Justice Quarterly, 2017
Vol. 34, No. 6, 1044–1068, https://doi.org/10.1080/07418825.2016.1244286

Explaining Dosage Diffusion During Hot Spot Patrols: An Application of Optimal Foraging Theory to Police Officer Behavior

Evan T. Sorg , *Jennifer D. Wood*, *Elizabeth R. Groff* and *Jerry H. Ratcliffe*

Drawing from the concepts of optimal foraging theory, this paper presents and tests the assumptions of a foraging theory of police behavior during hot spots patrols. The theory explains why, over time, officers involved in hot spots policing interventions would leave the hot spots they are assigned to police and begin working within other locations. We test what factors influence the amounts of activity that officers undertake outside of their assigned hot spots and at nearby streets using data gathered as part of the Philadelphia Foot Patrol Experiment. Officers performed more activity outside of their beats as the experiment progressed. Several theoretically relevant variables predict the level of activity that officers perform outside their beats, including the size of the target area and the amounts of crime occurring within and outside of the target area. "Dosage diffusion" might be one reason why hot spot interventions have diminishing effects over

Evan T. Sorg is an Assistant Professor in the Department of Law and Justice Studies at Rowan University, an instructor and affiliated researcher in the Center for Security and Crime Science, Temple University, and a former New York City Police Officer. His research involves police innovation, evaluation and geographic criminology. Jennifer Wood is an Associate Professor in the Department of Criminal Justice at Temple University. She conducts research in the areas of policing and regulation. Her current work centers on the public health dimensions of police work, including pre-booking strategies for addressing the health needs of justice-involved people. She is the North American editor for *Policing and Society: An International Journal of Research and Policy*. Elizabeth R. Groff is an Associate Professor in the Department of Criminal Justice at Temple University where she is also associated faculty in the Center for Security and Crime Science and has a secondary appointment in the Department of Geography and Urban Studies. Her research interests are in the areas of geographic criminology, agent-based modeling, police practices and the use of technology in policing. Jerry Ratcliffe is a Professor of Criminal Justice at Temple University. His research examines police effectiveness in crime reduction, intelligence-led policing and spatial analysis of urban crime patterns. Correspondence to: Evan T. Sorg, Department of Law and Justice Studies, Rowan University, 201 Mullica Hill Road, Campbell Library, Glassboro, NJ 08028, USA. E-mail: sorg@rowan.edu

Routledge
Taylor & Francis Group

time. From an optimal foraging theory perspective, hot spots requiring police officers to constrain their actions to pre-defined areas can be perceived as counter-intuitive by the officers, especially over extended periods of time. The results of this study support the suggestion that hot spots patrols should be short-term and randomly rotated across hot spots.

Keywords dosage diffusion; hot spots policing; initial deterrence decay; crackdown decay; Philadelphia Foot Patrol Experiment

Introduction

Hot spots policing has a robust evidence base. The most recent meta-analysis of hot spots policing has suggested that it is an effective strategy that can generate crime and disorder reductions at high crime places (Braga, Papachristos, & Hureau, 2014). The return on this investment has its foundation in the "law of crime concentration," which states that "for a defined measure of crime at a specific micro-geographic unit, the concentration of crime will fall within a narrow range of bandwidths of percentages for a defined cumulative proportion of crime" (Weisburd, 2015, p. 138). Current estimates suggest that 50% of crime occurs at a very small percentage of street segments (between 2.1 and 6%) in an entire jurisdiction. It follows that if police focus on locations where the volume of crime is highest, they have a greater likelihood of reducing aggregate levels of crime (Mastrofski, Weisburd, & Braga, 2010).

Building on the base of evidence supporting hot spots policing, scholars have begun to ask more precise questions about hot spots deployments. For example, some studies have explored the optimal amount of time police should spend at hot spots in order to reduce crime most efficiently (Koper, 1995; Telep, Mitchell, & Weisburd, 2014). This question is important because some theoretical and empirical work has suggested that the deterrent effect of police patrol decays as the length of deployment increases (Koper, 1995; Sherman, 1990; Sorg, Haberman, Ratcliffe, & Groff, 2013). One possible explanation lies in Sherman's (1990) articulation of initial deterrence decay. Offenders may overestimate the potential of being caught at the onset of a police deployment yet reconsider the risk over time and thus resume offending. This has been used to explain the decaying deterrent effect of police operations previously (Koper, 1995; Sorg et al., 2013). From this perspective therefore, the deterrence decay problem is explained in reference to changing behaviors of offenders over the course of a hot spots operation.

In addition to explaining deterrence decay as a result of offender adaptation and decision-making, Sherman (1990) coined the term crackdown decay to refer to the implementation of a crackdown decaying over time. Sherman (1990, p. 10) refers to this as a "regression to the mean level of effort" by police themselves, through either a diversion of officers to other duties by administration or through a reduction in effort by officers over time. In this paper, we describe and test a complementary yet distinct perspective on the crackdown decay problem by focusing on the behaviors of police (as "treatment" providers) over a hot spots intervention period. In particular, we examine a mechanism that we refer to as *dosage diffusion*. Dosage diffusion explains deterrence decay in a way that is theoretically distinct from concepts like initial deterrence decay, which involve offender perceptions and decision-making. In contrast, our concept of dosage diffusion explains deterrence decay founded in officer decision-making about how to best respond to the criminal environment given organizational culture and expectations, institutional norms that have, until now, been largely overlooked in discussions of crackdown decay.

Dosage diffusion is the application of a policing treatment that informally extends beyond the areas where it was initially intended and designed. With this in mind, our study seeks to explain why, over time, officers leave their assigned hot spots to patrol at locations outside of the places they were assigned. If hot spot deployments rely on deterrence, then the absence of officers at hot spots over time lessens the crime prevention benefit they could potentially provide. Thus, understanding why dosage diffusion occurs could explain why some spatially-focused programs appear to fail as well as provide an avenue to increase the efficacy of other hot spot interventions.

Previous qualitative work has suggested that some police move outside of the boundaries of the hot spot areas that they were assigned to patrol for reasons such as, (1) boredom, (2) the perceived need to respond to crime displacement, and (3) a desire to increase their production of measurable activity such as arrests or *Terry* stops (Wood, Sorg, Ratcliffe, Groff, & Taylor, 2014). As a result, they patrol larger geographic areas and apply dosages of police activity to locations surrounding their assigned beats over time (Sorg, Wood, Groff, & Ratcliffe, 2014). These previous qualitative findings are suggestive of behavioral ecology's "optimal foraging theory" as a potential explanation for police behavior during hot spots patrols. We therefore test the assumptions of this theory using data gathered as part of the Philadelphia Foot Patrol Experiment (Ratcliffe, Taniguchi, Groff, & Wood, 2011). Along with a theoretical contribution to the literature on police activity and crime response, this study has implications for the design and organization of hot spots patrols—especially within strict experimental conditions—and the evaluation of officers that perform them.

Previous Research Exploring Deterrence Decay

Sherman (1990) was the first to introduce concepts that could explain why police deployments did not have lasting effects. Koper (1995) then systematically investigated just how long the deterrent effect of police patrols at hot spots lasted. Based on his systematic observations during the Minneapolis Hot Spot Experiment (Sherman & Weisburd, 1995), Koper (1995) estimated that police patrols were effective only up until a critical threshold of about 15 min.

After this time, the relative effectiveness of hot spot patrols declined. This is commonly referred to as the Koper curve. He used initial deterrence decay to explain this finding. In the context of the Minneapolis experiment, initial deterrence decay assumes that offenders overestimated the risk of apprehension when officers were first placed on hot spot posts. Over time, offenders may have realized that they overestimated this risk and began reoffending. Given his findings, Koper (1995) suggested that police patrols could be most efficient if officers intermittently visited hot spots on a random basis and stayed at the location for about 15 min before randomly visiting another hot spot. This "crackdown-back off" (Sherman, 1990, p. 12) pattern's benefit is that fewer personnel resources need to be used compared to a "security guard style presence" (Sherman & Weisburd, 1995, p. 634) where an officer or team of officers spend large amounts of time such as entire shifts at a single hot spot. Randomly visiting different hot spots would also avoid deterrence decay by introducing an element of surprise and conveying that police are omnipresent. The crime reduction benefit of rotating hot spot patrols that lasted about 15 min was subsequently confirmed in Sacramento, CA (Telep et al., 2014).

Sorg et al. (2013) investigated the long-term impact of foot patrols performed at hot spots during the Philadelphia Foot Patrol Experiment. Rather than focusing on a temporal unit of minutes as Koper (1995) did, Sorg et al. (2013) investigated the impact over a bi-weekly temporal unit. They found that the effects of hot spot patrols were diminishing during the course of the summer-long intervention at this larger temporal unit. In particular, beats that were staffed for longer periods of time (22 weeks) had a decaying deterrent effect while those staffed for shorter periods of time (12 weeks) did not. Here again, initial deterrence decay was used to explain the diminishing effect over time. However, qualitative work performed during and after the Philadelphia Foot Patrol Experiment raised another potential explanation for the decline in effectiveness—dosage diffusion.

Qualitative Insights Related to Research Questions

The design and results of the Philadelphia Foot Patrol Experiment have been extensively reported elsewhere (see Groff, Johnson, Ratcliffe, & Wood, 2013; Ratcliffe et al., 2011; Sorg et al., 2013, 2014). Very briefly, this randomized, controlled experiment tested the impacts of rookie police officers patrolling on foot at 60 hot spots, 24 for phase one and 36 for phase two, during two, eight hour tours for about a three month period in the summer of 2009. Results suggested a 23% reduction in violent crime relative to equivalent control sites. Displacement analyses revealed a slight amount of displacement. This displacement was less than the overall treatment effect. Structured field observations were performed during the experiment by trained graduate researchers who walked with each set of 60 officer pairs at least twice during the experimental period. In addition, post-experiment focus groups were conducted with the officers, during which time they were asked questions about their experience with foot patrolling. In total, 20 focus groups that lasted approximately 80 min were conducted, and at least one officer from 59 out of the 60 foot beat pairs attended a focus group (Wood, Taylor, Groff, & Ratcliffe, 2015). We rely on these qualitative insights to engage with the theory and develop specific hypotheses related to our research question.

Field work performed during the course of the experiment revealed that some officers lamented being constrained to such small foot beat boundaries (Wood et al., 2014), which averaged only about .3 square miles, 21 street segments and 1.3 miles of streets. It was also observed, and subsequently reported by officers themselves, that police were leaving the boundaries of their foot patrol beats and policing outside of them, despite the fact that they were instructed to stay within a pre-defined boundary (Sorg et al., 2014). In fact, the areas that officers actually patrolled during the Philadelphia Foot Patrol Experiment were, on average, .13 square miles larger than their originally delineated beats, contained 98 more street intersections and had 5.7 miles more miles of streets (ibid., 2014) At least in terms of geographic coverage, the Philadelphia Foot Patrol Experiment resulted in a degree of dosage diffusion.

Officers offered several justifications for their actions. First, officers believed that they were effective in deterring crime. However, their effectiveness brought about declines in criminal behavior which left them little to do within their beat boundaries and boredom set in. As a result, some officers reported patrolling larger geographic areas to break up the monotony of an uneventful eight hour shift. Second, although some officers believed their hard work deterred crime, others believed that it simply resulted in crime displacement. Some officers saw a need to respond to this displacement by chasing crime and criminals "around the corner." This game of "cat and mouse," (Wood et al., 2014, p. 370) as one officer put it, caused officers to ignore their spatial constraints and patrol outside of their boundaries. Finally, some officers were cognizant of the fact that their effectiveness as officers was gaged by the quantity of measurable official actions that they took. That is, the number of arrests that they made, the number of summonses that they issued and the number of individuals subjected to a *Terry* stop. Given the deterrence or displacement that the officers believed was occurring, some reported leaving their beats to increase their recorded activity. Perceived crime and disorder declines was seen by some officers as a bit of a conundrum. Although deterring crime is the objective of hot spots patrols, some officers were conscious that failing to generate recordable activity left the impression that they were not performing their duties, and it also conflicted with the "crime fighting" and "bandit catching" that police culture tends to value (Wood et al., 2014, p. 371).

Simply put, in the absence of criminal behavior that they could act upon and influence, officers' sense of productivity and effectiveness was diminished. The resultant pressure to seek out and identify criminal behavior—even if it was outside an officer's assigned beat area—is suggestive of potential links to behavioral ecology's optimal foraging theory (Stephens & Krebs, 1986). This theory seeks to explain and predict how animals go about selecting, obtaining and consuming food. Following a review of the theory's basic tenets, we set about to test its utility in explaining police behavior in the course of a hot spot initiative.

Optimal Foraging Theory

Optimal foraging theory was originally developed as an explanation for the survival behavior of foraging animals. One dimension of this behavior was their movements within and beyond their "patches" in search of prey. According to the theory, foragers make calculated decisions about how long they will stay within an individual patch to hunt. These decisions are based on the potential gains in terms of caloric intake versus energy expended in search of prey. Over time, this "gain function" will "depress" (Stephens & Krebs, 1986, p. 33) as the prey population is consumed or engaged in evasive actions given the presence of the forager in the patch. Once a patch reaches a certain level of depression, it is hypothesized that foragers will proceed to a more productive patch. Prey is considered a single item that a foraging predator consumes, while patches can be thought of as "clumps of food or simply heterogeneities in the prey distribution" (Stephens & Krebs, 1986, p. 13). In other words, prey are food items and patches are places where foragers search for these food items. Patch models derived within the theory seek to explain how long foragers will hunt within a patch before moving elsewhere.

Optimal foraging theory is not new to criminology. For example, Bernasco (2009) explained how many of optimal foraging theory's concepts can be related to offender decision-making when carrying out property crimes. Likewise, Johnson and Bowers (2004) explained residential burglary patterns by applying concepts from optimal foraging theory. To a limited extent, therefore, this theory has been applied analogously to the behavior of criminal offenders. Here, we explore the potential for optimal foraging theory to explain officer decision-making, thus further extending the theoretical perspective to criminology. Before outlining our theoretical concepts, we caution readers not to literally interpret our parallels with optimal foraging theory. We are, of course, not suggesting that police are like predators in search of criminals for prey.

Much like crime events, prey items are not randomly distributed across space. Rather, both tend to cluster at particular places. Prey cluster in patches, and crime clusters at hot spots. In this light, optimal foraging theory is tested here for its capacity to explain the behavior of police during hot spots interventions, with a focus on the question of why police leave their assigned hot spot beat to patrol elsewhere. We engage with optimal foraging theory's patch models to assist in developing hypotheses related to our research questions.

As noted above, optimal foraging theory suggests that once a patch reaches a certain level of depression, foragers will proceed to a more productive patch with greater availability of prey. To apply optimal foraging theory to police behavior, the extant quantitative and qualitative data suggest that officers' hot spots were depressing in terms of criminal activity over time. As a result, some officers reported patrolling in the streets that bordered their hot spots in order to generate official activity. Given this finding, we operationalize the geographies of the buffer zones that were adjacent to the hot spots as an "alternate patch" where police could patrol. In doing so, we are able to estimate whether patch attributes influence whether dosage diffusion will result. The buffer zones were created at the conclusion of the intervention and generally extended about two blocks outside of the targeted hot spots, though with some variation as is precedent in the literature (Ratcliffe & Breen, 2011).[1]

Hypotheses Drawn from Optimal Foraging Theory's Concepts

Foraging models involve three elements: currency assumptions, decision assumptions and constraint assumptions (Stephens & Krebs, 1986, p. 5). Currency assumptions involve two principles: "currency" and "choice". For a foraging lion, the currency might be zebras consumed per day, and for an anteater the currency might be ants consumed per minute. In other words, the currency involved in these models is the rate of energy gain. Choice principles are what the forager seeks to achieve by foraging, or whether its goal is energy maximization, energy minimization or energy stability. In conventional foraging models energy maximization is often the assumed choice principle. Maximization is assumed because greater amounts of energy produce a greater likelihood of survival, and it allows the forager to expend more energy on non-foraging related activities such as fighting, fleeing or reproducing (Stephens & Krebs, 1986, p. 8).

In our foraging theory of police behavior, we operationalize the currency as official police actions in a given time frame. For the purposes of our analysis, we assume maximization. Police do not literally require official actions to survive; however, the officers involved in our experiment reported that they were cognizant that their job performance was largely gaged by the amount of police activities that they recorded. Some officers reported that this was how their supervisors and peers assessed their work ethic. For example, Wood et al. (2014, p. 372) reported that some officers "… felt the only way to get recognized was to write tickets, make arrests etc." Wood et al. (2014, p. 372) also cited a researcher's field diary entry which stated that:

1. Although there were 60 hot spots, the close proximity of the hot spots required some buffer zones to be combined. In total, 55 buffer zones were drawn, as 10 beats shared a buffer zone with another beat.

> One officer seemed to be very insecure. He complained that the other officers think that they aren't doing anything (in terms of making arrests). [The] officer continued that it's difficult to make arrests because there's not a lot of activity on their beat.

In other words, officers are cognizant that they require recordable police activities such as arrests, summonses and recorded field interviews (including activity such as *Terry* stops) in order to avoid appearing as though they are shirking their crime fighting duties. Therefore, they will try to maximize this activity over time. This is likely especially true for rookie officers, who are often under pressure to make a name for themselves among their peers and supervisors (Barker, 1977). Thus, the rate of energy gain is roughly analogous to the increased credibility of officers from the activity that they generate. With our currency and choice defined, we now move on to form specific hypotheses based on optimal foraging theory's decision and constraint assumptions.

Decision Assumptions of Optimal Foraging Theory as Applied to Police Behavior

Stephens and Krebs (1986, p. 5) pose decision assumptions as a question: which of the foragers problems (or choices) are to be analyzed? For optimal foraging theorists, the answer to this question relates to the behavior the scientist seeks to explain. As noted, we engage with optimal foraging theory's patch models in attempting to explain why officers would leave their assigned hot spot and police elsewhere. Stephens and Krebs (1986) characterize patches as having a "gain function," where the expectation value of gain for patch *i* given t_i units of foraging time is E (Gain | $T = t_i$). In the same way, we might think of a hot spot as having a gain function with regard to recordable police activity, where E (Activity | $T = t_i$). For both a patch and a crime hot spot, higher gain functions would be associated with a lesser amount of time foraging or patrolling outside of the patch or hot spot, as foragers/officers have no need to expend the energy required to travel elsewhere to forage.

However, if the areas surrounding a hot spot offer a greater rate of gain, we might expect officers to patrol at these locations more often, as they may be seen as more productive grounds. Stephens and Krebs (1986, p. 91) explain that foragers might leave a full or partially full patch for patch "sampling and assessment," or to investigate whether a nearby patch is a superior foraging ground. Here, officers might begin leaving their hot spots in order to assess whether the nearby areas are good places to generate activity. If officers discover that this is the case, we would expect them to spend more time performing official duties in the buffer zone. With these points in mind, we can hypothesize the following:

H_1: Foot beats with higher levels of crime will have more opportunities to generate activity, and the officers will leave their beats and perform activity in the buffer zone less frequently and at a slower rate.

H_2: Officers will perform more activities within the buffer zone more frequently if it has a high level of crime, as this may be seen as an optimal activity-generating ground. This relationship will hold even after controlling for activity availability within the buffer zone.

These models assume that the forager searches for prey in a patch and as it consumes prey, there are fewer preys remaining. As there are fewer preys in the patch, the gain function declines. As prey is consumed, patches approach depression, or there is a decline in the rate of energy gained within a patch (Charnov, 1976). Depression might occur in two ways. As the predator consumes prey, the number of prey available is reduced, the potential to encounter prey is reduced and the gain function will depress due to this decline in prey availability. Depression might also occur because prey become aware of the forager and subsequently take evasive actions in order to avoid said forager, for example, through leaving the patch. Therefore, there may not be a significant decline in prey, yet the predator may have fewer encounters to exploit due to evasive actions by prey, which will cause the gain function to depress. Once the gain function of a patch depresses to a certain point, it is expected that the forager will move to another patch to forage.

So how does this relate to police? Just as prey availability might decrease for a predator over time, criminal behavior within patrolled hot spots might also decline. As noted, many of the officers involved in the Philadelphia experiment commented that a reduction in crime and disorder was evident, making it harder for them to detect criminal behavior. This was confirmed quantitatively. In addition, field observations revealed that many of the officers believed that criminals took evasive action to avoid having their criminal behaviors detected by the police. For example, some officers commented that criminals displaced both spatially and temporally. The crime numbers game (Eterno & Silverman, 2012), however, still requires police to generate activity in order to demonstrate that they are performing their duties in the same way that animals still require food to survive. Therefore, as recordable police activity within the foot beat declines, we hypothesize that police will move out of their beats and conduct a greater amount of activity within another patch, here the buffer zone. If criminals are taking evasive actions, including moving to locations outside of the officers' beats (i.e. spatial displacement), we hypothesize that the officers perform more activity outside the foot beat. With this, we can form two more hypotheses:

H_3: Officers who perform greater amounts of activity within their assigned foot beat will undertake fewer activities outside of their beat and inside the buffer zone because they are generating the activity that they require.

H_4: Due to crime depression and evasive action by offenders, officers will perform more activity in the adjacent buffer zone over the course of the experiment. Officers working lower crime beats will forage in the buffer zones sooner since their beats will depress sooner.

Constraint Assumptions of Optimal Foraging Theory as Applied to Police Behavior

In foraging theory, constraints are defined as "all factors that limit and define the relationship between the currency and the decision variables" (Stephens & Krebs, 1986, p. 10). Constraints can be either intrinsic to the forager, such as foraging ability, or extrinsic and placed on the forager by the environment. We focus on extrinsic constraints, as confidentiality requirements did not allow for the collection of information about the individual officers. The environments within which the officers worked naturally limited the extent of activity that they were capable of undertaking. This relates to the amount of crime in the beat, as noted in hypothesis H_1, but also to how conducive to criminality their beats and the surrounding buffer zones were. Because crime and offenders concentrate near certain criminogenic facilities (McCord & Ratcliffe, 2007), these would likely offer more opportunities to generate activity and could represent places where patrolling for activity could be carried out efficiently. We might expect patches containing these facilities to be foraged in more often and, likewise, buffer zones containing these facilities to be foraged in more often. This might also include nodes that draw large numbers of people for both legitimate and illegitimate purpose, such as commercial locations.

Finally, the number of street segments in the foot beat and the buffer zone will naturally impact the amount of activity that can be undertaken. Officers working in beats with fewer street segments are more likely to influence the actions of offenders because their presence will be more concentrated. Likewise, with fewer places to patrol, officers might perceive their beats as depressing at a faster rate. With this in mind, we present our final hypotheses:

H_5: There will be less activity within the adjacent buffer zone if there are criminogenic facilities within the foot beat

H_6: There will be more activity within a buffer zone if it contains criminogenic facilities

H_7: Officers will undertake activity in the buffer zone more often if there are large amounts of commercial areas in the adjacent buffer zone, and leave less often if there are more commercial land uses in their beats.

> H_8: Officers working on smaller foot beats will generate more activity in the buffer zone more often. These officers will forage in the adjacent buffer zone sooner.

In sum, the proposed theoretical model makes the following predictions: (1) Over time, the amount of police activity within the buffer zones will increase, but more quickly or slowly depending upon the level of crime in the beat and buffer zone, (2) the greater the amount of crime occurring within the buffer zones, the more activity the officers will undertake within them, even after controlling for differential foraging opportunities, (3) officers assigned to higher crime beats will perform fewer activities in the buffer zones, (4) if there are criminogenic facilities within the buffer zones or a higher percentage of commercial land use, the officers will undertake more activity within them and, (5) beats with criminogenic facilities and larger percentages of commercial land use will have less activity being undertaken within the buffer zones.

Data and Methods

In order to test these hypotheses, we use a geographic information system (GIS) to assign our data to "patches" and longitudinal multilevel models to examine how the effort expended by police officers in the buffer zones of their beats changes with the characteristics of the target beat, the characteristics of the buffer zone and over time.

Outcome Variable

We use a database of police activity supplied by the Philadelphia Police Department to explore our theory. The database contains all records of activity that Philadelphia police officers documented in 2009. Officer activity includes all instances an officer performs an official action, for example a field interview or completes a crime report. When performing an action the officer notifies radio dispatch of the nature and location of said action, and the dispatcher subsequently records this information digitally. Our outcome variable is the number of police-initiated activities undertaken within the buffer zones aggregated to seven experimental time blocks. To identify proactive police activity performed by the officers involved in the experiment within the buffer zones, we followed a multi-step process. Since each pair of officers was assigned a call sign, a unique identifier that is used to identify a particular pair, we first extracted all incidents that were assigned to foot patrol officer call signs from the database. The incident locations were supplied by the PPD as geocoded files. These locations were then overlaid on the buffer zones that were used to measure displacement and those falling within the boundaries were extracted. We then selected out proactive activities which included officer-initiated pedestrian stops related to disorder crimes,[2] drug violations including suspected dealing, selling and possession, and traffic stops for various infractions of the motor vehicle code. The end result is a count of proactive actions taken by foot patrol officers in the buffer zones.[3]

These counts were then combined and aggregated to seven time blocks. Recall the experiment was implemented in two phases. Phase one was deployed on 31 March 2009 and concluded on 31 August 2009 and phase two was deployed on 7 July 2009 and concluded on 28 September 2009, for 154 and 84 days respectively. Since the beats were operating over different time periods, we were required to aggregate days into a common time metric. We first calculated the greatest common divisor, which returned a value of 14. However, because 14 time blocks made each time block for the phase two beats consist of only 6 days, the counts of activities within the buffer zones was very low and consisted of numerous zero values. We therefore aggregate activity in the buffer zones to the next greatest common divisor of 7.

Models

The dependent variable in our models is the number of self-initiated activities that the foot beat officers performed in the buffer zones over the course of the Philadelphia Foot Patrol Experiment. Given the nested structure of these data series (changes in activity numbers over time at level one nested within buffer zones at level two) longitudinal multi-level models were estimated (Raudenbush & Bryk, 2002). This method is also appropriate given our interest in variation in the trajectory of growth of the outcome, changes in levels of activity conducted outside the foot beat, and the ability to estimate cross-level interactions to explore what factors influence the levels of activity conducted outside the beat over time by entering predictors of intercepts and

2. Disorder stops include being stopped for prostitution, public drunkenness, loitering, and the violation of city ordinances such as carrying an open container or public urination. We excluded activities and arrests related to other offenses because these activities are likely to be a combination of reactive response to 911 calls and proactive policing. Since we are only interested in the extent to which officers were foraging for activity, we only include activities that are proactive and police initiated. As Ratcliffe et al. (2011:813) note, the activities we include in our outcome measure "are largely left to police to initiate, especially in higher crime areas." This was also observed during field observations. Since the PPD generates a separate record if a pedestrian stop results in an arrest (one for the pedestrian stop and one for the arrest), there was no need to include arrests in our figure because this would have in effect double counted the incident if an arrest was made. Although the officers were on foot, our field observations suggested that officers were performing vehicle stops by standing on the corner and waving cars over if vehicle infractions was observed.

3. We recognize that by excluding activities undertaken outside of the buffer zones we are missing some activities that the officers conducted. However, in order to calculate variables for patch attributes, a closed geographic boundary is required. We are therefore modeling only one patch that officers could have chosen to forage in (the buffer zone). Drawing standardized boundaries for other patches outside of the buffer zone was not possible.

slopes at level two. Each model is estimated as an overdispersed Poisson model with an exposure variable of number of days per time block. All variables are centered around the grand mean.

Level one

At level one the characteristics used in the model are time-varying covariates. A linear and quadratic time variable is entered to account for the linear (1—7) and non-linear (1—49) progression of time over the seven time blocks.

Level two

In order to test the proposed model, level two consists of several theoretically relevant variables. We first enter two variables with counts of crime, one consisting of crimes that occurred within the buffer zones and one of crimes that occurred in the foot beats during the experimental period. Our crime measure consists of the following crime classifications: homicide, robbery, aggravated assault, burglary, rape and violation of the uniform firearms act. We chose these most serious categories of crime because the police department stresses tackling these types of incident during supervisors' roll call, and therefore the locations of these incidents are more likely to influence their decisions to police at specific places. These data were extracted from the Philadelphia Police Department's 2009 incident database, which contains all records of crime occurring within the City of Philadelphia. These data are geocoded by the Philadelphia Police Department's automated system at a rate in excess of 98%, making them appropriate for geographic analysis (Ratcliffe, 2004). Using a GIS, we assigned each crime to the beat or buffer zone in which it occurred.

We also include a variable consisting of the count of activities undertaken at each foot patrol location during the experimental period. These data were extracted from the same database using the same method as the outcome variable. Unlike the outcome variable, we include all activities that the officers undertook in this variable, regardless of whether the activity was proactive or reactive, it is still an activity that the officer can attribute to their record.

We include two separate count variables for beats and buffer zones which contained criminogenic facilities. These geographic data were supplied by the PPD crime analysis unit in the form of individual shapefiles for each type. Facilities included in this variable are those which have been previously found to be correlated with crime: bars and beer establishments (Roncek & Maier, 1991), subway stations (Block & Block, 2000), check cashing businesses (McCord & Ratcliffe, 2007), drug treatment locations (Taniguchi & Salvatore, 2012), halfway houses (Rengert, Ratcliffe, & Chakravorty, 2005), homeless shelters (McCord & Ratcliffe, 2007), pawn shops (McCord & Ratcliffe, 2007),

Table 1 Descriptive statistics

Variable	Sum	Mean	SD	Min.	Max.
Activity in buffer	1,582.00	26.37	21.53	.00	107.00
Activity in beat	6,928.00	115.47	92.12	6.00	417.00
Crime in buffer	1,233.00	20.55	10.05	4.00	48.00
Crime in beat	703.00	11.72	8.66	1.00	37.00
Pre-intervention crime in buffer	577.00	9.62	5.09	2.00	27.00
Beat street segments	1,279.00	21.32	8.62	6.00	48.00
Buffer street segments	4,315.00	71.92	28.23	24.00	146.00
Beat criminogenic facility	108.00	1.80	1.22	.00	5.00
Buffer criminogenic facility	206.00	3.43	2.84	.00	13.00
Beat % commercial land use	–	16.38	11.82	1.62	48.63
Buffer % commercial land use	–	11.71	10.10	1.73	36.23

parks (Groff & McCord, 2011) and public housing communities (Haberman, Groff, & Taylor, 2013). We also used areal weighting to calculate the percentage of commercial land use contained in each buffer zone and foot beat, and include these as two separate variables in our analysis.

To control for differences in the size of the foot beats and the buffer zones, the number of street segments each contained is entered. To control for the opportunity to generate activity within the buffer zone, the pre-intervention counts of crime occurring in the buffer zone during the 3 months before the experiment are entered at level two. These include the same categories of crime as noted in the crime measure above. Descriptive statistics appear for all variables appear in Table 1.

Results

Following the suggestions of Raudenbush and Bryk (2002)a series of models were run. The first unconditional model where no variables are entered and where only exposure is controlled confirmed statistically significant variation in the number of activities performed by officers across the beats ($p < .001$). The next analysis of covariance (ANCOVA) model controlling for exposure, time, and quadratic time at level one, and the independent variables at level two confirmed that these across-beat differences remained significant. Here the slope of time is treated as fixed, and variables at level two are used to predict the intercept. Results appear on the left side of Table 2. Consistent with the theoretical model, the amounts of activity within the buffer zones was following an accelerated linear trend, with each passing time period resulting in approximately 46.5% more activity being conducted within the buffer zone.

Several of the level two variables reach statistical significance and conform to the outlined theoretical model. For each additional crime that occurred

Table 2 Multilevel model results

	Fixed effects ANCOVA			Full model		
Fixed-effects	ERR	(SE)	*t*-ratio	ERR	(SE)	*t*-ratio
Level-one						
Time	1.465	(.058)	6.621**	1.460	(.057)	6.623**
Time^2	.941	(.009)	−6.670**	.940	(.009)	−6.850**
Level-two						
Activity in beat	1.002	(.002)	.952	1.002	(.002)	1.030
Crime in buffer	1.040	(.010)	3.818**	1.041	(.010)	3.895**
Crime in beat	.977	(.011)	−2.204*	.976	(.010)	−2.463*
Pre-treatment buffer crime	1.016	(.026)	.632	1.017	(.026)	.640
Beat street segments	.990	(.004)	−2.256*	.990	(.004)	−2.333*
Buffer street segments	1.037	(.012)	2.998**	1.037	(.012)	3.082**
Beat criminogenic facility	.929	(.070)	−1.058	.929	(.069)	−1.070
Buffer criminogenic facility	.984	(.057)	−.269	.985	(.057)	−.262
Buffer % commercial	1.021	(.011)	1.889	1.021	(.011)	1.867
Beat % commercial	.987	(.010)	−1.214	.988	(.010)	−1.203
Predicting time slope						
Crime in buffer	–	–	–	.999	(.002)	−.203
Crime in beat	–	–	–	1.007	(.003)	3.082*
Beat street segments	–	–	–	.996	(.002)	−2.271*
Buffer street segments	–	–	–	1.001	(.001)	.775
Random effects	χ^2	Variance	df	χ^2	Variance	df
Intercept	623.564**	.637	49	670.344**	.653	49
Time (Slope)	–	–	–	68.828	.006	55

Notes. Models specified as Poisson distributions with overdispersion. Outcome variable is proactive activities conducted in the buffer zones. Exposure variable is days per time block.
Abbreviations: ERR = Event rate ratio; SE = Standard error; df = degrees of freedom; χ^2 = Chi-square; ANCOVA = Analysis of covariance.
*$p < .05$; **$p < .01$.

within the buffer zone, a 4.0% increase in activity within the buffer zone is expected, even after controlling for differences in activity availability with the pre-treatment crime count variable at level two ($p < .001$). Likewise, with every one crime increase in the foot beat during the experimental period, a 2.3% decrease in activity in the buffer zone is expected. In addition, officers patrolling in smaller beats performed more activity within the buffer zone, with each additional street segment the beat had being associated with about 1.0% less activity being performed in the buffer zone.

As hypothesized, larger buffer zones had more activities performed within them; with each one unit increase in the number of street segments within the buffer zone, about a 3.7% more activity is expected. Criminogenic facilities within the beats and buffer zones did not predict variation in activity within the buffer zones after controlling for all variables in the model, nor did the proportions of commercial land use in the beat or buffer zone.

In the final intercepts-and-slopes-as-outcomes full model, the statistically significant level two variables are used to predict the intercept and the freed (varying) slope of linear time. As a first step, the slopes of time and quadratic time were freed to vary across the foot beats. The quadratic time variable did not have statistically significant random effects, and it is therefore treated as fixed and not predicted. The slope of linear time was found to have statistically significant random effects, and was therefore allowed to vary across the buffer zones and was predicted by the statistically significant level two variables. Results are reported in the second half of Table 2.

Two variables predict statistically significant variation in the effect of time on the extent of activity undertaken in the buffer zones. There was a positive association ($\beta = .008$; $p < .01$) with performing activity in the buffer zone and the amounts of crime that occurred within the foot beat. In other words, the positive slope of time is steeper for higher crime foot beats, indicating the officers are performing greater amounts of activity in the buffer zones as time progresses. This relationship is shown in the model graph appearing in Figure 1.

This figure depicts the slopes of time over the time series grouped by the averaged upper and lower quartile foot beats in terms of the levels of crime in the foot beat after estimating, and therefore controlling for everything in, the full model. Officers working in lower quartile foot beats began foraging for activity in the buffer zones early on in the time series and continued to follow

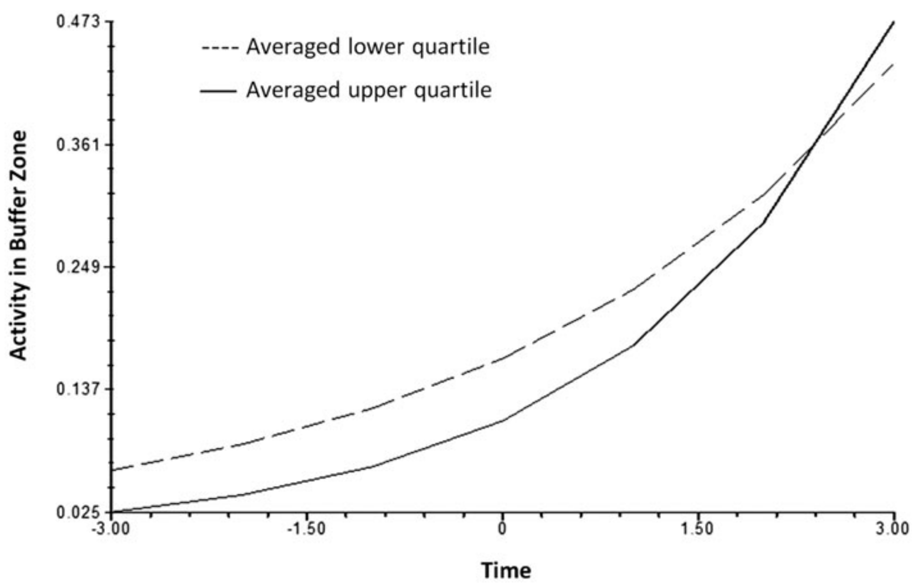

Figure 1 Model graph of averaged upper and lower quartile beats by level of crime.

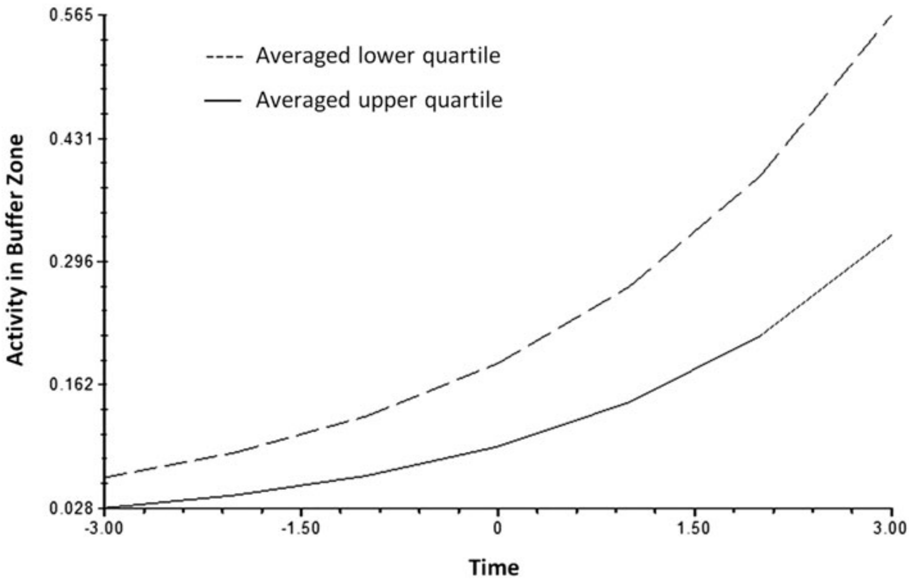

Figure 2 Model graph of averaged upper and lower quartile beats by number of street segments in beat.

an upward linear trend throughout the experiment. Officers working in upper quartile beats began performing activity in the buffer zones later in the time series, yet towards the end of the experimental period there is a marked increase in the extent to which they were performing activities outside of their beats. This suggests that the majority of foraging inside the buffer zones for higher crime beats was done towards the end of the experimental period, and also offers an explanation for the positive coefficient.

In contrast, there was a negative association between performing activity in the buffer zone and larger foot beats ($\beta = -.003$; $p < .05$). Put another way, the effect of time progressing on performing activity in the buffer zone was strongest for beats that were smaller. This relationship is depicted in the model graph appearing in Figure 2. This figure illustrates the slope of time averaged by the upper and lower quartile foot beats in terms of the number of street segments. For beats in the upper quartile, it takes a greater amount of time for officers to undertake activity in the buffer zone, and for the entirety of the experiment they undertake much less activity within the buffer zones as compared to the lower quartile beats. Beats within the lower quartile of street segments begin conducting activity in the buffer zones early on, and the slope steepens over the course of the experiment.

Limitations

Before moving on, the limitations of this study deserve discussion. First, using officer activity to gage the extent of policing in the buffer zones does not account for the actual amount of time these locations were policed. It may be that some officers spent time policing the buffer zones yet did not take official actions. Unfortunately, we have no way to know whether this was the case. Furthermore, the fact that the officers were rookies might attenuate our results, as they may have been especially motivated to generate activity to appear to be "good cops." Different results may have arisen if the officers involved in the experiment were veteran officers. Of course, issues of external validity are "always an empirical matter" (Taylor, 1994, p. 164) and "a study done with typical participants … in a typical situation … may have less external validity than a study with atypical participants … and in non-typical situations" (Taylor, 1994, pp. 164, 165). Future work will have to explore whether the uniqueness of rookie officers could have influenced our results, and how the foraging patterns of more seasoned officers may have impacted our findings.

Discussion

This study examined officer foraging behavior in response to hot spot patrol assignments that were static over time. We found support for all but two of our hypotheses. In this section, we discuss the theoretical and policy implications of the findings.

Theory

Our statistical models were informed by concepts of optimal foraging theory and developed to predict what would cause dosage diffusion during hot spots patrols. How did these predictions fare? We did find that, overall, officers were foraging for more activity in the buffer zone as time progressed, suggesting that as hot spots began to reach some level of perceived depression (i.e. it was difficult to produce quantifiable evidence that officers were actively working), officers moved to the buffer zones to find disorderly and illegal activity. H_1 predicted that officers working in higher crime beats would perform less activity in the buffer zone and the transition to patrolling more in the buffer zones would take place more slowly. We found support for this hypothesis in our analysis. The amount of crime that occurred in the foot beat during the experiment was associated with fewer activities undertaken in the buffer zone. We also found that officers in these higher crime beats progressively performed more activities in the buffer zone towards the end of the time series. In sum, higher amounts of crime were associated with officers foraging less in the buffer zones overall, yet as time went on, and perhaps as their hot spots reached depression, there was a marked uptick in the extent to which officers left their beats to generate activity. The slope of time steepens dramatically at the end of the time series for the higher crime beats, suggesting that patch depression took longer, yet once these beats did depress, there was a great deal of foraging/patrolling in the buffer zones.

H_2 predicted that police would perform more activities within the buffer zone if it had a high level of crime. We also find support for this hypothesis. Even controlling for the level of crime three months prior to the experiment, therefore holding constant the opportunity to generate activity, officers performed greater amounts of activity in the buffer zones if they were more violent during the experimental period. This suggests that officers may have tried to maximize their recordable activity by foraging in particularly violent locations more often. However, we do not find that there is a temporal component to this relationship, as there was no significant interaction when this variable was used to predict the slope of time. Although officers foraged in more violent buffer zones overall, the level of crime in the buffer zone does not appear to have influenced the trajectory of the slope of time in any meaningful fashion.

We did not find support for H_3, as the total number of activities undertaken in the beat during the experimental period was not a significant predictor of the extent of activities undertaken within the buffer zone. We initially hypothesized that officers who perform greater amounts of activity within their assigned foot beat will undertake fewer activities outside of their beat and inside the buffer zone because they are generating the activity that they require. However, it may be that we overlooked the importance of choice principles when laying out our hypotheses. We assumed a priori that police would attempt to maximize recordable activity. This might explain this insignificant finding. If officers are truly trying to maximize the amounts of activity they accumulate, then it may be that regardless of what they have already accumulated, they will continue to forage vigorously in order to maximize their recordable activity. With maximization assumed, it may be that the level of activity already accumulated has little impact on how vigorously police will forage for more activity, be it within the beat or in the buffer zone.

With regard to our predictions about land use and criminogenic facilities in the beats and the buffer zones, we do not find support for these hypotheses. After controlling for crime within the foot beat and buffer zones, the percent of commercial land use and criminogenic facilities were not associated with more or less foraging. It may be that for police, levels of crime are more influential in deciding where to police rather than attributes of the locations. However, we also assume in our analysis that all of these facilities and commercial spaces were equally criminogenic. Although prior research has demonstrated that these facilities and land uses, on average, generate and attract crime, not all of these places are likely to be equally criminogenic. It may be that limited knowledge of these facilities and commercial areas both from the researchers and the officers, aside from their locations, disallows us from distinguishing how truly criminogenic these locations are, which may be impacting our results.

Finally, the number of streets in the areas that the officers were assigned to police was a significant predictor of the level of foraging within the buffer zone. Officers who worked in beats with fewer street segments not only performed greater amounts of activity within the buffer zones, but also began to do so with greater frequency early on and over the course of the experiment. As we theorized, it seems likely that these beats would depress sooner and result in a greater amount of activity being conducted in the buffer zone over time and overall.

In sum, many of the concepts of optimal foraging theory appear to be relevant in predicting police officer behavior over the course of this particular hot spot policing intervention. We should stress, however, that these results should be interpreted strictly in the context of a hot spot intervention explicitly designed to deter and disrupt criminal behavior in violent areas. Put another way, it could be that this particular initiative may have fostered the organizational and cultural conditions for foraging behavior. The question of whether a different type of place-based police intervention would manifest in similar patterns of police behavior—such as a community policing initiative focused on enhancing citizen experiences of procedural justice—is yet unknown. Future (and previously conducted) experiments may offer opportunities to explore these questions. In addition, we should note that two questions related to dosage diffusion that we were unable to model deserve investigation.

Designing and Evaluating Hot Spots Patrols

Given the heterogeneity in how hot spots patrols have been implemented, it is difficult to precisely define the optimal dosage (i.e. time) officers should dedicate at hot spots. For example, is a fixed presence or intermittent patrol more effective? Will 15 min have the same effect as 8 hours? A number of deployment schemes enjoy some support within the literature. Recent work suggests that officers patrolling across various hot spots, for only 15 min at a time, were effective in reducing crime relative to control locations in a randomized trial in Sacramento, California (Telep et al., 2014). This method of deployment was first advocated by Sherman (1990), and later supported by Koper's (1995) observations during the Minneapolis Preventative Patrol Experiment. Koper (1995) suggested that around 15 min was the optimal amount of time to patrol, and any additional time patrolling had diminishing returns due to initial deterrence decay. Sorg et al. (2013) also found that benefits during the foot patrol experiment were declining in locations as the length of the deployment increased. These results suggest that an additional reason why program benefits might decay over the course of an intervention is dosage diffusion (i.e. the patrolling of police outside of target areas as crime and disorder decrease). We believe that our work adds to the growing evidence-base that suggests that short, intermittent police patrols in hot spots, such as those employed in Sacramento, may be the most effective and efficient type of deployment.

With officers off their beats more often over time, this could also be a contributor to the declining deterrent effect found during the Philadelphia Foot Patrol Experiment. Collectively, the work of Sorg et al. (2013), Telep et al.

(2014), Koper (1995) and Sherman (1990), suggests that shorter deployments at hot spots, perhaps rotated across various hot spots, may be the most efficient use of police resources. If offenders adapt quickly, and if police are likely to contest the boundaries of their patrol areas over time, patrolling fixed locations for long periods of time may not be the most efficient use of police resources. Future work might consider replicating the Telep et al. (2014) study to test the crime reduction benefits of short, random and intermittent patrols before firm conclusions with regard to deployment time can be made. A strong confirmation of Telep et al. (2014) results would involve a direct comparison of officers patrolling at hot spots for varying lengths of time. Nevertheless, our findings suggest that dosage diffusion is another reason why long, fixed police deployments at hot spots may not be optimal.

Evaluations of place-based interventions can be challenging. Social scientists must work in the laboratories of cities, which are dynamic environments rather than controlled labs, and these interventions involve actors (police) who face a number of pressures, both internal and external, which affect their actions and decisions. One particular pressure that officers reported feeling was that of the police numbers game, or the perceived or actual need to produce quantifiable activity. Although we found no evidence that police commanders imposed quotas on officers during the experiment, which has been alleged in other departments (Eterno & Silverman, 2012), the officers did implicitly feel a need to generate activity. This raises questions about how officers participating in hot spots interventions should be evaluated. Should officers be judged by the number of arrests they make, the number of pedestrian stops that they conduct, or the number of summonses that they issue? Or should they be judged on the "ends"—crime and problem reduction or prevention—rather than the "means" by which they are achieved (Goldstein, 1979)?

The central premise of problem-oriented policing, for example, is that if the police solve problems contributing to crime rather than respond to incidents, make arrests or perform increased numbers of pedestrian stops. Although the glorification of the "crime fighter" that is steeped in police culture encourages the generation of activity and making arrests, police leaders would be wise to use additional measures in gaging the quality of police officers (Brady, 1996). At the very least, it must be recognized that the goals of hot spots patrols (crime prevention) may not align with the values inherent in police culture (crime fighting), and that this tension must be addressed organizationally prior to the initiation of hot spot deployments.

The implications of these tensions are not trivial. As we have argued elsewhere (Sorg et al., 2014), officer boundary adherence during experimental evaluations is a critical yet oftentimes overlooked aspect of dosage measurement. Officer foraging outside their assigned beats, and potentially inside buffer zones and control areas, could negatively impact the accuracy with which direct treatment effects, crime displacement, and the diffusion of crime control benefits is measured. Along with our previous work, this analysis further supports Rosenbaum's (2006) claim that at least some of the diffusion of crime of crime control benefits that have been uncovered could be due to boundary misspecification. Future place-based policing evaluations should consider this possibility and develop plans to mitigate dosage diffusion and appropriately measure it. For example, related to officers' perceived need to respond to crime displacement, steps to mitigate dosage diffusion might include presenting officers with research evidence suggesting that displacement is not a definite outcome of place-based interventions and theoretical concepts related to why not.

We recognize one organizational constraint that conceptually differentiates patrol officers from foraging animals. Within the constrictions of geographical limitations (mountain ranges, wide rivers and so on), animals are able to freely forage in any area. While this is clearly a distinction between the officers and the targets of the original optimal foraging theory, there are also circumstances where animals do not stray into neighboring territory if that territory is controlled by a dominant animal of the same species; yet, the distinction remains. In the Philadelphia Foot Patrol Experiment, the officers were ordered to remain in their beat, though field notes suggest that some captains (in their initial instructions) allowed their officers to stray from their beats. This instruction to remain in one location rather than freely forage is a constraint not necessarily placed on wildlife—even though as a constraint it was contested by officers, especially as time unfolded. In practice, a few officers obeyed their orders to some degree, while most initially followed their instruction but then sought more productive working areas, and others strayed relatively quickly. But we recognize this conceptual difference between the application of optimal foraging theory to animals and police officers, what at the same time drawing valuable lessons from the broad application of the principle.

As a final note, these findings have larger implications for the process of designing experimental police interventions like hot spots patrols. Conventionally, line officers have little input into their role as "treatment providers" (Wood et al., 2014) even though their behavior over the course of an experiment is essential to implementation fidelity. Based on field observation data, we have previously argued that the input of line officers into the design of experiments could help to anticipate and mitigate officer non-compliance with treatment conditions, especially boundary adherence (Sorg et al., 2014; Wood et al., 2014). From a foraging perspective, it may well be critical for police leaders and researchers to strategically harness the local or "patch knowledge" of officers as experiments unfold, as patch conditions change, and as police behavior alters.

Acknowledgements

We would like to thank reviewer number three for raising these points. Future research might address whether the acceleration of officer conducted activity

outside of their beats linked directly to the decreases in crime within targeted beats over time. Another important question for theory and practice would be whether officer movement outside of their assigned beats linked to a decay in the crime reduction benefits that our previous work had uncovered (Sorg et al., 2013). Although we attempted to model these relationships in our analysis, the HLM model reliability estimates dropped below the .05 threshold suggested by Raudenbush and Bryk (2002). Notwithstanding, the support for our foraging theory of police behavior has implications for how hot spots policing in particular is designed, organized and evaluated.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by Robert Wood Johnson Foundation Center for Health Policy.

ORCID

Evan T. Sorg http://orcid.org/0000-0001-7877-3933
Elizabeth R. Groff http://orcid.org/0000-0001-7745-0198
Jerry H. Ratcliffe http://orcid.org/0000-0002-0730-6761

References

Barker, T. (1977). Peer group support for police occupational deviance. *Criminology, 15*, 353-366.

Bernasco, W. (2009). Foraging strategies of homo criminalis: Lessons from behavioral ecology. *Crime Patterns and Analysis, 2*, 5-16.

Block, R. L., & Block, C. B. (2000). The Bronx and Chicago: Street robbery in the environs of rapid transit stations. In V. Goldsmith, P. McGuire, J. Mellkopf, & T. Ross (Eds.), *Analyzing crime patterns: Frontiers of practice* (pp. 121-135). Thousand Oaks, CA: Sage.

Brady, T. V. (1996). *Measuring what matters: Part one: Measures of crime, fear and disorder*. Washington, DC: US Department of Justice, Office of Justice Programs, National Institute of Justice.

Braga, A. A., Papachristos, A. V., & Hureau, D. M. (2014). The effects of hot spots policing on crime: An updated systematic review and meta-analysis. *Justice Quarterly, 31*, 633-663.

Charnov, E. L. (1976). Optimal foraging, the marginal value theorem. *Theoretical Population Biology, 9*, 129-136.

Eterno, J. A., & Silverman, E. B. (2012). *The crime numbers game: Management by manipulation*. Boca Raton, FL: CRC Press.

Goldstein, H. (1979). Improving policing: A problem-oriented approach. *Crime and Delinquency, 25*, 236-258.

Groff, E. R., Johnson, L., Ratcliffe, J. H., & Wood, J. W. (2013). Exploring the relationship between foot and car patrol in violent crime areas. *Policing: An International Journal of Police Strategies & Management, 36*, 119-139.

Groff, E. R., & McCord, E. S. (2011). The role of neighborhood parks as crime generators. *Security Journal, 25*(1), 1-24.

Haberman, C. P., Groff, E. R., & Taylor, R. B. (2013). The variable impacts of public housing community proximity on nearby street robberies. *Journal of Research in Crime and Delinquency, 50*, 163-188.

Johnson, S. D., & Bowers, K. J. (2004). The stability of space-time clusters of burglary. *British Journal of Criminology, 44*, 55-65.

Koper, C. S. (1995). Just enough police presence: Reducing crime and disorderly behavior by optimizing patrol time in crime hot spots. *Justice Quarterly, 12*, 649-672.

Mastrofski, S. D., Weisburd, D., & Braga, A. A. (2010). Rethinking policing: The policy implications of hot spots of crime. In N. A. Frost, J. D. Freilich, & T. R. Clear (Eds.), *Contemporary Issues in Criminal Justice Policy* (pp. 251-264). Belmont, CA: Wadsworth, Cengage Learning.

McCord, E. S., & Ratcliffe, J. H. (2007). A micro-spatial analysis of the demographic and criminogenic environment of drug markets in Philadelphia. *The Australian and New Zealand Journal of Criminology, 40*, 43-63.

Ratcliffe, J. H. (2004). Geocoding crime and a first estimate of a minimum acceptable hit rate. *International Journal of Geographical Information Science, 18*, 61-72.

Ratcliffe, J. H., & Breen, C. (2011). Crime diffusion and displacement: Measuring the side effects of police operations. *The Professional Geographer, 63*, 230-243.

Ratcliffe, J. H., Taniguchi, T., Groff, E. R., & Wood, J. D. (2011). The Philadelphia foot patrol experiment: A randomized controlled trial of police patrol effectiveness in violent crime hotspots. *Criminology, 49*, 795-831.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchal linear models: Applications and data analysis methods* (2nd ed.). Thousand Oaks, CA: Sage.

Rengert, G. F., Ratcliffe, J. H., & Chakravorty, S. (2005). *Policing illegal drug markets: Geographic approaches to crime reduction*. Monsey, NY: Criminal Justice Press.

Roncek, D. W., & Maier, P. A. (1991). Bars, blocks, and crime revisited: Linking the theory of routine activities to the empiricism of "hot spots". *Criminology, 29*, 725-753.

Rosenbaum, D. P. (2006). The limits of hot spots policing. In D. Weisburd & A. A. Braga (Eds.), *Police Innovation: Contrasting Perspectives* (pp. 245-263). New York, NY: Cambridge University Press.

Sherman, L. W. (1990). Police crackdowns: Initial and residual deterrence. *Crime and Justice, 12*, 1-48.

Sherman, L. W., & Weisburd, D. (1995). General deterrent effects of police patrol in crime "hot spots": A randomized, controlled trial. *Justice Quarterly, 12*, 625-648.

Sorg, E. T., Haberman, C. P., Ratcliffe, J. H., & Groff, E. R. (2013). Foot patrol in violent crime hot spots: The longitudinal impact of deterrence and posttreatment effects of displacement. *Criminology, 51*, 65-101.

Sorg, E. T., Wood, J. D., Groff, E. R., & Ratcliffe, J. H. (2014). Boundary adherence during place-based policing evaluations: A research note. *Journal of Research in Crime and Delinquency, 51*, 377-393.

Stephens, D. W., & Krebs, J. R. (1986). *Foraging theory*. Princeton, NJ: Princeton University Press.

Taniguchi, T. A., & Salvatore, C. (2012). Exploring the relationship between drug and alcohol treatment facilities and violent and property crime: A socioeconomic contingent relationship. *Security Journal, 25*, 95-115.

Taylor, R. B. (1994). *Research methods in criminal justice*. New York, NY: McGraw-Hill.
Telep, C. W., Mitchell, R. J., & Weisburd, D. (2014). How much time should the police spend at crime hot spots? Answers from a police agency directed randomized field trial in Sacramento, California. *Justice Quarterly, 31*, 905-933.
Weisburd, D. (2015). The law of crime concentration and the criminology of place. *Criminology, 53*, 133-157.
Wood, J. D., Sorg, E. T., Ratcliffe, J. H., Groff, E. R., & Taylor, C. J. (2014). Cops as treatment providers: Realities and ironies of police work in a foot patrol experiment. *Policing and Society, 24*, 362-379.
Wood, J. D., Taylor, C. J., Groff, E. R., & Ratcliffe, J. H. (2015). Aligning policing and public health promotion: Insights from the world of foot patrol. *Police Practice and Research, 16*, 211-223.