, as well as mentions of the participation of organized crime groups (Asian-based, and biker gangs). For methamphetamine:

> Canada-based organized crime groups' participation in the methamphetamine trade has grown significantly since 2003. By 2006, law enforcement intelligence noted that Asian organized crime and traditional outlaw motorcycle gangs operating in Canada had increased the amount of methamphetamine they manufactured and exported, primarily into the USA, but also to Oceania and East and South-East Asia. For example, Australia identified that methamphetamine from Canada accounted for 83% of total seized imports by weight, for Japan the figure was 62%. Although only 5% of domestically manufactured methamphetamine was exported in 2006, by 2007 that figure was 20% (UNODC, 2009, p. 134).

For ecstasy:

> Since 2003/04 Canada has emerged as the primary source of ecstasy-group substances for North American markets, and increasingly for other regions. As of 2007, identified ecstasy laboratories were large-capacity facilities primarily controlled by Asian organized crime groups, utilizing precursor chemicals trafficked from China in sea containers. In 2007, it was estimated that 50% of domestically produced ecstasy was trafficked outside of Canada. Most of this was thought to be destined for the USA, Australia and Japan... In 2007, Japan identified Canada as the single

> biggest source for seized ecstasy tablets, followed by the Netherlands, Germany, and Belgium. (UNODC, 2009, p. 141)

The methodology used for obtaining these estimates was not described, so the factual basis for making such claims is completely unknown (although they most certainly come from law enforcement reports). But the effects of these claims were certainly felt, as Canada became a meth production hub in the eyes of the rest of the world. Given the clandestine nature of the ATS markets, no definite production figures exist. The number of ATS trafficking cases in Canada declined from 9,000 in 2005 to 4,000 in 2007. The amount of labs detected in Canada annually remains relatively low compared to the US (17 vs. 5,700), but it is their larger size that seems to pose the greatest problem. While only 14 of the 5,700 US labs qualified as "large", a majority of the 17 Canadian based labs could be classified as such (UNODC, 2009). But "large" is much larger in some contexts than others. Cunningham et al. (2009), for example, report that large-scale labs in the US produce 5-7 kg during a cook, compared to 70-90 kg for large Mexican labs. The Canadian superlabs do not appear to be different than those found in the US. According to the numbers provided in Plecas et al. (2005) for BC, 17 of the 33 labs detected between 2003 and 2005 could qualify as superlabs (more than 5kg/cook).

Another piece of the puzzle is the reverse trends between US and Canada: while the number of seized laboratories has been steadily declining in the US since 2003, the numbers have risen in Canada, and also in Mexico (UNODC, 2009). According to a recent evaluation study by Cunningham et al. (2009): a) the trends between all 3 countries are inter-related; and b) the trends are affected by precursor regulations implemented in each country. According to Cunningham et al. (2009), the 1995 ephedrine and 1997 pseudoephedrine US regulations seemed to have created incentives for US producers to import their precursors from Canada. When Canada followed through with regulations of their own in January and June 2003, producers increasingly turned to Mexico for chemicals. Note that Mexico recently adopted similar regulations in 2007 (Cunningham et al., 2009) – of which the effects on the US and Canada remain to be seen.

Such a situation has been described by Broude and Teichman (2009) as a case of the US consciously 'outsourcing' meth production to other countries while doing nothing to prevent domestic meth use. Broude and Teichman suggest that the US is attempting to rid itself of the production hub label first, before turning to demand-related issues (hopefully). If one believes the above mentioned UNODC report regarding the importance of Canada as a producer, the strategy appears to be working.

Overall, seizure and detection data suggests that Canada is among the largest ATS producing nations (UNODC, 2008, 2009; RCMP, 2007). For example, Canada ranked sixth in the world in meth/amphetamine seizures with 1.54 mt seized (UNODC, 2009, p 136) and fourth in ecstasy seizures (p 142) with 985 kg seized in total. But these numbers should be used and interpreted with extreme caution. For example, the 1.54 mt seized in 2007 represented a 2500% increase from the preceding year where only 60kg were seized by the police. This reminds us of the volatility of seizure data from one year to the next, especially for smaller markets like ATS. One very large seizure may greatly influence the absolute numbers. Seizures rates, like drug-related offense rates in general, are also dependent on police priorities and funding. Trends should be monitored further before they can be used to assess the size of the market or police detection rates.

3 Methods for Estimating the Quantity of ATS

3.1 Estimates Using UNODC Assumptions

We used the data and assumptions found in the UNODC (2009) report to provide rough estimates of the quantity of ATS potentially consumed in Canada. Table 4 provides these estimates and breaks down the parameters used in the calculation. Note that the UNODC provides estimates for the "amphetamine group" (which includes meth but also other substances) and ecstasy. An estimate for meth only is nonetheless provided using the 0.2% prevalence rate found in the most recent general drug use survey.

Table 3. Estimated annual consumption of ATS substances in Canada in 2007 using UNODC (2009) assumptions

	Amphetamine group (meth+amphetamines)	Ecstasy (MDMA)	Methamphetamine
Prevalence rate (15-64)	1.3%	0.9%	0.2%
Annual consumers	299,204	207,141	46,031
Average consumption (grams/year)	11.8	5.45	11.8
Metric tons consumed	3.53 mt	1.13 mt	0.54 mt

Table 4 suggests that Canadian users annually consume 1.13 and 0.54 metric tons of ecstasy and methamphetamine respectively. When the whole amphetamine group is considered, the consumption increases to 3.53 metric tons. Are these numbers plausible? For one, they are likely to be too low – the prevalence of users does not take the heaviest users into account (although the average consumption rate does, which might compensate for the lower prevalence of users[2]). For another, they are highly dependent on the prevalence and average consumption rates, which are also subject to much uncertainty. Consider the quantity of ATS seized in Canada in 2007: 1.54 mt for the amphetamine group (up from 60 kg in 2006), and 985 kg for ecstasy. Transforming these quantities into seizure rates should not be done, for the simple reason that much more ATS is produced than the quantities reported in Table 4. In other words, an estimate of total production (including quantities exported) is needed. The only way to estimate total production is to first derive an independent estimate (independent in the sense of not being based on the prevalence of users) of the number of producers (and/or labs) in activity, and an estimate of average production per lab.

[2] Personal communication with Dr. Chris Wilkins, a widely-published meth and cannabis expert from New Zealand, revealed that the average consumption rates for meth used above may be too high. Using data from the 2009 New Zealand National Household Drug Survey (NZNHDS) and 2009 Illicit Drug Monitoring System (IDMS), he and colleagues estimated that 3.8 grams/user/year for meth would be a reasonable estimate. The methodology involves separating users in two categories – frequent (12+ times/year – 20% of all users) and occasional (- than 12 times/year – 80% of all users). Frequent users would use up to 17.8 grams/year, while occasional users would use 0.3 grams/year.

Estimating production in the cannabis industry shares similar data requirements. Bouchard (2008a) showed that an estimate of total cannabis production can be provided using a combination of capture-recapture estimates of the number of producers and fieldwork data on the division of labor and productivity of cultivation sites of various sizes. In that study, it was estimated that the 13,000 cultivation sites in Quebec were producing 300 metric tons of cannabis annually, and over 50% of that total was produced by a minority (2,000) of large hydroponic sites (those would be the equivalent of "superlabs" in the ATS production industry). Drawing from the 2004 Canadian general population drug use survey (Adlaf et al., 2005) and average consumption estimates for occasional and heavy users, that study estimated that 100 metric tons was potentially consumed in Quebec. Of the remaining 200 mt, 31 mt were seized by law enforcement agencies, which meant that up to 56% of total cannabis production in Quebec (169 mt) was potentially exported out of province (to the US and to other provinces). As shall be seen below, given access to similar types of data, estimates could be derived for the production of ATS in Canada.

3.2 Methods to Estimate the Size of Illegal Markets

Estimating the size of the ATS markets requires that methodologies other than those employed in traditional surveys be employed. This is especially important in the case of ATS because Canada has been identified as an important exporting country, and because none of the traditional survey methods are suitable for estimating the prevalence of ATS producers and suppliers. Provided below is a brief review of potentially useful statistical methods to estimate the size of illegal populations – especially those other than drug users. Then the focus will be on capture-recapture methods as a brief review of some of the applications of such methods for ATS markets will be conducted. Issues in choosing an appropriate model are discussed and a demonstration is provided as to why Zelterman`s model appears to be the most cost-effective to use for research and policy purposes.

For simplicity, we divide the potential estimation methods into two families[3]: multiplier methods, and capture-recapture methods.

3.2.1 Multiplier Methods

Within this family are grouped all methods using a ratio from an observed part of the population to make inferences on the unobserved part of the population. For example, multiplier methods have been used to estimate the size of the heroin using population in Australia from a ratio of overdoses per user (Law et al., 2006). As in Brecht and Wickens (1993), it can formulated quite simply as:

(1) $N = d/p$

Where N is the total population of users, *d* is the number of overdose deaths, and *p* is the probability of dying from heroin use during a year. Knowing, for example, that one out of 100 heroin users die of overdose during a given year, we can estimate a prevalence of 10,000 heroin users knowing that 100 overdoses occurred over the course of a year (100/0.01 = 10,000). Because it is dependent on many factors including the lethality of a drug, variations in purity, location or methods of use, the rate of overdose per user varies per type of drug, and even per region for a similar drug. Multipliers of 100 and 125 have been shown to provide suitable estimates of heroin use in Australia a few years ago (Degenhardt, 2004) (the proper multiplier may be different nowadays). What would the multiplier be for the meth, or MDMA markets? Assuming 16 meth overdose deaths for 2005 in BC (Wood et al., 2009), a multiplier of 125 would produce an estimate of 2000 meth users in BC – a number that appears to be substantially too low given what is already known about meth prevalence in BC More research needs to be conducted on the appropriateness of using this method to estimate the size of the meth market, especially research comparing death by overdose rates for heroin and meth users[4].

[3] Though potentially interesting, not covered here are slightly more complicated estimation methods based on regression analysis. Some of the most interesting options in that regard are extensions from the standard capture-recapture models (e.g. truncated Poisson regression in Van der Heijden et al., 2003).

[4] One fruitful way to think about the proper multiplier is to examine the lethality of meth compared to other drugs. A recent article by Gable (2004) reviewed a number of studies that examined the issue. The study found that the safety ratio (lethal dose/effective dose) for heroin was 6 – the smallest among all legal and illegal drugs examined, meaning that the risks of overdoses were much higher for heroin than for other drugs. The safety ratio for crystal meth was 10 (+150mg/15mg) – comparable to alcohol, higher than heroin, but lower than ecstasy which was 16

Can these methods be transferred to the supply side? Yes they can, and they have been. These methods are well-known in law enforcement circles in the estimation of total drug production. Assuming that 5%, 10% or 20% of drugs are intercepted and already knowing the quantity of drugs seized, some law enforcement agencies attempt to estimate total production. The problem is of course that we don't really know what the detection rates actually are (they have to be estimated through other methods) and these rates are likely to vary from one year to the next (especially if the rates are driven by a particularly large seizure). Hence, the amount of uncertainty is thus much larger than for other methods.

A simple example using ATS seizure data should make that clear. UNODC (2009) reported that 1.54 mt of meth/amphetamine substances were seized in Canada in 2007. Assuming a 10% detection rate, meth/amphetamine production would be estimated at 15 mt (1.54/0.1 = 15.4 mt). But should one use the 2006 seized quantities of 60 kg, production would be estimated at 600 kg – or 25 times less than in 2007. While an increase in production from 2006 to 2007 is likely, a 25-fold increase isn't. Such methods should be used with extreme caution, if used at all.

Other studies have used variations in the multiplier methods that could be useful in estimating the number of drug dealers (Bouchard and Tremblay, 2005; MacCoun and Reuter, 2001). The ratio of interest has been discussed earlier in this report: the number of users per dealer. This ratio can be obtained from surveillance investigations (Lacoste and Tremblay, 1999), but also from surveying drug dealers directly in prison settings. After corrections taking into account variations in productivity per dealer, these ratios were found to be around 7 to 10 users per dealer for crack, heroin, and cocaine (Bouchard and Tremblay, 2005). Assuming one has a valid estimate of the number of ATS users and a users-per-dealer ratio, the number of ATS dealers could be estimated using such a method (N dealers = users/users-per-dealer). The substantial degree of uncertainty and the number of assumptions involved in using this method warrant extreme caution.

(2g/125mg). From this, we can safely assume from the safety ratios that the proper multiplier for meth and ecstasy will be higher than for heroin (125) but it's hard to determine how much higher (e.g. meth: 10/6 = 1.67 times higher than heroin?, ecstasy 16/6 = 2.67 times higher?).

Finally, Easton (2004) drew upon econometric methods to derive an estimate of the number of cannabis cultivation sites in British Columbia. While more complicated than the typical multiplier methods, the method is discussed here because the final element of the calculation involves making assumptions about the probability of detection for cultivation sites. To simplify, Easton (2004) starts from the number of sites detected in a year, multiply this number by an estimate of the rate of return for average site, and divide this number by an estimate of the probability of detection for an average site. While the method is interesting, it makes a number of assumptions about profits, costs, and probabilities of detection that should ideally be measured more directly. Capture-recapture methods allow one to estimate, rather than assume probabilities of detection. As always, estimates should be derived from a number of methods in order to assess validity and to establish a plausible range.

3.2.2 Capture-Recapture Methods

Capture-recapture methods have been proven to provide reliable estimates of hidden populations, including illegal populations. Much like for the multiplier methods, it relies on a pattern found in the observed part of the population to make an inference on the unobserved part. The major difference is that the inference follows a mathematical distribution, usually variations of the Poisson distribution. Such distributions have been shown to reproduce quite well the distribution of rare events, such as the distribution of arrests and re-arrests in an illegal population, or the distribution of entry and re-entry into treatment for drug using populations. These methods are relatively easy to implement, and importantly, they do not require any new data collection exercises. Capture-recapture estimates are derived from existing lists of individuals arrested for a specific offence (e.g. ATS dealing), and once the data are ready for analysis, many of the models simply require a handheld calculator to derive estimates. Many of the relevant capture-recapture studies have been reviewed earlier in this report. Below we review the ones that were focused on the ATS markets as they are also representative of many similar studies on other populations.

3.2.2.1 Capture-recapture Studies of ATS

The key word search in various databases for capture-recapture studies of the meth/MDMA markets proved to be disappointing. Only one study (Chiang et al., 2007) used capture-recapture methods to estimate the size of the methamphetamine market (in Taiwan), and none for MDMA, anywhere in the world. For various reasons, most capture-recapture studies focus on populations of illicit drug users at large (e.g. “illicit drug users” or “injecting drug users”). The reasons for this include a) lack of distinctions regarding specific substances used; b) small sample size for any drug type making capture-recapture models difficult to estimate; and c) poly-drug use behaviour making it difficult to apply such methods to one type of drug.

Chiang et al. (2007) used prison and hospital records to estimate the heroin and methamphetamine user populations in northern Taiwan from 1999 to 2002. The use of these two types of records was important as the authors argued that both provided estimates for separate sub-populations of users: a) those at risk of being arrested and sent to prison for detoxification; and b) those at risk of being diagnosed as methamphetamine users in medical records. To the extent that the overlap between both data sources is not significant (typically less than 2% of “captured” users were found in both datasets on a given year), the estimates derived from both sources could thus be combined to obtain the total number of users. Drawing from Chao’s (1987) mixed Poisson estimator, they found increasing use of heroin over that period (from 0.27% to 0.72% prevalence). Methamphetamine use fluctuated within an overall decreasing trend (from 2.38% to 1.24%).

Hser (1993) estimated the population of amphetamine (and other drug) injectors in Los Angeles County in the late 1980s. She used both treatment admission and criminal justice-based urinalysis and interview data to estimate populations of adult injectors. Treatment-based estimates projected approximately 60,000 dependent injection drug users in 1989 while criminal justice-based estimates put the figure at 190,000 (not necessarily dependent) injection drug users. Of these, between 8,000 (treatment estimate) and 60,000 (criminal justice estimate) amphetamine users were estimated. Therefore, between 0.001% and 0.009% of the population of Los Angeles County (6.53 million in 1990) were amphetamine injectors. Importantly, Hser notes that treatment data over-represent heroin users and underestimate other drug users as treatment regimes were more focused on heroin than other drugs.

Hser's (1993) study also showed something important for choosing an appropriate model: a simple homogenous model (a single rate of entry into treatment is assumed and applied to every user[5]) will not fit such populations (or other criminal populations) very well. Using a single rate of capture: a) under-estimates the number of users entering into treatment only once; b) over-estimates the number of users in the middle of the distribution (seeking treatment 2-3 times/year); and c) completely underestimates the "prolific" users – those seeking treatment multiple times. This suggests an underlying heterogeneity among drug users that is also routinely found in arrest data. To the extent that the unobserved (untreated) users are more likely to resemble the one-treatment episode patients, then the model underestimates the prevalence of untreated (but treatable). Zelterman's mixed Poisson model has been shown to provide more reliable estimates of hidden populations.

3.2.2.2 Choosing a model

There are many variations in the capture-recapture family of models, all with slightly different assumptions about the population of interest and how it behaves prior to, and after capture. Reviewing all such variations is outside the scope of this report. Instead, the focus will be on one method (Zelterman`s truncated Poisson estimator) that proved to be robust in a number of contexts, especially for the estimation of illegal populations where the assumptions of the Poisson distribution[6] may be violated (Bouchard, 2007; Bouchard and Tremblay, 2005; Choi and Comiskey, 2003; Smit et al., 1997; Bohning et al., 2004). One reason why Zelterman`s estimator proved to be robust with such populations is simple: its logic is based on the idea that the projected rate of capture for those individuals not yet captured more closely resembles the rate found for those individuals captured only once or twice. In others words, offenders who have

[5] In reality, some users will never seek treatment while others seek it constantly (after relapsing every time). The same can be said of people at risk of being arrested.
[6] The assumptions are as followed: 1) the population under study must be closed (no entries and exits); 2) the population has to be homogenous (same capture rate for everyone); 3) the probability for an individual to be observed and re-observed must be held constant during the observation period.

been arrested only once during a year are more likely to ‘resemble’ those who have not been arrested than offenders arrested many times. Zelterman`s estimator is given by:

(2) $Z = N / (1- e(-2*n2/n1))$,

where Z is the total population, N is the total number of individuals arrested, n1 is the number of individuals arrested once, and n2 is the number of individuals arrested twice in a given time period.

The end result is that Zelterman`s model produces robust estimates in almost any context, with many different types of capture distributions. To demonstrate this, Zelterman`s model was re-analyzed with the capture-recapture data found in four other studies applying other models that provided full arrest/re-arrest distributions (Table x, Appendix B). How does Zelterman behave compared to other models, and with different kinds of distribution? It was found that Zelterman gives very similar results (within a few percentage points) to the heterogenous Poisson model used by Greene and Stollmack (1981) and Collins and Wilson (1990). This is important because the heterogenous model is considered to provide a perfect fit with most arrest data. Zelterman is slightly more conservative, which is often an asset in such exercises.

The main conclusion is that Zelterman does a very good job as a capture-recapture estimate, at very low costs. The model is much simpler than most other models. It also requires only one database (which can be crucial for difficult to track populations), while many other models require the linkage of many databases to construct a capture distribution. Zelterman is also robust to many different types of data, and it is conservative by nature. To be sure, the analysis found in Wilson and Collins (1992) was reproduced, comparing the performance of several one sample estimators to estimate a population of insects (Appendix B). After conducting different tests of robustness, the very similar Chao and Zelterman estimators came out on top and were chosen by the authors.

4 Data Requirements for Applying These Methods to ATS Markets

This section discusses the data requirements for estimating the size of the meth and MDMA markets in Canada, and whether such data are already available in Canada. For the data that are not readily available, the kind of data collection procedures that should be developed is discussed. Emphasis is put on issues and challenges in estimating production.

Prior to discussing the specific data requirements and collection issues at length, it is helpful to specify the basic form of the computations that will ultimately be used to integrate the different data components, as these clearly show the major parameters that data collection initiatives must aim at satisfying. For example, Bouchard (2007, 2008a) proposed the following equation to estimate the number of cannabis cultivation sites:

(3) $$S = \sum (Z_i/c_i)\lambda_{i,n}$$

where S is the annual number of cultivation sites at risk of detection, Z is the prevalence of growers of type i, c is the number of co-offenders working on a median size plot of type i, and λ represents the proportion of seizures for type i and of sizes n.

Bouchard (2008a) then started from this prevalence of sites estimate to derive an estimate for the size of production, in metric tons of cannabis produced. He proposed 3 related estimates, all using the same four baseline parameters: a) the prevalence of production sites of given size and cultivation technique; b) the mean number of plants (from seizures data); c) an attrition factor; and d) the mean number of crops per year. Then, Bouchard (2008a) transformed plants into quantities by drawing on three different yield-per-plant parameters: 1) the mean yield per plant (in ounces); 2) the mean quantity produced per lamp (in ounces); and 3) the mean quantity of cannabis produced per watt (in grams).[7]

Because fieldwork data showed that plant yield decreases as a function size (larger sites grow smaller sites, overall), the yield per plant for a type of cultivation site has been calculated by

[7] The key parameters for estimates 2 and 3 only concern indoor and hydroponic cultivation sites, and are closely related to the kind of ratios used for ATS labs.

regressing plant yield (in ounces) on the number of plants grown in fieldwork data. The equation can be written as:

(4) TPV_{cannabis} = S*(Adj. mean size*oz/plant*crops/year)

The adjusted mean size simply reflects the mean number of plants seized by the police minus plant attrition (for any harvest, not all plants will produce). The equation produces an estimate in ounces which can be transformed into metric tons. Using equation 4, Bouchard (2008a) estimated cannabis production at 300 metric tons for Quebec in 2002.

The same strategy can be applied to estimate the total production of meth and MDMA[8]. For both meth and MDMA, total production volume for a given time period can be most compactly expressed as:

$$(5) \qquad TPV_{\text{Meth/MDMA}} = \sum_{i=1}^{N} (c_i * kg_i * p_i),$$

where *TPV* denotes total production volume (which could be restated in metric tons), ∑ is the summation operator, *c* is the count of clandestine production facilities of size *i* (*i* = 1 through *N*) at risk of detection, *kg* represents the total weight in kilograms of product generated by clandestine production facilities of size *i*, and *p* represents a purity weight ranging from 0.0 to 1.0. The indicator *i* is needed to reflect varying production volumes and purity across the different facility sizes (which would be coded using an ordinal scale). A decision should be made on whether *TPV* should be estimated irrespective of purity (by fixing p at 1.0). Eq. 5 is in fact an estimate of *pure* quantity of meth/MDMA produced. This is an important decision to make because neither consumers nor seizure reports take purity into account. In other words, in order to compare $TPV_{\text{meth/MDMA}}$ to the quantity of product consumed or seized in Canada, purity should *not* be taken into account in the calculation.

But there is at least one good policy-related reason to take purity into account and estimate the quantity of pure meth or MDMA produced. For example, it appears likely that purity may be

[8] The initiative for adapting the formula to the meth and MDMA markets comes from Cameron McIntosh, who led the write-up for issues related to equation 5.

lower in smaller “mom-and-pop” labs (which typically support the ATS habits of the cook and a small circle of users) than in “superlabs” (Cunningham et al., 2009). Taking purity into account could potentially help to assess the impact of precursor regulations and enforcement practices.

After computing *TPV*, it could then be adjusted for the amount seized (computed directly from police agency data) and consumed domestically (calculated based on the count of users and their reported usage rates), yielding an estimate of product available for export. Doing so allowed Bouchard (2008a) to estimate that among the 300 metric tons of cannabis produced in Quebec in 2002, 100 mt were available for local consumers, 33 mt were seized by the police, and 167 mt was thus available for exports.

While the calculations required for estimating *TPV* and adjusting it further to reflect seizure and consumption patterns are relatively simply to specify and apply, obtaining reliable data as input for the various parameters is a much harder task. The following sections discuss the accessibility of such data in the Canadian context, and offer some recommendations and guidelines for data collection where gaps are evident.

4.1 Arrest and Treatment Data

Capture-recapture models are naturally applied to arrest and treatment data. For the latter, the objective is to estimate the number of users “in need of treatment” from the patterns in users who enter and re-enter into treatment. Such data is crucial to reach the heaviest meth/MDMA users who cannot be reached through conventional survey methods. While specific surveys do reach this clientele, they are not designed to estimate the size of markets. Treatment data have been shown to provide reliable estimates of drug users, including ATS users (Hser, 1993; Chiang et al., 2007). While treatment data are not necessarily centralized in one large dataset (which would be ideal), such data should be available in most Canadian province. The best example from published data is found in Ontario. There the Drug and Alcohol Treatment Information System (DATIS) tracks client information for over 160 organisations across the province (DATIS, 2009). It provides such information as client demographic data, admissions, and discharge, as well as specifying the substance(s) for which treatment is being sought and the type of treatment received. The BC Addiction Information Management System (referred to by BC, 2004) would appear to provide similar information.

Arrest data is routinely collected in every police department around the country, and is typically centralized under one unified dataset covering multiple jurisdictions (ideally, the entire province). Bouchard and Tremblay (2005) relied on Quebec's MIP (Module d'Informations Policieres) to estimate the prevalence of dealers and users "at risk of being arrested" for different types of drugs (though not ATS). Bouchard (2007) used the same dataset to estimate the number of cannabis growers in Quebec. There are a few minimal requirements for such data to be amenable to capture-recapture analyses:

- Each individual has a unique identifier so that a recapture can be properly identified and coded as such. While it is critical that the identifier is (initially) based on a combination of given name, last name, and birth dates of arrestees, the data can be anonymized by the law enforcement agency before providing access to researchers (if analyses are not conducted in-house).

- Each capture is tied to a specific date, in a recognizable jurisdiction. The length of time between can be coded and used to divide arrest distributions in different time periods. Bouchard (2007) recommends estimating models for periods of three years – thus giving enough time for a captured offender to be released and re-captured again.

- Each capture is tied to a specific offence (or a series of offences), for a specific drug (crystal meth, ecstasy, etc). This is important to make drug/offense-specific estimates, and also assess the potential overlap between markets and offences (e.g. dealer selling both meth and ecstasy). This is why, ideally, the analysis should be conducted with the full arrest dataset (as opposed to a restricted `drug offenses` dataset for instance). The latter is especially crucial in the case of the meth and ecstasy markets because of the real possibility that the police officers cannot confirm the exact nature of the drug at time of arrest/recording. Uncertain cases might be recorded as "synthetic drugs" or possibly as "other drugs," though this is worse for estimation purposes. *It is imperative that the* *coding be as specific as possible to provide the best assessment of the situation as possible.*

- Each category of offence should produce a minimum number of captures and recaptures to be amenable to capture-recapture analysis. For less frequent offences, this sometimes means to extend the time period or the geographical area considered. Bouchard (2007) used 3 years and the entire province of Quebec to produce estimates. This was most important for the less frequent hydroponic cultivation offences where only 8 recaptures were recorded between 1997 and 1999 on over 600 total arrests. This is especially important in the case of ATS production offences, which may be too rare in most provinces to produce reliable capture-recapture estimates[9]. In such cases, various methods of the multiplier family should be employed in conjunction with arrest data.

4.2 Seizure Data

Bouchard (2007, 2008a) used a combination of arrest and seizure data to estimate the number of cannabis cultivation sites at risk of detection in Quebec for 1998-2002: a) the arrest data produced capture-recapture estimates of the number of growers at risk of being arrested; b) the seizure data was used to get crucial information on the size distribution of sites using different cultivation techniques (outdoor, indoor (soil), hydroponics). Combined with fieldwork data on the division of labour in commercial and non-commercial sites (how many offenders for X number of plants?), an estimate of the number of sites at risk of detection could be derived.

Seizure data was collected by the Surete du Quebec in the course of a larger data collection exercise that was used in evaluating eradication efforts (Projet “Cisaille”). The lead investigator would call an office at the headquarters in Montreal to describe the site after each and every seizure before he/she sent the plants for destruction. *If not already in place, a similar procedure should be established as soon as possible for clandestine ATS laboratory seizures*. It is essential to do so because arrest datasets do not contain information on size. Data on laboratories should

[9] Careful consideration should thus be given to the creation of methods of the multiplier method family for ATS production. Arrest data should nonetheless be part of a larger set of indicators. Estimates from multiple methods should be derived for triangulation purposes.

be collected in one location (or a very small number of locations) (e.g. one database for all RCMP detachments). Too few seizures are conducted annually for this to represent extra work load for investigators in charge.

Note that information on past cases of clandestine laboratories should also be collected from case files. Such an exercise has been conducted by Diplock et al. (2005) for 33 laboratories detected in BC in 2003-2005. Similar data collection should be pursued and routinely implemented in every province, for every case detected over the past 10 years. The names and birthdates of the suspects should be collected and anonymized so that capture-recapture methods can be used where applicable.

4.3 Offender Data

As mentioned previously, it is essential to know more about the division of labour in ATS labs of different sizes in order to estimate the size of the industry. Such data collection procedures are much different than the others previously discussed in that they involve direct contact with “cooks” and other offenders who had direct involvement in ATS labs. Whether the sample size remains small, or whether such offenders were involved in small or large endeavours does not prevent one from using such data – simple regression techniques can be used to make inferences (see Bouchard, 2007; 2008a). It is not likely that such data collection procedures will lead to large sizes either. A report by Diplock et al. (2005) on clandestine meth labs in BC showed that only 23 suspects were apprehended in the 33 total cases in the province from 2003 to 2005. Interestingly, these suspects were no different than the suspects found in cannabis cultivation cases: they were likely to have prior convictions, especially for non drug-related offenses in the case of meth lab offenders (the only significant difference between the two groups).

Given the small size of the population of cooks, ethnographic work is not likely to help to reach this population. The use of Internet surveys proved to be a valuable source of data on recreational drug users (Stetina et al., 2008) and even cannabis growers (Decorte, 2008; Hakkarainen and Perala, *in press*). While similar methods could be used to survey meth and MDMA users (and potentially learn more about use and purchase patterns than in general population surveys), the population of ATS producers would appear to be too small for this method to be worthwhile. Online surveys could nonetheless be used to explore ATS users' knowledge of production and producers, and their perceptions on the quality of their purchases.

Currently, there are two standard ways that can be used to reach ATS cooks:

- *Interviews with inmates*. If conducted by independent researchers, interviews in incarceration settings have proven to provide extremely rich sources of information in a variety of crimes and criminals. Prison records throughout Canada should be scanned to retrieve all offenders with a conviction for ATS supply[10] and/or production offences. Structured interviews with a university researcher should be scheduled for all inmates who agree to do so. Past research with drug offenders in prison settings showed that a majority of inmates generally accept to be interviewed by independent researchers after conviction (Morselli and Tremblay, 2004; Decker and Chapman, 2008). Examples of questionnaires for drug offenders can be found in numerous studies, including Matrix Knowledge Group (2007), Decker and Chapman (2008), or Reuter and Haaga (1989). Such a questionnaire should be adapted to provide detailed information on the division of labour and profits in ATS labs, and the dynamics of distribution/exportation (post-production). Ideally, data collection procedures would be routinely implemented so that every ATS production suspect is interviewed by a researcher after conviction.

- *Analysis of case files*/*Interviews with police investigators*. If access to prisons is slow, analyzing case files (see Diplock et al., 2005) and surveying police officers can be used as an alternative. Such a survey should involve strictly officers who have worked on ATS lab cases where information on the division of labour within the lab was collected. *The interviews should be focused on specific (detailed) cases, not on ATS labs in general*[11]. The interviews would complement what can be learned from an analysis of the case files.

[10] The selection criteria should be extended to supply offences in general in order to catch all possible candidates who have knowledge of ATS labs, and to collect information on the distribution/exportation of ATS.
[11] The use of a standard Delphi method is not recommended here: data should always be collected from specific cases as opposed to perceptions and personal opinions.

In addition, it is highly recommended that Canada implements data collection procedures on drug offender arrestees like the ADAM/DUMA surveys. Such surveys proved to be crucial in uncovering trends in drug use and drug dealing in the countries in which it has been implemented (Bouchard, 2008c). Note that arrested users and dealers may be interviewed on their supply sources, including connection to local ATS labs.

5 Prevention and Suppression Strategies

The purpose of this section is to provide a brief overview of the some of the issues (methodological and others) that necessarily arise when thinking about ATS-related prevention and suppression strategies. Given the methodological focus of this report, the most direct policy implication is that any attempt at evaluating the effectiveness of prevention and suppression strategies should be accompanied by the proper methodological tools to estimate the size of the market, and monitor its evolution over time. Even before getting there, the preceding section highlighted how a number of simple data collection strategies should first be implemented.

One of the lessons of past work on evaluating police interventions on drug markets is that the available indicators (number of arrests, seizures) mostly serve as a representation of police "activity", not police "effectiveness". To be sure, an increase in arrest or seizure rates does not mean that the probabilities of arrest or detection are also increasing. For example, a capture-recapture study by Bouchard (2007) showed that the near two-fold increase in the number of arrests for cannabis cultivation in Quebec between 1998 and 2002 was performed at a time where the population of cannabis growers was increasing at a very fast rate – from 30,000 to over 50,000 growers from 1998 to 2002. In other words, the risks of being arrested remained essentially the same. Only in incorporating such methods as tools used by crime analysts can a genuine comprehension of the impact of law enforcement and other strategies be achieved.

There are a variety of approaches to prevention of ATS use, and a similar variety for the suppression of ATS production. These approaches range from strict precursor regulation (e.g. Cunningham et al., 2009) to a regulated adult ATS market (Haden, 2008). It is well beyond the scope of this report to provide specific recommendations on which strategies should be implemented. This should be the object of a separate report where the evidence regarding the effectiveness of various strategies is assessed systematically (what works?).

The first important point is that the assessment of approaches destined to reduce meth/MDMA use should (at least initially) be separated from those aimed at reducing production. One reason is because interventions focusing on production and supply are unlikely to have much impact on consumption (MacCoun and Reuter, 2001), while the reverse is not necessarily true (all is else equal, reductions in quantity of drugs demanded will affect the quantity supplied). For example, a significant decrease in ATS lab seizures in the US was not accompanied by a decrease in consumption – offenders appeared to have merely re-directed their efforts towards importing more of the product from Mexico and Canada (Broude and Teichman, 2009; Cunningham et al., 2009; UNODC, 2009). In other words, any future success in reducing ATS production in Canada does not mean that it has affected consumption, and vice-versa. To be effective, both types of objectives (supply reduction, demand reduction) should be thought through as requiring different types of strategies.

It does not mean, however, that interventions on the supply side do not affect the demand side at all. Cunningham et al. (2009) showed, for example, that precursor regulations in forms aimed at large scale meth producers in the US led to a reduction in purity throughout the country. Similarly, precursor regulations aimed at small scale producers (e.g. over-the-counter medications) was followed by an increase in purity (by driving out low quality producers). Such variations in purity create uncertainty that may lead to adverse consequences for drug users, such as more overdoses.

The more general point is that most repressive policies have unintended consequences on the health of users which may increase the amount of social harms, rather than decrease them (MacCoun and Reuter, 2001). And perhaps even more importantly, the police cannot, and should not do this alone. Serious consideration should be given to what Cherney et al. (2006) call the multilateralization of policing, which consists in engaging a variety of social institutions in thinking about supply reduction strategies not normally considered as drug law enforcement. The key words are regulation and persuasion, rather than coercion. Cherney et al. (2006) offered a detailed account of the various ways to engage the pharmaceutical industry in cooperating with the police towards a common goal.

This argument can be generalized. Coordinated approaches that incorporate education (of both users and non-users), regulation of precursor substances, purchase monitoring, harm reduction strategies, and law enforcement are likely to be more effective than single-factor approaches. Birckmayer et al. (2008), for example, suggest that multiple re-enforcing prevention interventions which directly involve affected communities have the greatest potential effectiveness on ATS markets. As for any illegal market, supply will be most affected with interventions aimed at reducing demand. A better understanding of meth and ecstasy use is vital in designing prevention strategies that work. By tracking market size over time, the efficacy of those initiatives can be measured in terms of their effect on ATS consumption and production in Canada.

6 Conclusion

This report provided a review of current existing knowledge on the size of the meth and ecstasy markets in Canada. It also proposed a discussion of the methods that can be used to provide valid estimates of those markets, and suggested a few approaches to exploit existing data or develop new data collection procedures to learn more about ATS markets in Canada, especially in regards to production. It was found that trends in the general and student populations are stable or on the decline, and that no discernible trends could be detected in the populations of heavy users. It was also found that there is too much uncertainty in regards to the existing data to truly assess the role of Canada in the global ATS trade. But there is hope – as shown by our review of some of the existing methods to estimate the size of illegal markets, and much of the data already exists.

Below are a few general guidelines provided on how to approach the estimation of the meth/MDMA markets from what has been learned in past exercises on other markets.

A maximum number of different indicators should be collected and examined for detection of trends. These include: a) meth/MDMA treatment admissions; b) arrests for meth/MDMA-related offences; c) meth/MDMA-related overdoses; d) meth/MDMA purity levels; e) meth/MDMA drug prices; f) importation of key precursors; g) domestic and overseas seizures.

Estimating the number of drug users is a necessary, but not sufficient starting point. Although imperfect, more data is available on use than production and trafficking. It is not sufficient to determine the size of production because of the position of Canada as a potential exporting country. But a good estimate of the quantity consumed is necessary to assess the size of potential exports (Bouchard, 2008a).

The number of dealers should (loosely) follow the number of users. For example, an increase in capture-recapture estimates of the number of retail dealers should normally be accompanied by a similar trend in the number of drug users. This is why the use of users-per-dealer ratios can be envisioned to estimate the prevalence of ATS dealers (Bouchard and Tremblay, 2005). But there are some exceptions to this, such as when competition among dealers increases in a given market where drug use is stable.

In the context of domestic production, the population of producers, dealers and users may not grow in parallel. While the number of dealers should loosely follow the number of users, the same cannot be said of the number of producers which, in the presence of an exportation market, can follow different trends entirely. This is why the decline in the number of recreational users detected in general surveys does not necessary have an impact on trends in domestic production.

Triangulation of estimates from different methods is essential. No one method is reliable enough to be used without proper checks for validity, which should include alternative estimates derived from different methods.

Appendix A: Literature Search Strategy

An extensive search of the literature using capture-recapture methods was undertaken to estimate the prevalence of illicit populations, but also to review the existing knowledge on the Canadian meth and MDMA markets in general. A number of strategies were employed, with varying levels of success.

First, citations noted by key sources arising out of the database search were chased and added to the reference list below. The following articles were considered as key sources:

> Berry, Brent. "A Repeated Observation Approach for Estimating the Street Homeless Population." *Evaluation Review* 31,2 (April 2007): 166-199.
>
> Bohning, Dankmar, et al. "Estimating the number of drug users in Bangkok 2001: A capture–recapture approach using repeated entries in one list." *European Journal of Epidemiology* 19,12 (December 2004): 1075–1083.
>
> Roberts, John M., Jr., and Devon D. Brewer. "Estimating the prevalence of male clients of prostitute women in Vancouver with a simple capture–recapture method." *Journal of the Royal Statistical Society, Series A* 169,4 (2006): 745-756.
>
> Mascioli, F., and Rossi, C. (forthcoming in 2010). Capture-recapture methods to estimate prevalence indicators for evaluation of drug policies. *Bulletin on Narcotic Drugs.*

For completeness, references cited in the following article were added:

> Bouchard, M. (2007). A capture-recapture model to estimate the size of criminal populations and the risks of detection in a marijuana cultivation industry. *Journal of Quantitative Criminology, 23*, 221–241.

Second, a keyword search was conducted in the databases "Criminal Justice Abstracts", "National Criminal Justice Reference Service", and "PubMed Central". The keywords used for the methamphetamine and MDMA search were:

> [methamphetamine OR "crystal meth" OR ecstasy OR MDMA] AND ["capture-recapture" OR "population estimate" OR "population estimation" OR "market size"]

The CJA and NCJRS databases gave no results. The search in PubMed central gave 12 articles, but only 4 were of interest for the current report: Chiang et al., 2007; Brady et al., 2008; Milloy et al., 2008; Brouwer, 2006 (cited below).

A broader database search was also conducted for capture-recapture literature on crime in general. The keywords used for this search were:

crim* AND [“capture-recapture” OR “population estimate” OR “population estimation” OR “market size”]

Again, the CJA and NCJRS databases produced no results. PubMed central produced 57 studies: 8 new ones were on topic (two overlapped with previous search) and were added to the list: Frisher et al., 2007; Hay and McKeganey, 2009; Aceijas et al., 2006; Cooper et al., 2008; Mastro et al., 1994; Neugebauer and Wittes, 1994; Laporte, 1994; Hser et al., 1998.

Thirdly, CJA and NCJRS were searched using the broadest possible terms. This was not done in PubMed as this would have resulted in a large proportion of irrelevant hits given the wider range of fields covered by PubMed. The keywords were:

“capture-recapture”

The CJA search returned 13 articles of which 6 were reviewed (Augustin and Kraus, 2004; Bennett et al., 2006; Hay and Gannon, 2006; Hay and Smit, 2003; Millar et al., 2006; Monkkonen, 2001). NCJRS turned up 17 articles of which an additional 5 were examined (Bloor et al., 1991; Comiskey, 2003; Krause et al., 2003; Maxwell, 2000; UNODC GAP, 2003)

Fourth, reports and grey literature were examined. The websites for the following groups were examined for indications of the existence of relevant reports: 1) United Nations Office on Drugs and Crime, 2) Centre for Addiction and Mental Health, 3) Centre for Applied Research in Mental Health and Addiction, 4) B.C. Centre for Excellence in HIV/AIDS (led by Evan Wood and his group). All of the studies relevant for the purpose of this report were added below.

Appendix B: Capture-Recapture Studies

Table 4. A review of capture-recapture studies in criminology and a re-analysis with Zelterman's estimator

	Study	Type of offender, year	Methods used	Study's best estimate (risk %)	Z's estimate (risk %)	Δ %
1a	Greene and Stollmack (1981)	Index offenders, 1974	Heterogenous Poisson	29 493 (26%)	28 523 (27%)	-3%
1b		Index offenders, 1975	Heterogenous Poisson	30 298 (26%)	29 842 (26%)	-2%
2a	Collins and Wilson (1990)	Adult car thieves, 1987	Heterogenous Poisson	201 (29%)	208 (28%)	+3%
2b		Juvenile car thives		141 (51%)	123 (59%)	-15%
3a	Van der Hejden et al. (2003)	Illegal possession firearms (1998-99)	Hetegenous Poisson regression model	62 722 (4%)	50 886 (5%)	-23%
3b		Drunk driving (2000)		113 771 (9%)	101 129 (10%)	-13%
4	Riccio and Finkelstein (1985)	Burglars, 1976	Homogenous Poisson	2179 (60%)	4063 (32%)	+46%

Table 5. Performance of 14 "one sample" estimators on a population of insects (from Wilson and Collins, 1992)

	Version 1	**Version 2**[a]
Darroch (1958)	854	856
Darroch (updated) (1958)	831	833
Darroch and Ratcliff (1980)	837	838
Craig (1953)	899	901
Zelterman (1988)	**797**	824
Chao (1987, 1989)	803	**795**
Overton (1969)	503	-
Burnham and Overton (1978)	985	-

a. Derived by Wilson et Collins (1992) from original estimators (Version 1).

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