CHAPTER 7

WILDLAND ARSON MANAGEMENT

Jeffrey P. Prestemon and David T. Butry

1. INTRODUCTION

Wildland arson has received scant attention in the resource economics literature, yet is the cause of many large and damaging wildland fires. Research into wildfire management and policy in the United States has been principally concerned with wildfire suppression, fuels treatments, fire science (behavior), and economic efficiency questions. This is unfortunate, because wildland arson in some parts of the United States comprises well over a quarter of all fire starts and is the third most common type of arson behind arson fires in residential and educational structures (Icove and Estepp 1987). From an ecological and wildland management standpoint, wildland arson fires comprise an important piece of the overall wildfire production process. (See chapter 3 for a more detailed discussion of fire production processes). Its response to wildland management may differ from other sources of fire, such as lightning and other human caused ignitions, so special measures may need to be taken to address it. Additionally, the damages resulting from arson wildfires may differ from those ignited by other sources. Wildland arson fires are ignited close to high values at risk (Butry et al. 2002)—structures, especially, and so they are a threat to public safety that could be higher than are other kinds of fires. In fact, wildland fires in general threaten more homes than do fires that originate within structures (Cohen 2000). Recent high-profile, expensive, large arson wildfires such as the Hayman fire near Denver in 2002 (Kent 2003) and the Rodeo-Chediski fire in Arizona that same year illustrate the importance of understanding and focusing attention on potential costs and losses from arson. (See chapters 8 and 11 for in depth analyses of how to value the damages from wildfires and other disturbances.)

The dictionary definition of wildland arson is as a fire set intentionally and for malicious purposes. However, the popular usage of the term could be broader (Hall 2005). In history, fires were very often set intentionally, although not always with malice as a component of the intent (Doolittle and Lightsey 1979). As Doolittle and Lightsey (1979) found in their extensive surveys of firesetting in the South, a more inclusive term for unauthorized or even technically illegal setting of fires is "firesetting" and those setting the fires as "woods-burners." Indeed, a small but significant share of wildfires recorded, with some discretion,

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by government agencies are those started by children, and these are identified as distinct from those by older individuals, which are classified as "incendiary." The implication is that children as firesetters are assumed to not possess the malice required of a classification of the fire as "incendiary." In this chapter, we use the word "arson" when we refer to the nominal classification of a fire cause by law enforcement or wildland managers. We use the term "firesetting" when we want to encompass all deliberately set wildfires, whether or not they are set with malicious intent. We are not able to discern the shares of fires started with and without malice using aggregate wildfire data, as all fires determined to have not been set by children are classified by law enforcement and wildland managers as "arson" or "incendiary."

Arsonists (structure and wildland) commit their crime with a wide array of motives. The Australian Institute of Justice (2005, p. 1), summarizing research by several analysts, including research on serial arsonists by Sapp et al. (undated) and Icove and Estepp (1987) (among others), indicates that wildland arsonists are driven by two classes of motives—vandalism and excitement. Vandalism is an umbrella term used to describe "wilful, mischievous, wanton destruction... [and is] often [the] result of boredom or frustration" (Australian Institute of Justice 2005, p. 1). Similarly, the umbrella term "excitement" captures a set of motives that include "thrills, attention, or recognition." Willis (2004) provides a summary of these potential motives. While a recurrence throughout the literature is that the typical arsonist is a white male, poorly educated, of lower intelligence, from a dysfunctional family, and a loner, there appears to be some variation by motivation (Inciardi 1970). For instance, Inciardi finds that arson for financial gain (e.g., as insurance fraud) is more likely to be done by older (approaching 30), middle class individuals with above-average intelligence, whereas vandalistic arson tends to be performed by teenagers. Nonetheless, Doolittle and Lightsey (1979) claim that a significant share of wildland arson fires are set as acts of retaliation and revenge. In the following pages, we describe how fires classified as arson have been explained by analysts and how and why they may have changed over time. The relevance of motive arises when seeking to understand the importance of hypothesized drivers of changes in wildland arson rates over time and differences in those rates across space.

The objectives of this chapter are to (1) review the importance of arson using recent data, (2) explain how wildland arson has been described and examined in various fields of study, (3) report new research that has characterized wildland arson as a complex, spatio-temporal process whose broad patterns may be familiar to wildland fire managers as well as to criminologists, and (4) synthesize the available research to make recommendations to wildland managers and law enforcement on potential methods of reducing aggregate arson rates. To accomplish these objectives, we provide data on wildland arson on national forests in the United States and in Florida statewide. After this background, we briefly discuss how sociologists and criminologists have or may offer explanations for observed arson wildfire. We then describe recent findings on wildland arson in

Florida. We follow this with a report on a small empirical analysis of how wildland arson compares with other crimes in Florida. The conclusion lays out our findings and describes future research directions that would advance our understanding of this phenomenon.

2. ARSON RATES IN THE UNITED STATES AND FLORIDA

Before advancing explanations for how to explain arson fire patterns, it is useful to provide some background on what has been observed in the United States. Figure 7.1 shows an index of area burned (index for area burned in 2002 = 100) by arson-ignited wildfires and the count of arson ignitions (index for number ignitions in 2002 = 100) on all national forest-managed lands of the United States. Over the period 1970-1985, arsonists successfully ignited an average of about 1,700 wildfires, while from 1986-2002, roughly 1,260 such fires were set. The dotted linear trend line in the figure illustrates that the rate of wildland arson ignitions has declined. Over that same period, the area burned by arson-ignited wildfires increased from about 57,000 acres per year to 88,000 acres per year, with peaks showing that arsonists had ignited so many large fires during some years that they burned over 200,000 acres.

More information, at finer spatial resolution, can be obtained by examining such trends and variations in plausible explanatory variables for arson. Figure 7.2

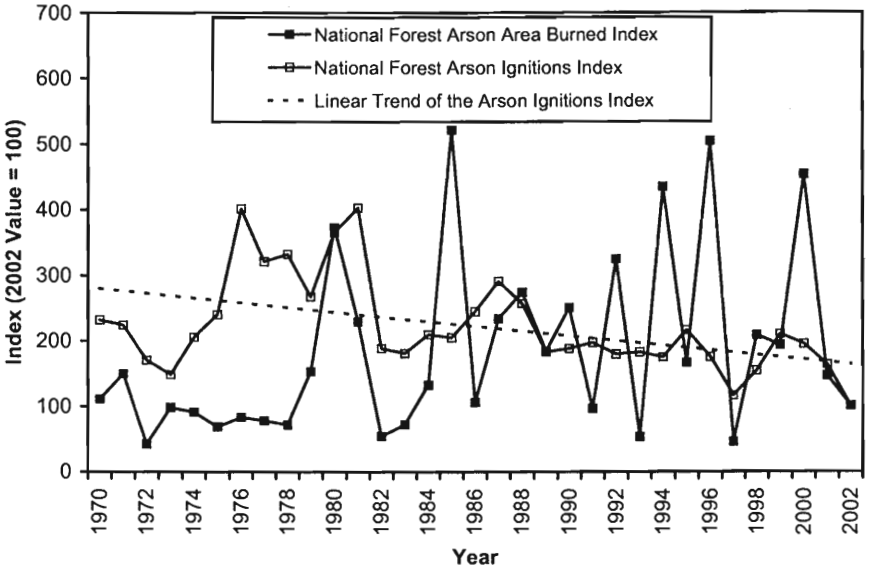

Figure 7.1. Indices of wildland arson area burned and ignitions on all U.S. National Forest System acres, 1970-2002.

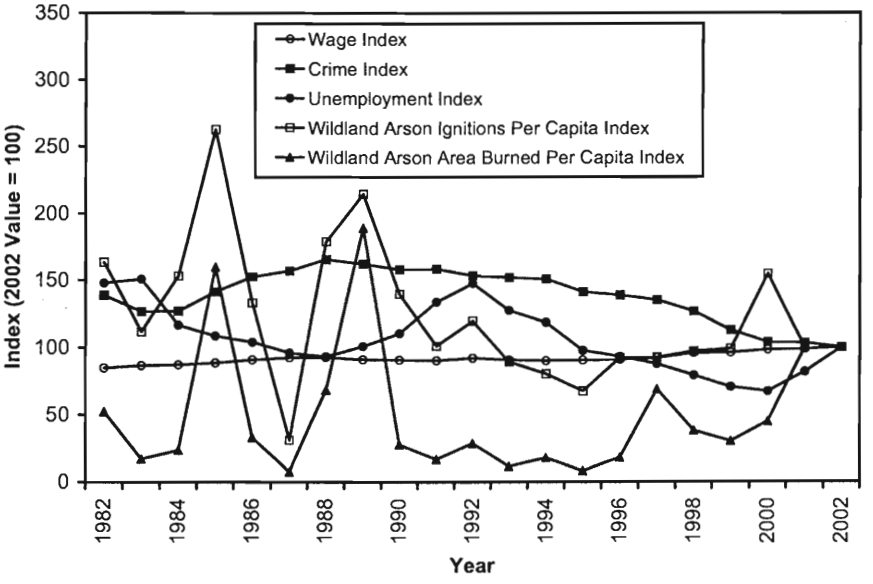

Figure 7.2. Indices of wildland arson ignitions per capita and area burned, index crimes, unemployment, and real retail wage in Florida, 1982-2002.

plots the number of arson wildfires ignited per capita statewide in Florida as an index (2001 = 100), 1982-2002. It also plots the area burned by arson wildfires as an index (2001 = 100).

Arson-ignited wildfires still burn a significant share of wildland in Florida—over the years 1992 to 2002, they comprised 20 percent of all burned acres—and negative trends in the occurrence might not have netted a better situation for residents of the state. From 1982-1991, arson wildfires annually burned an average of about 62,000 acres, while from 1992-2002, the average was about 38,000. Concurrently, annual ignitions dropped from 1,695 to 1,131 per year between those two periods, implying that the average size of an arson wildfire stayed approximately constant, at 31 and 33 acres in the two periods, respectively. In short, arson fires appear to have declined in both frequency and aggregate extent. But during this same time frame, the number of people and other values threatened by arson wildfires in Florida have grown. Between 1982 and 2002, Florida's population grew by 57 percent and total income grew by 114 percent. We recognize that research is lacking about whether actual values at risk from arson wildfires have changed. However, if the spatial distribution of values at risk were uniform and changed in magnitude directly with real income earned in Florida, then we could conclude that reductions in arson wildfires have been about sufficient to keep up with rising values at risk of arson wildfire loss. In other words, arson wildfires appear to be just as threatening today as they were over twenty years ago.

3. ARSON AND SOCIOLOGY

Sociological explanations for wildland firesetting center on normative (socially acceptable) and retaliatory behavior (Kuhlken 1999), implying that firesetting may or may not be incendiary, i.e., set with malicious intent. It is the diversity of intents that Doolittle and Lightsey (1979) describe in their typology of southern firesetters. These authors identified three firesetting archetypes among Southern United States "woods-burners." First, most active woods-burners were young (early to mid-20s), white males, of lower educational achievement, who were under-employed and of lower or lower-middle class economic status. Members of this group were loners whose favorite past-time was hunting. Second were individuals who were less active in firesetting than the first group, consisting of white males averaging 46 years of age, with higher living standards. This group perhaps was numerically larger than the first group. A third group was identified as low economic and social status individuals, often with criminal backgrounds, looked upon unfavorably by the community; they were the stereotypical, criminal woods-burners (arsonists), from the perspective of land management agencies and law enforcement.

Doolittle and Lightsey (1979) outlined how some firesetting can be classified as a normative activity, and evidence suggests its historical prevalence as such in the U.S. South (Kuhlken 1999). In general, firesetters belonging to the first two groups identified by Doolittle and Lightsey (1979) were not regarded negatively by the rest of the community because they usually were partaking in a normative activity. As a normative activity, firesetting could at least be classified from the community's perspective as a crime defined by a bad law, as it might have been classed by Cesare Beccaria (1738-1794), the "father" of modern criminology. Woods-burners looked upon fire as a necessary component of forest management: to clear undergrowth, eliminate pests, improve wildlife and livestock forage opportunities, and for site preparation following timber harvesting. Firesetting by some members of the first and second groups can be seen as carrying on long-standing traditions of active land management, in spite of nominal legal prohibitions. This assessment by Doolittle and Lightsey (1979) validates later descriptions by Pyne (1995), who documents such firesetting for management purposes as spanning many cultures worldwide. This normative behavior among firesetters also helps to explain Doolittle's (1978) finding that prescribed fire use can lead to reductions in incendiarism. Prestemon et al. (2002), Mercer and Prestemon (2005), and Prestemon and Butry (2005) provide empirical support for the negative relationship between incendiary fires and prescribed fire in Florida, as well. The last three studies based their results on data from the mid-1990s and later, not on fires set during the time of Doolittle and Lightsey's analyses. But aside from the obvious explanation that rising use of prescribed fire in some parts of Florida might have reduced fuels and incendiary firesetting success by arsonists, it is plausible that, at least historically in Florida, higher rates of arson observed there in early 1980s might have included normative firesetting activity

that has abated as prescribed fire has expanded. Furthermore, it is possible that normative firesetting, while classified by government agencies and law enforcement as "incendiary," has changed over time as a result of changes in the culture that supported it.

Fire has also long been employed as a tool of antisocial behavior and political violence, at scales large and small (Goudsblom 1992). Doolittle and Lightsey (1979) indicate that fire has been used as a weapon of retaliation in the South, apparently by members of any of the three groups of firesetters that they identified. When used in this way, fire is employed to punish other landowners for restricting forest access for previously allowed public activities (e.g., hunting); the greater the degree of restriction, the greater the rate of illegal firesetting in retaliation. In their study, they found that such acts were frequently directed at corporate landowners. U.S. Forest Service lands (national forests) were also set afire when local residents faced similar access problems (through road closures, etc.) or when federal land managers imposed new regulations of public lands grazing, prosecuted illegal dumping, and created opportunities for developed recreation by non-local residents. Doolittle and Lightsey (1979) conclude that incendiarism is one way that landowners can retaliate against a more powerful neighbor or land manager. These findings document a rural, southern United States version of a phenomenon, described by Gamst (1974, p. 48), as being present for centuries in human societies in many cultures. Molina (1997), who documented the same phenomenon in northwestern Spain, Gamst (1974), and Doolittle and Lightsey (1979) have shown that fire is frequently used as tool of social protest and revenge in response to use-restrictions of the land by the politically and economically powerful.

4. ARSON IN CRIMINOLOGY

Criminology is the study of laws, their violation, and how society responds to violations. Some criminologists attempt to explain spatial and temporal crime patterns: how crimes of various kinds, once defined, vary over space and over time, typically as a function of social, environmental, and economic variables. Variables used to explain crime typically derive from theories about the causes of crime, and many theories are available from criminology that could help us to understand spatial and temporal patterns of wildland arson. Crime pattern modeling or crime mapping can be descriptive and it can be quantitative. Crime pattern modeling of wildland arson might reveal how wildland arson is both an environmental and a sociological phenomenon.

Cohen and Felson (1979) depict a routine activity approach in order to understand crime patterns. While their routine activity approach is focused on "direct contact predatory violations" (robbery, homicide, assault, etc.), in many ways it can be applied to arson crimes. For instance, Cohen and Felson (1979) discuss how, for a crime to be committed, several necessary factors must exist: an offender, a target, and a lack of "capable guardians" (e.g., police or neighborhood

watch groups). The routine activities approach explains that crime varies across space and over time according to how everyday human activities vary over space and time—for example, among neighborhoods, over the course of a year, perhaps in response to seasonal or economic differences and changes. These variations modify the convergence among the offender, the target, and the lack of guardians. For instance, in many places, spring and summer times drive people out from their homes to parks, city streets, and vacation spots. Being away from one's home leaves one vulnerable to being personally targeted by criminals (who might assault or rob) or it leaves one's home vulnerable to thieves (who would burglarize it).

A large literature exists on mapping crime and predicting the places and times of future crime based on statistical models of crime patterns, often referred to as "hotspotting" (Townsley et al. 2003). These models have been developed especially for aiding in understanding and dealing with serial crime in urban settings, and the relevant literature dates back several decades (Shaw and McKay 1931, 1942, Lottier 1938, Boggs 1966, Harries 1980). More recently, the science of crime pattern understanding and prediction has gained traction because of advances in statistical modeling techniques, geographic information systems, and computing power (Corcoran et al. 2003, Deadman 2003, Bowers and Johnson 2004, Johnson and Bowers 2004). In wildland arson, hotspotting models are in their infancy. One reason for slow development has been lack of data or modeling constructs.

These theories of crime requiring an opportunity would seem to require elaboration to encompass wildland arson. For example, Prestemon et al. (2002), Mercer and Prestemon (2005), Butry and Prestemon (2005), and Prestemon and Butry (2005) have shown how arson wildfire area burned appears to react strongly to fuel conditions and weather—the same factors influencing other kinds of wildfire. Figures 7.3 and 7.4 highlight the seasonal arson peaks in Florida in late-winter to early-spring further and daily (hourly) peaks in ignitions in the mid-day, both of which are times of increased non-arson wildfire probability. But the broader crime literature does, indeed, include weather or seasonality in models explaining crime. For example, Rotton (1985) and Cohn (1990) found a positive correlation between certain kinds of crime and air temperature (among other atmospheric factors). Broadly across the United States, aggregate crime rates are positively correlated with average annual temperature, and the correlation seems stronger for violent crime.[1] Perhaps confirming the link between routine activities and weather, some kinds of crime follow systematic (seasonal) patterns (Farrell and Pease 1994, Felson and Poulson 2003). Other patterns are even finer scale and likely relate to routine activities associated with societies.

[1] The correlation between average annual temperature and the major crime index is 0.38, while that for violent crime is 0.43. These correlations are based on data from 1972-2004, where each pair of observation is a state's 1972-2004 average crime index or violent crime index and the state's 1970-2004 average annual temperature (Florida Department of Law Enforcement 2005c, National Climatic Data Center 2006).

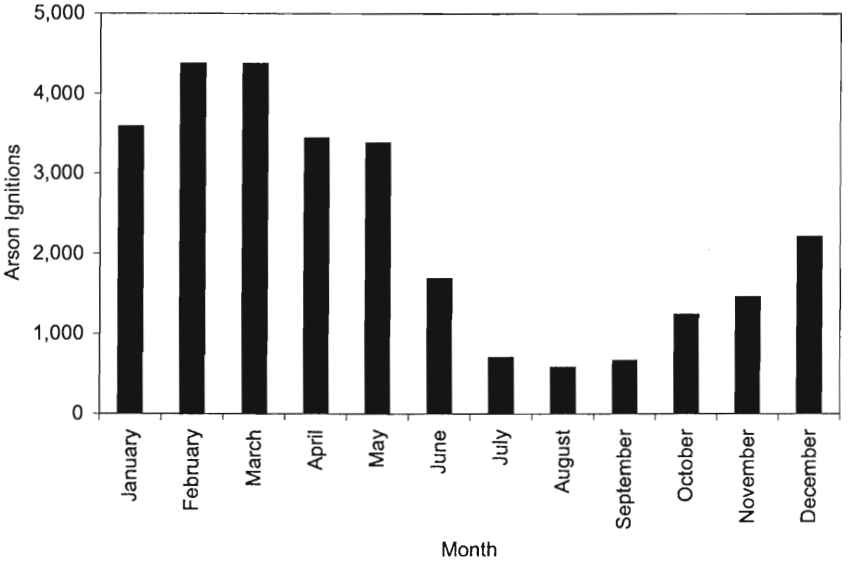

Figure 7.3. Arson ignitions by month in Florida, 1982-2002.

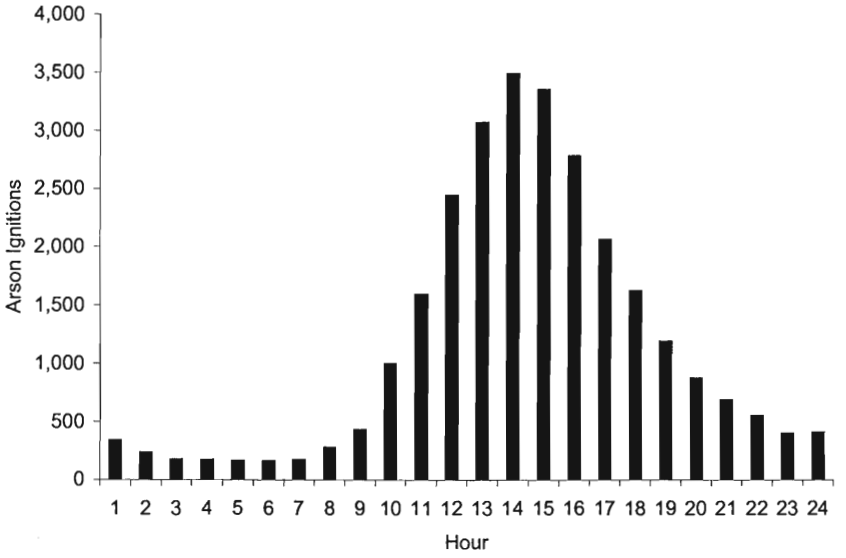

Figure 7.4. Arson ignitions by hour of the day in Florida, 1982-2002.

DiTella and Schargrodsky (2004) showed how car thefts in Argentina also had systematic components linked to days of the week. Also, many kinds of crimes vary diurnally, which has been attributed to the advantage provided to criminals by the cover of darkness and hence community oversight and policing efficacy,

and to diurnal patterns of human activities related to work, leisure, and substance abuse timing (Cohen and Felson 1979, Cohn 1993, Hipp et al. 2004). While arson ignitions in Florida appear to follow seasonal and daily patterns, perhaps indicating that weather and climatic conditions exist for successful ignition. Figure 7.5 shows that other factors influence arsonist behavior, such as opportunities to burn. Figure 7.5 clearly illustrates a weekend effect, which is not likely to be driven by weather and climate conditions, but rather by other socioeconomic factors, such as leisure time.

The Federal Bureau of Investigation classifies wildland arson as a property crime, although we know of no research that has sought to characterize its relationships to other major categories of crime. Data show that the overall statistical relationship between wildland arson and aggregate crime measures are weak. Although some violent and non-violent crimes differ in their responses to labor market conditions and aggregate wealth (Grogger 1998, Gould et al. 2002, Burdett et al. 2003), law enforcement, and poverty (Hannon 2002), we know of no published study that has sought to evaluate whether wildland arson is more similar to certain types of crimes than to others. Perhaps a reason for the lack of identified statistical relationships is that wildland arson is a less frequent crime, implying that there is insufficient information to clearly establish statistical relationships. We might hypothesize that, because arson involves an effort to attack a target, it could be classified as a violent act (Crowe 2000) and so should share underlying causes with violent crimes. In contrast, Rider (1980) found that convicted arsonists are more likely to have committed prior property

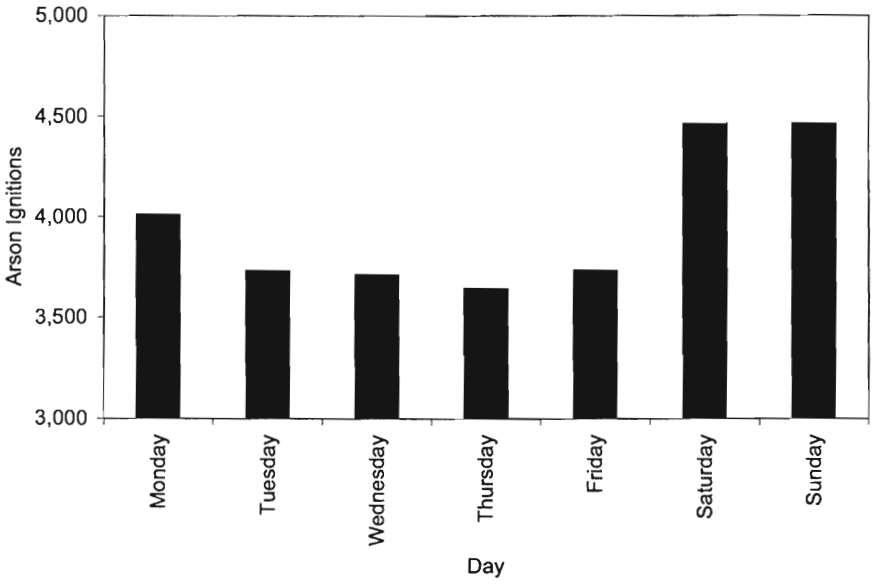

Figure 7.5. Arson ignitions by day of the week in Florida, 1982-2002.

crimes and that convicted non-arsonists are more likely to have committed violent crimes. Indeed, evidence suggests (Cabe 1996) that some arsonists ignite fires in order to obtain employment or even salvable timber (Molina 1997). Therefore, wildland arson incidence rates should have characteristics of both categories.

There is statistical evidence that wildland arson should be related to other kinds of crimes, even while correlation analyses could fail to turn up connections. For example, arson wildfire ignitions in Florida counties relate to the same set of socioeconomic variables that affect other kinds of crimes (Prestemon and Butry 2005), even while simple correlation statistics do not appear to support this contention. Data on wildland arson and general categories of crime in Florida (Florida Division of Forestry 2002, Florida Department of Law Enforcement 2005b) show that wildland arson ignitions per capita, statewide, over the period 1982-2001 were slightly negatively correlated with violent crime per capita (murder, forcible sex offenses, aggravated assault, and robbery) ($\rho = -0.06$) and slightly positively correlated with property crimes per capita (burglary, larceny, motor vehicle theft) ($\rho = +0.13$), while violent and property crime indices were very positively correlated ($\rho = +0.86$). Similarly, pooled county-level data for the period 1989-2001 in Florida show that county arson ignitions and a county index of aggregate violent and non-violent crime were negatively correlated ($\rho = -0.19$) (Prestemon and Butry 2005). As well, departures from 1989-2001 county average wildland arson ignitions per capita and county average crime indices (crimes per capita) had a population-weighted correlation of –0.08. What we show in the empirical application section of this chapter is that controlling for weather variables in conjunction with socioeconomic and law enforcement variables can enlighten hypotheses about whether wildland arson is similar to major crime categories.

5. ARSON IN ECONOMICS

We can synthesize the findings of criminological and sociological studies of wildland arson into an economic model of firesetting. Criminological research continues to define individual decision making as deriving from economic models of crime (Becker 1968), where crime is deterred when the overall expected costs (its opportunity costs) of committing a crime are high relative to its perceived expected benefits. This description of criminal decision-making dates to Jeremy Bentham's (1748-1832) utilitarian view of criminal activity. Bentham posited that criminals commit crimes when the expected rewards from commission exceed the expected losses, so that preventing or reducing crime could be achieved by adjusting the expected losses. Indeed, analysts have found that economic models of crime, while arguably a narrow view of criminal behavior, often fit crime data fairly well. In the case of wildland arson, such an "economic model" would appear to need to index the prevalence of normative behaviors supporting firesetting in the target population. Greater prevalence of normative beliefs in favor

of firesetting would translate into higher perceived benefits from the firesetting. Places or populations with greater prevalence of normative firesetting would have higher arson rates, *ceteris paribus*.[2]

Abstracting from the issue of normative firesetting, and following Becker's (1968) approach, we formalize the prospective arsonist's expected utility from successfully starting a wildland arson fire as:

$$E[U_i(O_i)] = \pi_i U_i(g_i - c_i - f_i(W_i, w_i)) + (1 - \pi_i)U_i(g_i - c_i) \qquad (7.1)$$

where E is the expectations operator, U_i is the prospective arsonist's utility, O_i is the number of offenses committed, π_i is the probability of being caught and convicted, g_i are the arsonist's psychic and income benefits from illegal firesetting, c_i is the production cost for firesetting, and f_i is the wealth loss experienced by the criminal if caught and convicted. Wealth loss is a function of wages (w_i) and employment status (W_i) (Grogger 1998, Gould et al. 2002, Burdett et al. 2003, Jacob and Lefgren 2003).

Expected utility theory implies that an arsonist will continue to ignite additional arson fires until the expected marginal gain in psychic or income benefits from the last ignition is exceeded by the sum of the expected loss in wealth from being caught and the production cost of the firesetting. Empirical findings in crime research also lends weight to the hypothesis that psychic and income benefits would be higher if there is more available wealth in a community, encouraging crime (Gould et al. 2002). For wildland arson, costs would be affected by opportunity costs of time (i.e., the net benefits accruing to the prospective arsonist of using time in an alternative way), weather affecting firesetting success, and the availability of information regarding potential firesetting success. The opportunity cost of time could be captured by wages, employment status, and the availability of leisure time. Greater wages or the opportunity to work and earn wages tends to raise opportunity costs; these costs could also be higher on non-leisure days. In the aggregate, wage rates of the target arsonist population and the unemployment rate would index such costs.[3] On fine time

[2] We contend that steady changes in such normative behavior over time can be captured in a statistical sense through time trends within populations and by cross-sectional dummies and time trends in panel data analyses. Average differences across space would be captured by the cross-sectional dummies in panel studies. Differences in the amount of normative behavior across populations in purely cross-sectional analyses would be more difficult to capture but could be indexed by measures of rural, lower economic status populations.

[3] Grogger (1995) shows how past arrests and convictions affect wages subsequently earned, but that the effect is limited. Grogger (1998) then elaborates a model wherein wages for youth are endogenous to those individuals' past crime committed and other variables, and some of his findings support this hypothesis. Further, wages were found to be negatively related to youth crime. Burdett et al. (2003) describe a labor market equilibrium model where employment levels, the wage rate, and the crime rate are jointly determined, but without formal tests of the theory.

scales, an indicator of weekends and holidays may control for the apparent lower opportunity cost of time on days of leisure.

Firesetting success, as measured by the time spent attempting to ignite a fire, would tend to be higher on dry, warm days and would depend on the availability of flammable fuels (Gill et al. 1987, Vega Garcia et al. 1995, Prestemon et al. 2002). In other words, firesetting costs, as captured by the opportunity cost of time spent attempting to ignite a fire, are higher when fuels are limited and the weather is not amenable to successful ignition (e.g., in wet conditions). A potentially cheap way to monitor firesetting success would be to observe success. The prospective arsonist would do this by observing the firesetting activities of another arsonist or by observing the success of his own firesetting attempts. Expectations of high success rates would translate into expectations of low opportunity costs of time in firesetting. Prestemon and Butry (2005) and Butry and Prestemon (2005), in their daily models of wildland arson ignitions, statistically controlled for this kind of short-run information-gathering by arsonists by lagging ignitions in both time and space. Their findings identified significant spatial and spatio-temporal clustering, which, in addition to validating casual evidence of spatial clustering of arson fires (Doolittle 1978), provide statistical support for the contention that arsonists observe and use firesetting success of themselves or others to facilitate copycat and serial behavior.

To the extent that so-called "copycat" firesetting derives from more complex psycho-social pathologies, the "firesetting production cost" approach may be an overly simplistic representation of observed human activities. Surrette (2002) describes juvenile copycat criminal behavior as facilitated through media. His assessment is that initial stimuli may differ across crime categories and social groupings. As well, copycat crimes emanate from established criminals who view crimes of others as a learning experience, practice the crime, and then commit it under amenable conditions. Copycat and serial firesetting behavior is a topic meriting additional exploration. To confirm spatio-temporal or temporal firesetting, analysts would need to establish serial behavior using forensic evidence. However, we believe that the economic model of crime elaborated above can be captured statistically by including measures of recent and (or) nearby ignition activity.

Research that relates the numbers of wildland arson ignitions to hypothesized drivers dates back at least two decades. This literature is smaller than the also limited literature modeling human-ignited wildfires (Gill et al. 1987, Vega Garcia et al. 1995), although the daily models that were estimated by those authors clearly have lessons on how to model intentional firesetting. Below, we describe a few of these statistical studies of wildland arson.

Donoghue and Main (1985) develop a state-level time series cross-sectional model that relates the annual total wildland arson ignitions to police levels and state-level dummy variables. They show how law enforcement might play a role in

wildland arson rates in the eastern United States, suggesting an economic model that would minimize the sum of arson wildfire losses and law enforcement costs. The general idea of including law enforcement or even fires of specific types has not been adopted in a fuller specification of the problem of optimal wildfire management (Rideout and Omi 1990, Donovan and Rideout 2003) or in models of optimal timber management under catastrophic risk (Martell 1980).

Prestemon and Butry (2005) model arson ignitions as a daily autoregressive process (prior ignitions influence future ignitions) that is also sensitive to law enforcement, socioeconomic variables (poverty, unemployment, retail wage), fuels management, wildfire history, and fire weather (Keetch-Byram Drought Index, El Niño) for several high arson multi-county regions in Florida. There are three notable findings from this research: (1) law enforcement is negatively correlated with arson rates; (2) fuels management is negatively correlated with arson rates; (3) arson ignitions are clustered in time in episodes that can last up to 11 days, which is consistent with serial and copycat arson. This last result is consistent with Surrette (2002), and it suggests copycat behavior. With arson wildfire, it validates a claim by Dennett (1980) and Crowe (2000) that media reports of wildfire lead to future instances of arson, as would-be arsonists are notified of the favorable ignition conditions or spur fantasies of heroism.

Butry and Prestemon (2005) adapt their purely temporally autoregressive arson ignition model to examine arson outbreaks at a finer spatial resolution (Census tracts and individual counties) in a way that would allow for detection of spatio-temporal clustering of firesetting in Florida. These findings include strong evidence that arson ignitions are clustered in both time and space, implying an arson outbreak in one area should be a signal to law enforcement that there is temporarily higher likelihood of future arson fires in surrounding areas. The implication here is that increased arson targeting by law enforcement could be effective at deterring fires in surrounding areas. This study also confirms initial analyses conducted by Doolittle (1978), which found that incendiary (arson) fires occur in clusters.

Brantingham and Brantingham (1981) describe a method by which the spatial pattern of serial crimes can be used to aid in apprehension of criminals. Canter and Larkin (1993) show how using an offense map to circumscribe the physical space containing all linked serial criminal acts can provide a zone within which law enforcement can search for a criminal base location (e.g., the criminal's home). Canter et al. (2000) and Ratcliffe (2004) provide examples of how to develop and use crime maps to improve law enforcement efficiency, leveraging information regarding the physical and temporal domain of the criminal activity. It would be possible, then, to use this spatio-temporal clustering of fires to focus law enforcement's efforts in deterrence of future arson fires. The multidimensional concentration of firesetting would appear to make it amenable to tools such as crime maps.

6. WILDLAND ARSON AND CRIME IN FLORIDA: AN EMPIRICAL ANALYSIS

Our empirical analysis seeks to clarify whether wildland arson is similar in its response to hypothesized causal factors as other kinds of crimes. We focus on wildland arson and crime in Florida. We specify our model based on research by statistical criminologists (Gould et al. 2002) and the recent research into wildland arson. The hypotheses that we test are whether arson wildfires respond to the same factors shown to have an influence over the rates of major categories of crime. As well, we seek to evaluate whether the degree and direction of the response to these factors is similar across crime types and thereby draw conclusions that could be helpful for managers, law enforcement, and analysts.

6.1 Data and Empirical Models

Our statistical approach is to estimate eight individual equations relating crime to the hypothesized causal or driving variables. These crime categories are the ones routinely reported to the Federal Bureau of Investigation and are reported as an index, in terms of the number of crimes committed per 100,000 residents of the state. As such, they are called index crimes: the violent crimes of murder (all types), rape, robbery, and aggravated assault; and the property crimes of burglary, larceny, motor vehicle theft; a fourth property crime sometimes included in federal data is arson (all types included). Here, our fourth property crime and eighth crime index is simply wildland arson. The wildland arson equation relates the number of arson ignitions (Florida Division of Forestry 2005) per capita statewide in each year to: the statewide count of full-time equivalent sworn police officers per capita (Florida Department of Law Enforcement 2005a), which indexes the arrest rate and deterrent effect of law enforcement; the statewide average length of sentence imposed on convicted nonviolent criminal offenders (Florida Department of Corrections 2005), lagged one year because these apply to averages from July of the previous year to June of the nominal year, which also accounts for one source of the opportunity cost of the crime, and should be negatively related to arson; the statewide retail wage rate (Bureau of Labor Statistics 2005), which has a negative expected effect on arson; the statewide unemployment rate (Bureau of Labor Statistics 2005), another measure of the opportunity costs of crime, which should be positively related to arson; the statewide per capita income (Census Bureau 2005), which should be positively related to arson, as it would capture the relative economic inequality between the prospective arson population and the broader population (Ousey 2000), although; the statewide poverty rate of all persons (Census Bureau 2005), which has long been suspected of being linked to crime (Ousey 2000); two variables that index environmental factors that would affect the success rate (hence some of the cost) of firesetting, including an El Niño-Southern Oscillation (ENSO) measure called the Niño-3 sea surface temperature (SST) anomaly

(National Oceanic and Atmospheric Administration 2005) and a dummy variable that controls for the extreme ENSO cycle of 1997-1998 ("D1998") (Prestemon et al. 2002, Prestemon and Butry 2005); and a time trend, which could capture changes in policing practices (including, in the case of wildland arson, efforts to contact potential firefighter arsonists [Cabe 1996] or normative firesetters [Doolittle 1978]), technology, and other influential demographic variables not directly modeled. Equations for the seven major index crimes are related to all of the same variables as in the wildland arson model, except that each has its own applicable statewide average sentence length and that these seven equations exclude the environmental variables.

Equations are estimated using three-stage least squares methods[4], using instruments to control for the simultaneous determination of police levels and crime rates on an annual basis and estimating all eight equations simultaneously. All variables, including the wildland arson and crime index variables we attempt to explain, are expressed in natural logarithms. Temporal autocorrelation is abated by temporally "lagging" dependent variables (i.e., having last year's crime index value help to explain this year's crime index value) and (or) by (in four cases) first-differencing (i.e., subtracting the previous year's value from the current year's value) the dependent (crime index) variable and the regressors (except for the time index variable, "year").

6.2 Results

Table 7.1, shows that wildland arson statewide in Florida behaves mainly according to our expectations from theory—it is negatively affected by police levels and wages and positively affected by unemployment and per capita income. However, in contrast to findings by Prestemon and Butry (2005) and in contrast to descriptive research by Doolittle and Lightsey (1979), it is not significantly related to the poverty rate. The former study had more detailed data on poverty, allowing a tighter match between locations and temporal variations of arson fires and locations temporal variations of poverty. The effect of poverty found here therefore might have been erased by aggregation bias, which tends to attenuate parameter estimates. The measures used to control for the success rate of firesetting, the Niño-3 SST anomaly and the 1998 dummy variable, relate to wildland arson as expected from previous analyses and theory: Drier weather associated with the cold phase of the ENSO cycle (negative values of the Niño-3 SST anomaly) leads to greater wildland arson rates; the severe 1997-1998 ENSO cycle explains a higher rate in 1998 with weak statistical significance (a probability level of 0.18).

The explanatory powers of the other seven crime models are comparable to, or higher than, our equation for wildland arson, but broad similarities exist between

[4] Due to an insufficiently long time series, we did not attempt to estimate this as a cointegrated system. This is an area worthy of additional analysis, however.

Table 7.1. Three-stage least squares estimates of statistical relationships between index crimes and wildland arson and hypothesized explanatory variables, statewide in Florida, 1982-2001.

	Parameter Estimate	Standard Error	t-statistic	Probability Level
Wildland Arson				
Constant	3563.63	1369.01	2.60	0.01
Police Per Capita	-10.26	3.65	-2.81	0.01
$Sentence_{t-1}$	1.31	0.58	2.25	0.03
Real Retail Wages	-13.56	6.52	-2.08	0.04
Unemployment Rate	1.69	0.66	2.57	0.01
Real Per Capita Income	23.01	6.86	3.35	0.00
Poverty Rate	0.98	1.25	0.79	0.43
1998 Dummy	0.40	0.29	1.34	0.18
Niño-3 SST Anomaly	-0.29	0.08	-3.44	0.00
Year	-483.64	184.70	-2.62	0.01
Murder				
Constant	55.34	10.08	5.49	0.00
Police Per Capita	-0.63	0.18	-3.47	0.00
$Sentence_{t-1}$	-0.56	0.07	-8.11	0.00
Real Retail Wages	-0.74	0.49	-1.50	0.14
Unemployment Rate	0.10	0.05	2.04	0.04
Real Per Capita Income	0.23	0.41	0.56	0.58
Poverty Rate	-0.11	0.10	-1.12	0.27
Year	-0.023	0.006	-4.21	0.00
Lagged Dep. Var.	0.09	0.09	0.96	0.34
Rape				
Constant	-8.90	11.95	-0.74	0.46
Police Per Capita	-0.10	0.26	-0.37	0.71
$Sentence_{t-1}$	-0.14	0.06	-2.21	0.03
Real Retail Wages	-1.51	0.62	-2.42	0.02
Unemployment Rate	0.03	0.06	0.53	0.60
Real Per Capita Income	0.28	0.49	0.57	0.57
Poverty Rate	0.09	0.11	0.83	0.41
Year	0.0081	0.0069	1.17	0.24
Lagged Dep. Var.	0.63	0.13	4.95	0.00
Assault				
Constant	22.99	3.84	5.99	0.00
Police Per Capita	-1.61	0.36	-4.48	0.00

(continued)

Table 7.1. Three-stage least squares estimates of statistical relationships between index crimes and wildland arson and hypothesized explanatory variables, statewide in Florida, 1982-2001. ***(continued)***

	Parameter Estimate	Standard Error	t-statistic	Probability Level
Assault *(cont.)*				
$Sentence_{t-1}$	0.00	0.05	-0.02	0.98
Real Retail Wages	-0.70	0.57	-1.24	0.22
Unemployment Rate	0.17	0.07	2.49	0.01
Real Per Capita Income	-0.39	0.47	-0.84	0.40
Poverty Rate	0.26	0.08	3.12	0.00
Year	-0.012	0.002	-5.99	0.00
Lagged Dep. Var.	-0.44	0.11	-4.00	0.00
Robbery				
Constant	9.20	11.87	0.77	0.44
Police Per Capita	-0.76	0.25	-2.97	0.00
$Sentence_{t-1}$	-0.30	0.05	-6.45	0.00
Real Retail Wages	-1.66	0.73	-2.27	0.03
Unemployment Rate	0.24	0.07	3.21	0.00
Real Per Capita Income	1.79	0.57	3.11	0.00
Poverty Rate	0.13	0.12	1.06	0.29
Year	-0.0025	0.0072	-0.35	0.73
Lagged Dep. Var.	0.61	0.06	9.81	0.00
Burglary				
Constant	6.44	3.74	1.73	0.09
Police Per Capita	-1.29	0.37	-3.51	0.00
$Sentence_{t-1}$	-0.18	0.06	-2.93	0.00
Real Retail Wages	-0.88	0.65	-1.34	0.18
Unemployment Rate	0.15	0.07	2.04	0.04
Real Per Capita Income	1.07	0.58	1.85	0.07
Poverty Rate	0.09	0.08	1.02	0.31
Year	-0.0032	0.0019	-1.73	0.09
Lagged Dep. Var.	0.28	0.10	2.74	0.01
Larceny				
Constant	9.07	3.40	2.67	0.01
Police Per Capita	-0.68	0.33	-2.07	0.04
$Sentence_{t-1}$	-0.06	0.06	-0.93	0.35
Real Retail Wages	-0.08	0.58	-0.14	0.89
Unemployment Rate	-0.03	0.07	-0.47	0.64

(continued)

Table 7.1. Three-stage least squares estimates of statistical relationships between index crimes and wildland arson and hypothesized explanatory variables, statewide in Florida, 1982-2001. ***(continued)***

	Parameter Estimate	Standard Error	t-statistic	Probability Level
Larceny *(cont.)*				
Real Per Capita Income	-0.86	0.53	-1.63	0.11
Poverty Rate	0.01	0.08	0.08	0.94
Year	-0.0045	0.0017	-2.66	0.01
Lagged Dep. Var.	0.38	0.13	2.88	0.00
Motor Vehicle Theft				
Constant	21.79	5.69	3.83	0.00
Police Per Capita	-1.72	0.52	-3.32	0.00
$Sentence_{t-1}$	-0.06	0.09	-0.70	0.48
Real Retail Wages	-0.30	0.94	-0.31	0.75
Unemployment Rate	0.11	0.12	0.97	0.33
Real Per Capita Income	0.09	0.81	0.11	0.91
Poverty Rate	0.20	0.12	1.64	0.10
Year	-0.011	0.003	-3.83	0.00
Lagged Dep. Var.	0.28	0.12	2.37	0.02

Equation Statistics	Obs.	R^2	Adj. R^2	Durbin-Watson
Wildland Arson	20	0.61	0.26	1.88
Murder	22	0.99	0.98	2.62
Rape	22	0.83	0.72	2.22
Assault				
First-Difference Model	21	0.60	0.33	2.39
Robbery	22	0.98	0.96	2.45
Burglary				
First-Difference Model	21	0.68	0.47	1.56
Larceny				
First-Difference Model	21	0.56	0.26	1.87
Motor Vehicle Theft				
First-Difference Model	21	0.65	0.41	1.78
Whole System	170			

Source: National Interagency Fire Center (www.nifc.gov/stats/suppression_costs.html)

arson and these other crimes in how variables relate to the modeled crime. In all other crime categories except rape, the most commonly significant explanatory variable for crime is police per capita, where it is negative and significant at a probability level of 0.05 or smaller for seven out of eight crime equation estimates. The negative relationship between crime and wages is observed for all four violent crimes (murder and assault with very weak statistical significance, probabilities of 0.14 and 0.22, respective; and rape and robbery with stronger statistical significance, probabilities of 0.02 and 0.03); a weak statistical effect (probability of 0.18) is also shown for burglary. After controlling for other factors, unemployment strongly (probability smaller than 0.05) and positively relates to murder, assault, robbery, and burglary. Besides wildland arson, real per capita income relates positively and significantly (probability of 0.07 or smaller) to robbery and burglary, which, with the exception of larceny, is as expected: criminals who take others' wealth steal more often when greater wealth exists.[5] Poverty is significant and positively related to only assault and motor vehicle theft, although with weak statistical significance. Measures of trends in these crime rates are typically negative and highly statistically significant (probability smaller than 0.01) for wildland arson, murder, assault, burglary, larceny, and motor vehicle theft.

These statistical results allow us to make several observations about the similarities and differences between wildland arson on the one hand and other index crimes on the other. We find that wildland arson behaves similarly to other crimes in response to variables capturing socioeconomic conditions. The primary contrast between wildland arson and other crimes is in the size of statistical relationships that crimes have with many of the explanatory variables. The absolute sizes of parameter estimates associated with each explanatory variable in the models shown in table 7.1 are measures of the statistical sensitivity of the crime index to changes in the explanatory variable. Wildland arson responds more sensitively to police force levels, wages, unemployment, per capita income, and unspecified other variables captured in the time trend, compared to other crimes[6]. The finding of the strong sensitivity of wildland arson to wages is consistent with what is

[5] Note that the retail wage rate, an indicator of the kind of work available to the low-skill criminal, is used as one measure of the opportunity cost to the criminal of participating in crime. Per capita income indexes theft opportunities. An alternative explanation for the positive effect of per capita income is that greater average wealth is correlated positively with greater crime reporting due to higher insurance coverage (Pudney et al. 2000). For wildland arson, the relationship to per capita income is more difficult to explain, but it could be that greater per capita income, for a given retail wage rate, indexes a greater aggregate income inequality and hence greater rates of social injustice and use of arson as a means of retaliation by the relatively less powerful (Doolittle and Lightsey 1979). Alternatively, as suggested by one reviewer of this chapter, greater wealth in a location or in time might be linked to less prescribed fire, which is unmodeled in our regression but whose relationships are documented by Butry et al. (2002).

[6] Part of this difference is that, perhaps, successful wildland arson crimes are reported, because they are so visible. With other crimes, under-reporting is likely to be serious (Pudney et al. 2000).

expected from a crime dominated by youth (Grogger 1998). That is, potential young criminals are highly sensitive to labor market opportunities as a result of their marginal status in such markets. Another explanation for the stronger measured sensitivity of wildland arson is that wildland arson is a narrowly defined crime type, while other crimes (e.g., larceny) are actually collections of crimes of a wide range of differences. Statistically, the result can be that the effects of individual variables are attenuated by errors in variables bias (Greene 1990). As well, wildland arson (like motor vehicle theft) appears to show no deterrent effect from stiffer sentencing. Aside from this, our results for arson and other crimes parallel findings from Gould et al. (2002) regarding labor market conditions: criminal activity responds to both unemployment and wages.

In summary, (1) wildland arson responds in the same way to many of the same variables as other crimes, and (2) wildland arson appears more responsive than other crimes to these variables. It is with robbery that it apparently shares the most common statistically significant relationships with explanatory variables, although similarity was not statistically tested. Still, greater confidence in our results for these similarities and differences could be obtained from more spatially detailed analyses of these crimes—perhaps at the county level, and for other places—and we believe that this would be a fruitful topic for additional study.

Data have shown that wildland arson has trended downward in Florida since the early 1990s, and the research reported here has identified some of the apparent socioeconomic underpinnings to these trends. Greater certainty about why arson has trended downward in Florida, after accounting for socioeconomic variables, might require more detailed analyses. These analyses would control for fuels levels, which might have been altered through fuels management programs in the state. Are these reductions statewide a function of wildland changes, fuels management, or in fact explained by the arrests and convictions of key individuals? If most arson fires are serial or copycat, catching the serial arsonist or the first arsonist at the beginning of a potential copycat string would have a relatively large impact on arson rates. If there has been success in this arena in Florida, it could have been enabled by new policing tactics and technologies that aid in locating and catching criminals. The negative trends found for other crimes lend weight to this hypothesis, we believe.

7. CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The survey of research presented in the first five sections of this chapter show that wildland arson behaves in patterns of spatio-temporal clustering and exhibits temporal regularity on daily and intra-annual scales that are similar to patterns found for other kinds of crimes. Data presented on national forest arson rates and those for Florida show that long run trends in wildland arson are similar to long run crime trends, as well. The empirical research conducted for this chapter shows that wildland arson in Florida appears to have undergone long

run changes that can be explained by the same factors that explain such changes for other major crime categories but that it has responded more sensitively to these factors than have other crimes. Hence, wildland managers and law enforcement should expect this crime to respond strongly in the future to changes in the variables expected to affect other major crimes. In other words, after accounting for weather and fuels, managers and law enforcement should expect that rising (falling) rates of other crimes would correspond with (or even be predictive of) rising (falling) rates of wildland arson.

Given the available research and the empirical results of this chapter, we conclude that wildland management and law enforcement actions are not the only variables explaining wildland arson rates. Arson ignitions also are responsive to weather and climate, and labor market variables. Changes in law enforcement and labor markets can explain much of the underlying trends in observed arson. Taking the change in the retail wage rate only (holding other variables constant) as an example, using the parameter estimates shown in table 7.1, and assuming that the statistical relationships found reflect causality, if these wages in 2001 were at the (lower) level experienced in 1982, then wildland arson ignitions per capita would have been 93 percent higher in 2001 than they actually were. Similarly, if the unemployment rate in 2001 were at the same level as in 1982, ignitions per capita would have been 45 percent higher.

Labor market, law enforcement, weather and climate patterns, and other socioeconomic variables do not tell the whole story of the long run changes in wildland arson. Remaining negative trends in wildland arson (and other crimes), after accounting for those other factors, lead us to believe that other factors should also be credited with reduced rates of wildland arson in Florida, and potentially for wildland arson on national forests in aggregate in the United States. Possible among these are rising rates of fuels management, efforts to reduce volunteer firefighter arson rates through special programs, and rising arrest rates of key individuals. Again, if most arson fires are serial or copycat, then catching the serial arsonist or the first arsonist at the beginning of a potentially copycat string would have a potentially large impact on wildland arson rates. If true, perhaps the negative residual trend in wildland arson seen in Florida, at least, is due to improving policing tactics and technology.

Based on the existing research, it appears that there are several possible avenues of attack against the problem of wildland arson. These include: (1) catching arsonists early and often by identifying arson hotspots in space and time, moving police into hotspots and into areas with higher overall wildland arson rates during those hours of the day, days of the week, and months of the year when wildland arson is most likely; (2) increasing police aggregate levels, which could enhance deterrence and raise the arrest rate; (3) reducing hazardous fuels levels; (4) monitoring underlying socioeconomic drivers of wildland arson and the rates of other crimes, which can be used as predictors of wildland arson rates in advance of a coming fire season; (5) monitoring underlying weather and climate drivers affecting wildland arson success, which can sometimes

be predicted in advance; following Cabe (1996), (6) working with fire departments to reduce volunteer firefighter-set fires; and, for policy makers, (7) seeking means of expanding labor market opportunities in rural, fire prone areas. Based on our statistical analyses and the literature, changes in variables affecting wildland arson also should affect rates of other crimes, indicating complementarities and trade-offs among crime types and wildland arson. Incumbent upon wildland arson researchers is to demonstrate the effectiveness of each approach in the context of the larger picture of crime.

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