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Colluding rhino poachers exploit space–time variation in opportunity and risk

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ABSTRACT

Human behavior shapes both our impact on nature and the success of solutions to safeguard it. We used crime opportunity and deterrence theory, together with methods from epidemiology, to link space–time patterns in 560 rhino poaching incidents (2011–2021) to poacher and ranger behavior in a South African rhino stronghold. Poaching activity was significantly associated with proximity to ranger camps. Together with supplementary evidence we present from internal investigations, this suggests that criminal syndicates collude with some rangers to facilitate poaching. Poachers repeatedly targeted specific regions of the reserve for set periods before shifting, mirroring the "near-repeat" behavior observed for other crimes. Poachers also avoided tourist activity and minimized time on the reserve. Results suggest poachers strategically leverage space–time variation in opportunity and risk. Solutions based on these behavioral insights include early response to space–time clusters of poaching, spatially targeted implementation of rhino dehorning, and bolstering ranger resilience to the corrupting influence of criminal syndicates.

1 | Introduction

Human behavior shapes both biodiversity loss and the effectiveness of solutions to reverse it (Bennett et al. 2017; St John et al. 2013). The illegal wildlife trade is one of the largest threats to global biodiversity, endangering thousands of species of plants, insects, and birds, as well as charismatic megafauna like elephants and rhinos (IPBES 2019; Margulies et al. 2019; t' Sas-Rolfes et al. 2019). This poses a significant threat to the integrity of protected areas and the attainment of global biodiversity targets under the Kunming–Montreal Global Biodiversity Framework (Convention on Biological Diversity 2023; Moore et al. 2018). Poaching for the illegal horn trade remains a major threat for all five species of rhinos (CITES 2022), while also diluting their ecological role in protected areas (Cromsigt and te Beest 2014), threatening the lives of the poachers and rangers involved in militarized exchanges (Duffy 2014; Galliers et al. 2022), compromising tourism (Lubbe et al. 2019), and disrupting local communities and institutions as criminal networks become embedded (Rademeyer 2023). While simplistic, we use the term "poacher" rather than the more general "harvester" due to its salience and applicability to the illegal harvesting of high-value rhino horn (Phelps et al. 2016).

One promising but underutilized tool for studying the behaviors of the local poachers, criminal syndicates, and corrupt officials who drive the illegal wildlife trade is crime science, which emphasizes quantitative evidence and empirical analyses of crime and its prevention rather than the characteristics of offenders and the criminal justice system (Fisher 2021; Wortley and Townsley 2016). Crime science has its roots in crime opportunity theory, which focusses on the immediate environment (time and place) where crime occurs, predicting that crime occurs with the space–time convergence of a motivated offender (in our case a poacher), an attractive target (a rhino with valuable horns), and the absence of a capable guardian such as an anti-poaching ranger (Felson 2013; Lemieux 2014). A complementary body of work focusses on crime deterrence—the reduction of crime under the threat of punishment (Nagin 2013). Empirical work, together with theoretical work in behavioral economics, suggests that the swiftness, certainty, and severity of punishment all influence the degree of deterrence (Cameron 1988; Kahler and Gore 2012; Moreto and Gau 2017), but that increasing the probability of being caught is a more effective deterrent than the severity of punishment (Nagin 2013). Both crime opportunity and deterrence theory may help explain where crime occurs in space and why, which is what we seek to do in the present study (Table 1; see Weekers et al. [2020] for a similar approach).

Finally, previous work has pointed to corruption as a key facilitator of the illegal wildlife trade (Kuiper et al. 2023; Wyatt et al. 2018). Across the globe, poachers and traders collude with state officials to facilitate the harvest, transport, and import of wildlife products (Van Uhm and Moreto 2018). Law enforcement officials (from rangers at the site level to border staff at points if entry) may turn a blind eye to or actively participate in criminal networks around illegal wildlife products (Bennett 2015). Broader research into corruption and collusion in other sectors suggest that it is a systemic issue that is shaped by socioeconomic conditions, individual motivations, and weak institutions (Gorsira et al. 2018; Treisman 2000).

Our objective was to investigate the drivers of space–time variation in rhino poaching by testing various hypotheses relating to the interacting behaviors of poachers, rangers, and rhinos. We used crime science and deterrence theory to generate the hypotheses, and methods from resource selection ecology and epidemiology to test them using 560 incidents (2011–2021) of poacher activity on Sabi Sand Nature Reserve (hereafter Sabi Sand) in South Africa.

2 | Methods

2.1 | Study Area

Sabi Sand is a private protected area within the Greater Kruger region of South Africa (Figure 1). South Africa protects an estimated 80% of the world's white rhinoceros and 33% of the world's black rhinoceros, with the majority occurring in the Greater Kruger (CITES 2022). Over the last decade, poaching has driven large and rapid declines in population numbers of both rhino species in this landscape (Ferreira and Dziba 2023). Historic injustices, socioeconomic inequality, corruption, complex illegal market dynamics, and entrenched criminal syndicates combine to drive and facilitate rhino poaching in our study landscape (Conrad 2012; HYPERLIN 2017; Rademeyer 2023). More details on the study area are included in the Supporting Information.

2.2 | Rhino Poaching Data

Sabi Sand employs a range of strategies to curb rhino poaching, including dehorning of rhino, tracking and detection dogs, detection camera technologies, and integrity testing (polygraph tests to identify reserve staff connected to criminal syndicates) (Kuiper et al. 2025). Poaching activity is intensively monitored (ranger density is high, multiple perimeter and interior patrols are conducted daily, while advanced camera technologies and tracking dogs aid detection; Kuiper et al. 2025). We therefore estimate that most carcasses are detected within hours of the poaching event, with 95%–100% of poached carcasses detected within a month (no carcasses estimated to be more than a month old have been detected; aging is based on visual judgment and carcass decay by experienced staff). All poaching activity (Figure 1) is recorded using handheld devices, including date and time, GPS location, incident type, carcass age, and other details.

2.3 | Landscape Predictors of Rhino Poaching

To inform which landscape variables may influence the locations of rhino poaching activity, we generated hypotheses around three drivers of poaching locations: (1) poacher behavior, (2) rhino distribution, and (3) ranger/tourism presence, which may deter poachers (Table 1). We then used Bayesian logistic regression models with the response variable coded as 1 for poaching events and 0 for a large number of randomly generated background (pseudoabsence) points (Barbet-Massin et al. 2012). This approach is akin to the resource selection function approach used to model habit selection in ecology (Manly et al. 2002). We used LASSO regularization to identify the predictors most strongly associated with poaching activity (Tibshirani 1996; Tredennick et al. 2021). We built two regression models:

1. *Rhino carcass model*: using all poached rhino carcasses detected ($n = 104$, 2011–2021).
2. *All activity model*: using all poaching activity, including carcasses, armed contacts between rangers and poachers, visual sightings of poachers, and gunshot reports ($n = 154$, 2011–2021).

We also tested whether the significance of spatial predictors changed over time using time period models (2011–2014 vs. 2015–2021 for rhino carcasses; Figure S3). Low samples sizes in the wet season ($n = 40$) precluded us from meaningful comparisons using season-specific models.

Finally, we investigated spatial patterns in poacher entry and exit points, as well as pathways between entry points, poaching events, and exit points. More details on the modeling approach and data are included in the Supporting Information.

2.4 | Identifying Spatial and Space–Time Clusters of Poaching

We analyzed poaching events as a point process and used Ripley's *K*-function and Monte Carlo simulations to test for spatial clustering among poaching events using the "*Kest*" and "*envelope*"

TABLE 1 | The spatial predictor variables that we hypothesized would influence the spatial behavior of poachers, rangers, or rhinos and thus the observed spatial distribution of poaching activity. Most predictors are hypothesized to influence poacher behavior, but some may influence other agents (rhinos, rangers).

Spatial predictor	Influences	Rationale for inclusion	Direction	References
Elevation	All agents	In Sabi Sand Nature Reserve, higher elevations are more exposed to detection and are harder to access.	Negative (poaching decreases with elevation)	Kuiper et al. 2020
Terrain ruggedness	All agents	Difficult to navigate for all agents. Energy and time saving to avoid.	Negative	le Roex et al. 2020
Distance to water source (river, pumped water sources, seasonal pans)	Rhinos and hence rangers and poachers	Rhinos may be more abundant near water sources as a basic requirement	Negative (lower poaching as distance to water increases)	Critchlow et al. 2015; Sibanda et al. 2015
Woody cover	Rhinos and poachers	White rhinos (>90% of rhino population) prefer open, less wooded habitats. Poachers may prefer covered habitat for concealment.	Positive or negative	le Roex et al. 2020; Waldram et al. 2008
Rhino density	Poachers and rangers	Poachers target areas of higher rhino density. May also be correlated with other predictors.	Positive	Critchlow et al. 2015
Distance to reserve fence	Poachers	*Accessibility*: higher poaching nearer fences as a key entry point	Negative	Beale et al. 2017
Distance to tourist lodges	Poachers	*Detection*: Poachers may avoid lodges due to higher probability of detection (passive surveillance)	Positive	Baral 2013
Distance to main roads	Poachers	*Detection*: Poachers may avoid main roads due to probability of detection.	Positive	Baral 2013
Distance to reserve gates	Poachers	*Accessibility*: poachers may access the reserve via gates, especially if gate staff are corrupt (internally involved)	Negative	Kuiper et al. 2025
Distance to ranger picket/base	Rangers and poachers	Detection/deterrence: Poachers may avoid ranger bases to reduce probability of detection, which may displace or deter poaching. Conversely, rangers may facilitate poaching through collusion with criminal syndicates.	Positive or negative	Dancer et al. 2022; Moore et al. 2018; Rademeyer 2023
Distance to buffering protected areas (reserves)	Poachers	Accessibility: Lower poaching nearer buffering PAs due to lower accessibility	Positive	Poulsen et al. 2017
Distance to adjacent towns (Figure 1)	Poachers	Accessibility: Poachers may be more likely to enter the reserve nearer towns	Negative	Faulkner et al. 2017

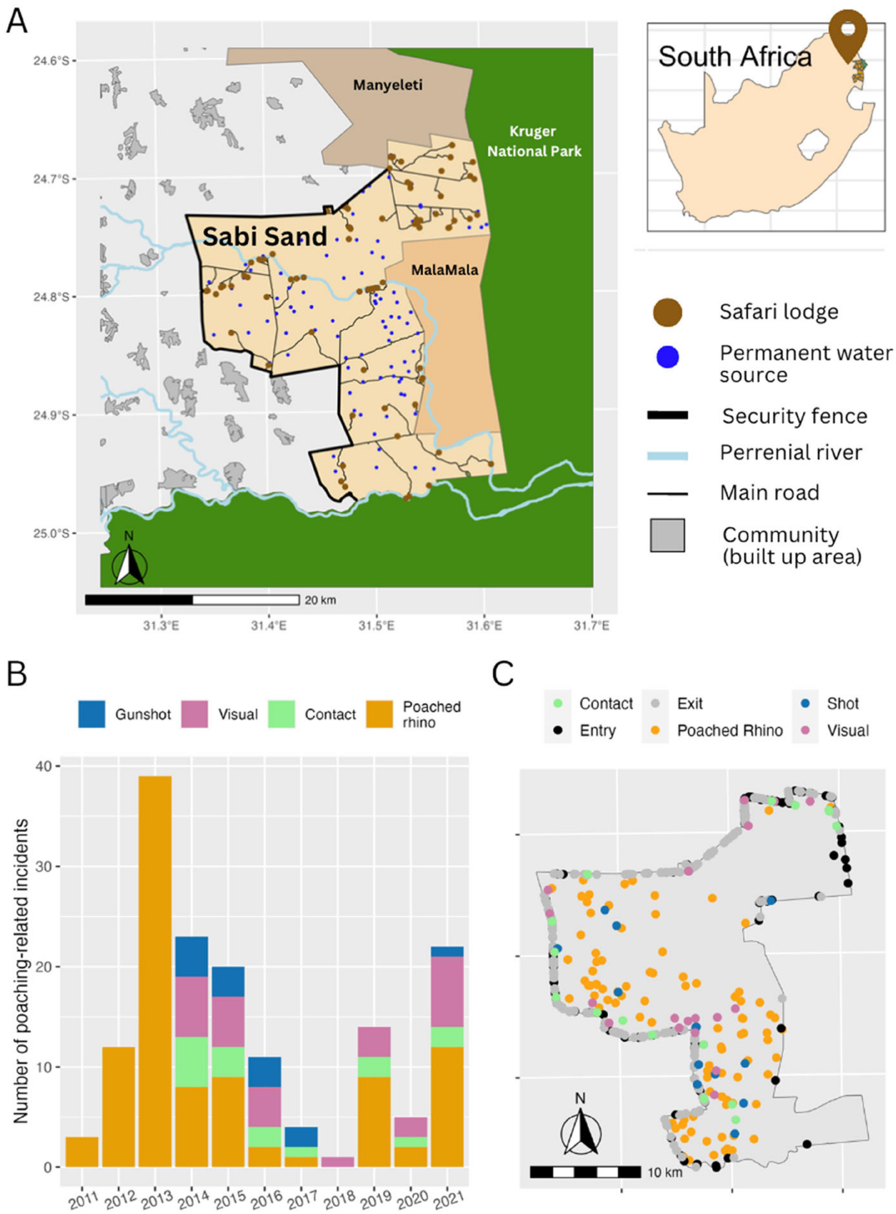


FIGURE 1 | (A) Map of Sabi Sand Nature Reserve: the security fence interfaces with the community/public land to the west, while Sabi Sand is buffered by various reserves to north (Manyeleti Provincial Nature Reserve) and east (Mala Mala Private Reserve and Kruger National Park). There are no fences between reserves, and the broader Greater Kruger landscape constitutes a global stronghold for both white and black rhinoceros. (B) Temporal and (C) spatial patterns of different categories of poaching activity analyzed between 2011 and 2021 (104 poached rhino carcasses, 28 visual sightings of poachers, 16 armed contacts between poachers and rangers, 13 detected gunshots, 164 detections of poacher fence entries, and 235 fence exits). Note the location of ranger camps is not shown for security reasons. Some entry and exit points may represent wild meat hunters rather than rhino poachers, whereas contacts, visuals, and gunshots were confirmed as linked to rhino poaching.

functions in the R package *spatstat* (Baddeley et al. 2015). Next, we tested the null hypothesis that the spatial and temporal processes generating poaching locations were independent using the function *stmctest* in the R package *splancs* (Rowlingson et al. 2013). This uses Monte Carlo permutations ($n = 999$) to generate a distribution of realizations of the null hypothesis, against which the observed test statistic was compared.

Next, we identified specific space–time clusters using the space–time scanning statistic permutation model (STSSP) in the software package *SatScan*, typically used to identify space–time clusters of disease outbreaks in epidemiology (Kulldorff 2010; Kulldorff et al. 2005). The STSSP model has become a standard method for identifying space–time dependence more generally, with examples ranging from leopard attacks on humans in India (Shivakumar et al. 2023) to mortality rates among forced migrants globally (Poole et al. 2020). We set the model to scan a temporal window of 1 week to 3 years (at 1-week intervals) and a spatial window of 0–15 km in order to identify potential space–time clusters over a wide range of time periods and areas.

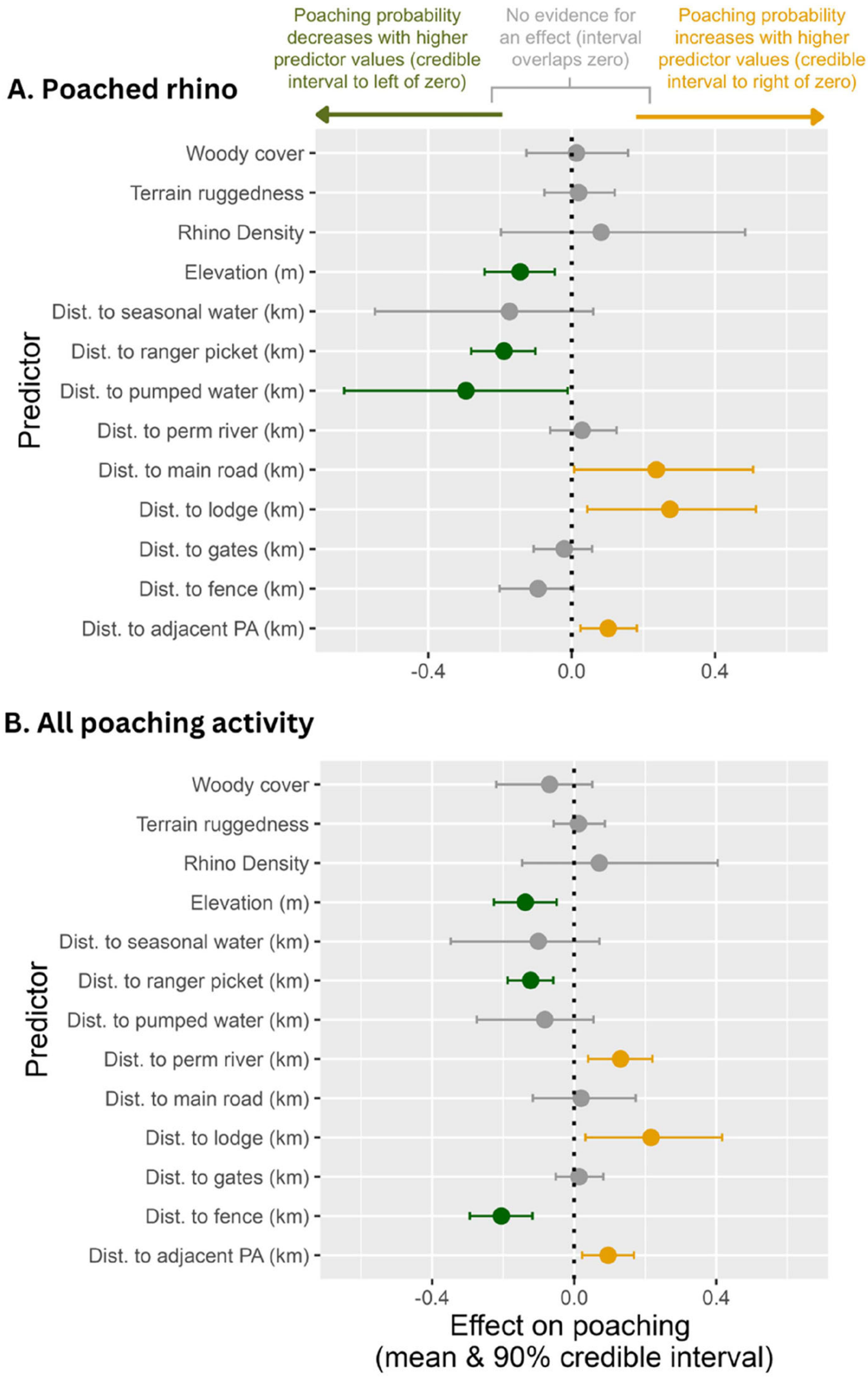


FIGURE 2 | The effect of each spatial predictor variable on the relative probability of poaching at a particular location based on (A) poached rhino carcasses ($n = 104$) and (B) all poaching activity ($n = 154$, including carcasses, plus visuals, contacts, and gunshots; see Section 2). Colored bars indicate predictors that have strong evidence for a positive (orange bars) or negative (green bars) relationship with poaching (90% credible interval does not include zero). Gray bars indicate no evidence for an effect on poaching (credible interval overlaps zero). We plotted 90% credible interval intervals for coefficient effects because they are more stable than 95% intervals for the Bayesian posterior, and because of our conservative regularization approach (McElreath 2018).

2.5 | Identifying Reserve Staff Colluding With Criminal Syndicates

In response to indications that reserve staff (rangers and others) may aid criminal syndicates in rhino poaching by providing key information, several Greater Kruger reserves (including Sabi Sand) have implemented integrity management systems involving regular polygraph testing of reserve staff (Kuiper et al. 2025; Rademeyer 2023). Given our hypothesis that ranger involvement with criminal syndicates may affect spatial patterns of poaching (Table 1), we present Supporting Information on the number of polygraph tests conducted, the number of failed tests, and

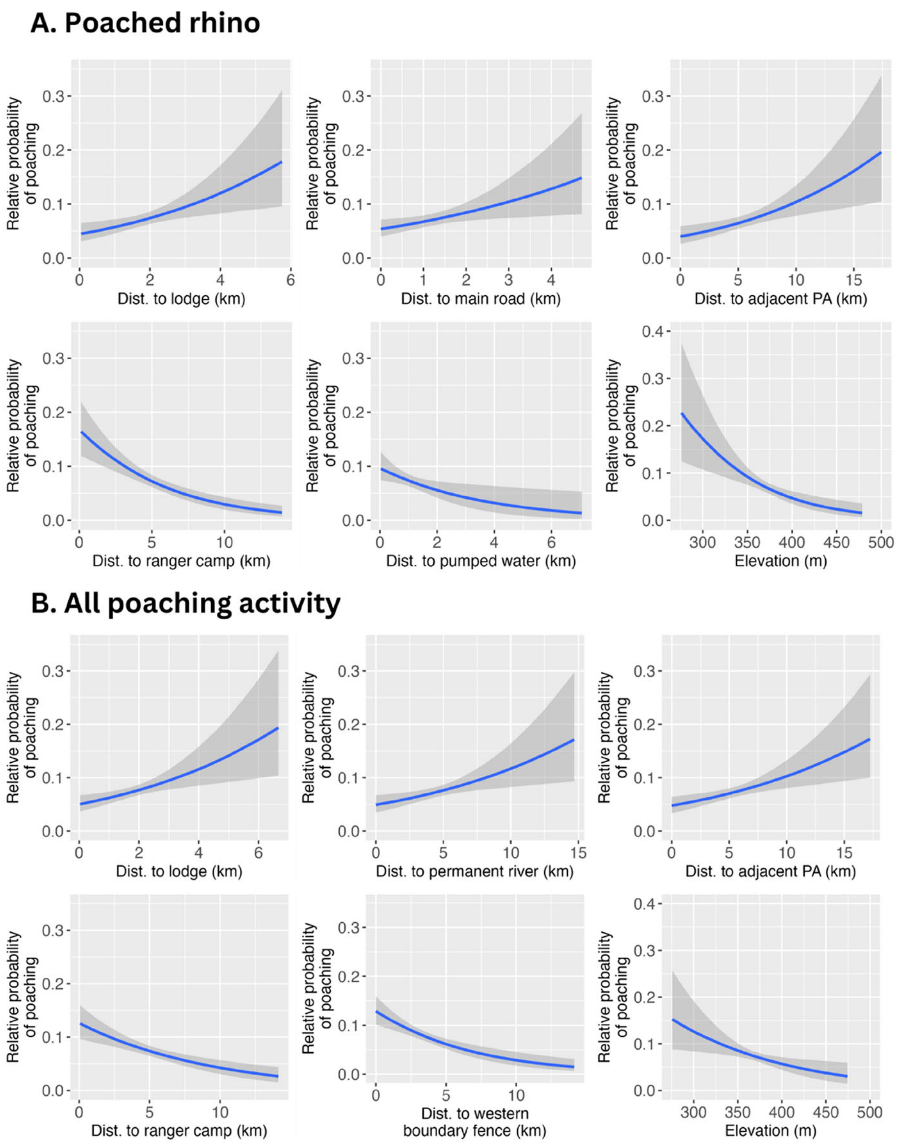


FIGURE 3 | The conditional effects (with 90% credible intervals) of the spatial predictors for which there was strong evidence (credible interval does not overlap zero) for an effect on the spatial distribution of (A) poached rhino carcasses ($n = 104$) and (B) all poaching activity ($n = 154$, including carcasses, plus visuals, contacts, and gunshots; see Section 2).

the dismissal of implicated staff between 2014 and 2023 (see Supporting Information text and Figure S1).

3 | Results

A total of 560 incidents of poaching activity were recorded on Sabi Sand (2011–2021; 104 poached carcasses, 28 visuals of poachers, 16 contacts between poachers and rangers, 13 detected gunshots, 164 detections of poacher fence entries, and 235 fence exits), with a large peak in rhino poaching mortality around 2013–2015 (Figure 1).

3.1 | Spatial Patterns in Poaching Reflect Variation in Opportunity and Risk

We found strong evidence for the effects of six key predictors on the spatial distribution of poached rhino carcasses, shedding light on our hypotheses relating to poacher, rhino, and ranger behavior. The probability of poaching was higher closer to ranger camps (there are five ranger camps across the reserve), closer to pumped water sources, and at lower elevations (Figures 2A and 3A). Conversely, the probability of poaching was lower closer to lodges, main roads, and adjacent protected areas (Figures 2A and 3A). The area under the curve (AUC) score for this model was 0.73. We found similar results in the model with all poaching activity, with poaching probability higher closer to ranger camps and the western boundary fence and lower closer to lodges and adjacent protected areas (Figures 2B and 3B). The effect of pumped water sources on all poaching activity was weaker than in the model with only rhino carcasses, while the effect of the permanent river became significant (higher probability of poaching further from rivers) (Figures 2B and 3B). The AUC score for this model was 0.74. These effects combined to produce spatial variation in the predicted probability of poaching across the reserve (Figure 4). The significance of spatial predictors remained broadly similar

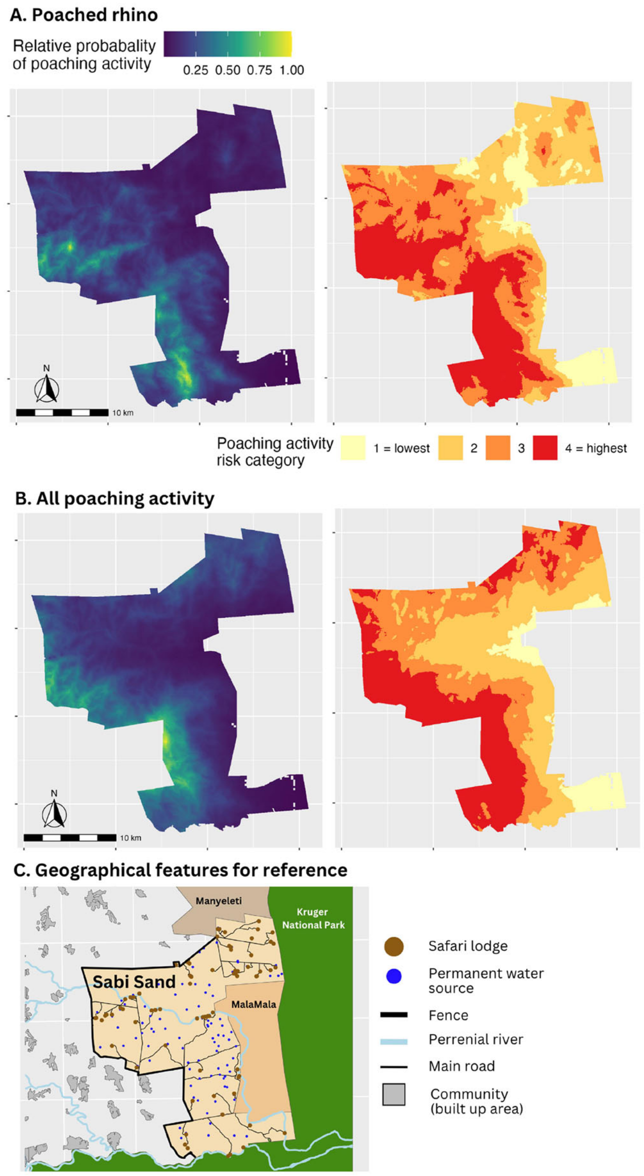


FIGURE 4 | The predicted probability of poaching activity across Sabi Sand Nature Reserve based on the LASSO-regulated Bayesian regression models fitted to (A) rhino carcass locations (n = 104) and (B) all poaching activity (n = 154, including carcasses, visuals, contacts, and gunshots; see Section 2). Left panels represent spatial variation in predicted poaching probability based on the model coefficients and pixel-level values for the spatial predictors. Right panels represent the same data but binned into four categories based on quantiles (0.25, 0.50, and 0.75) such that equal-area categories result.

over time (comparing a model using only 2011–2014 to one using 2015–2021 data; Figure S3).

3.2 | Spatial and Space–Time Clustering of Poaching Activity

Poaching incidents showed significant spatial clustering (Figure S4). We also found significant space–time dependence in the rhino poaching data (*stmctest*, $p < 0.05$), indicating that the spatial pattern of poaching changed over time with poachers tending to target specific regions at specific times (Figure 5). For example, in Cluster 1 (see Figure 5), 10 rhinos were poached within a radius of 4.4 km (an area of 58 km^2) between August 10, 2019 and October 1, 2021, while only seven rhinos were poached across the rest of the reserve (520 km^2) during the same period. Conversely, no rhinos were poached in a large area (no-poaching "Cluster" 6 with 10.1 km radius; Figure 5) for a period of 881 days, while outside that period, a total of 45 rhinos were poached in that same area (Figure 5). These long time periods suggest that space–time dynamics in poaching on Sabi Sand play out slowly.

3.3 | Poacher Entry and Exit Points

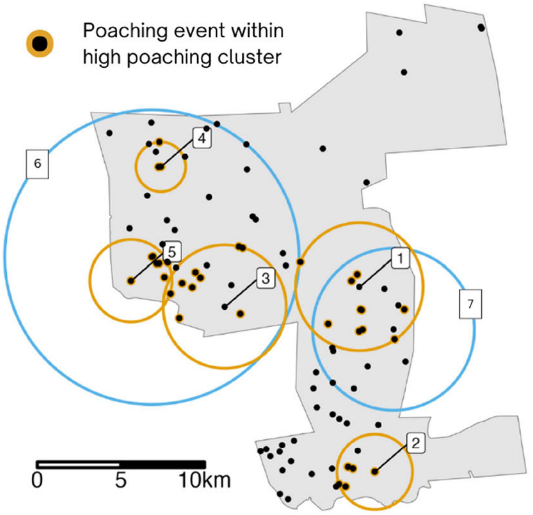
Poachers were more likely to enter the reserve nearer human communities, closer to ranger camps, and closer to reserve gates (Figure 6). For 12 incidents with data on both, the mean distance between the entry point and the poached rhino was 2.8 ± 1.6 km (mean ± SD; ~10%–15% of reserve width/length). Poachers used the same exit point as the entry point for 45% of incursions with data on both (Figure 6B). Distances between entry and exit points (2.5 ± 3.4 km, mean ± SD; ~10%–15% of reserve width/length) were substantially shorter than that between pairs of randomly generated boundary points (16.8 ± 8.7 km; Figure 6B). For 27 incidents with data on both, the distance between the poached carcass and exit point was on average 41% longer (3.5 vs. 2.5 km) than the straight-line distance to the nearest boundary, although the difference was not statistically significant (T-test, $p = 0.09$).

4 | Discussion

Below, we discuss our results in the context of the literature and highlight how our results lend empirical support to the following theoretical predictions (see introduction) related to how criminals dynamically respond to opportunity and risk. Routine activity theory predicts that crime occurs where opportunities are high and risks are low, and specifically where suitable targets and the absence of a capable guardian align (Felson 2013; Lemieux 2014).

4.1 | Poachers Seek to Minimize the Probability of Detection and Apprehension

Several of our spatial predicters act as proxies of the probability of criminal deterrence (Nagin 2013). Tourist presence deters poaching likely by increasing the probability of detection. Sabi Sand is a global tourism hotspot with numerous lodges and frequent safari drives, and tourists often report suspicious observations to anti-poaching teams. Baral (2013) found a similar results for poaching of Greater one-horned rhinoceros in Nepal, describing tourist vehicles as a form of patrolling. Beale et al. (2017) similarly found elephant poaching to be lower near hotspots of tourism activity in Tanzanian. The observed higher probability of poaching nearer the boundary fence, and the results from the reserve entry and exit analyses, suggests that poachers further reduce the probability of detection by minimizing the time spent on the reserve.



Space-time cluster	Radius (km)	Time period	No. days	Observed no. rhino poached in space-time cluster (*vs. expected*)	Observed no. rhino poached in spatial cluster (all time)	P-value
1	4.4	2019/08/10 - 2021/10/01	783	10 (*2*)	18	0.004
2	2.6	2021/05/22 - 2021/12/17	209	6 (*1*)	7	0.009
3	4.2	2011/02/12 - 2013/03/08	755	11 (*3*)	14	0.102
4	1.7	2012/12/29 - 2013/02/01	34	3 (*0*)	5	0.171
5	2.8	2013/05/04 - 2013/10/18	167	9 (*2*)	9	0.4
6	10.1	2019/07/20 - 2021/12/17	881	0 (*9*)	45	0.015
7	5.5	2011/02/12 - 2013/06/07	846	0 (*6*)	19	0.473

FIGURE 5 | Space–time clusters (circles) among 104 poached rhino carcasses in Sabi Sands Nature Reserve (2011–2021). A cluster is identified as a specific area (radius) for a specific period (days) where poaching is higher than would be expected (see Column 5 of the table) given the radius and time length of the space–time window. The statistical significance of clusters is established using the space–time permutation scan statistic typically applied to identify disease outbreaks (Kulldorff et al. 2005).

4.2 | Poachers Maximize the Probability of Encountering Suitable Targets

Our results suggest that poachers target waterholes as known locations where rhino may be predictably located (MauguiINK 2022), lending support to the prediction of routine activity theory that the suitable targets create space–time opportunities for crime (Felson 2013). Kuiper et al. (2020) found a similar pattern for elephant poaching in a Zimbabwean reserve, while Critchlow et al. (2015) found that illegal hunting in a Ugandan reserve correlated with target animal density. By targeting areas of high animal abundance, poachers minimize time on the reserve and thus the probability of detection. Sabi Sand began widespread dehorning of rhinos in 2022, a classic case of crime opportunity reduction (Kuiper et al. 2025; Lemieux 2014). The lack of a direct rhino density effect in our models might be explained by the fact that the aerial surveys from which rhino distribution was determined are conducted only once in the late dry season.

4.3 | Poachers Take Advantage of Windows of Low Risk and High Opportunity

Space–time cluster analyses suggest that poachers repeatedly targeted specific regions of the reserve at specific times, after which hotspots of poaching shifted elsewhere. This is analogous to clusters of disease incidence in small space–time windows (Kulldorff et al. 2005). Regions with heavy poaching in some years would have near zero poaching for extended periods in other years (Figure 5). Due to the large size and long time periods for some clusters (see Figure 5), these effects are unlikely due to variation in predictable patrol effort (Haas and Ferreira 2018). Similar space–time clusters of poaching were documented for illegal fishing in the Great Barrier Reef in Australia (Weekers et al. 2020). These patterns have been observed for other crimes (shootings, robberies, car theft) and described as "near-repeat" offending (Youstin et al. 2011). This chain of crimes may continue until detection and apprehension deter future incidents or better opportunities arise elsewhere (Wheeler et al. 2021). Though statistically significant, the space–time clusters represented long time periods (2–3 years; see Figure 5), suggesting that opportunities and risks changed slowly. One possible explanation—supported by anti-poaching staff through workshopping of our results with reserve staff—is that the shifting space–time clusters may reflect changing opportunities to collude with rangers at particular ranger camps in particular areas, with opportunities dissolving as colluding rangers are identified through polygraph testing (Kuiper et al. 2025).

4.4 | Poachers May Collude With Law Enforcement Officers to Create Opportunities for Crime

Corruption facilitates wildlife crime (Kuiper et al. 2023; Wyatt et al. 2018). Polygraph testing and follow-up investigations on Sabi Sand and several neighboring reserves have revealed numerous cases in which rangers have been involved in facilitating poaching, mainly through sharing rhino and patrol locations with poaching groups (Figure S1 and see Kuiper et al. 2025; Rademeyer 2023). Our results may thus be explained by increased ranger surveillance of areas near ranger camps and thus more opportunities to share information (on rhino and patrol locations) with criminal syndicates (see Beale et al. [2017] for a similar results). While rangers patrol widely and could share information from areas distant to camp, they spend significantly more time in and near their camps, and information nearer the camp is likely to be more current.

Rangers play an important role in deterring poaching activity at many sites globally as capable guardians (Dancer et al. 2022; Hilborn et al. 2006), yet our results and those elsewhere suggest they may occasionally facilitate poaching. In-depth qualitative analysis confirms corruption as a common facilitator of wildlife

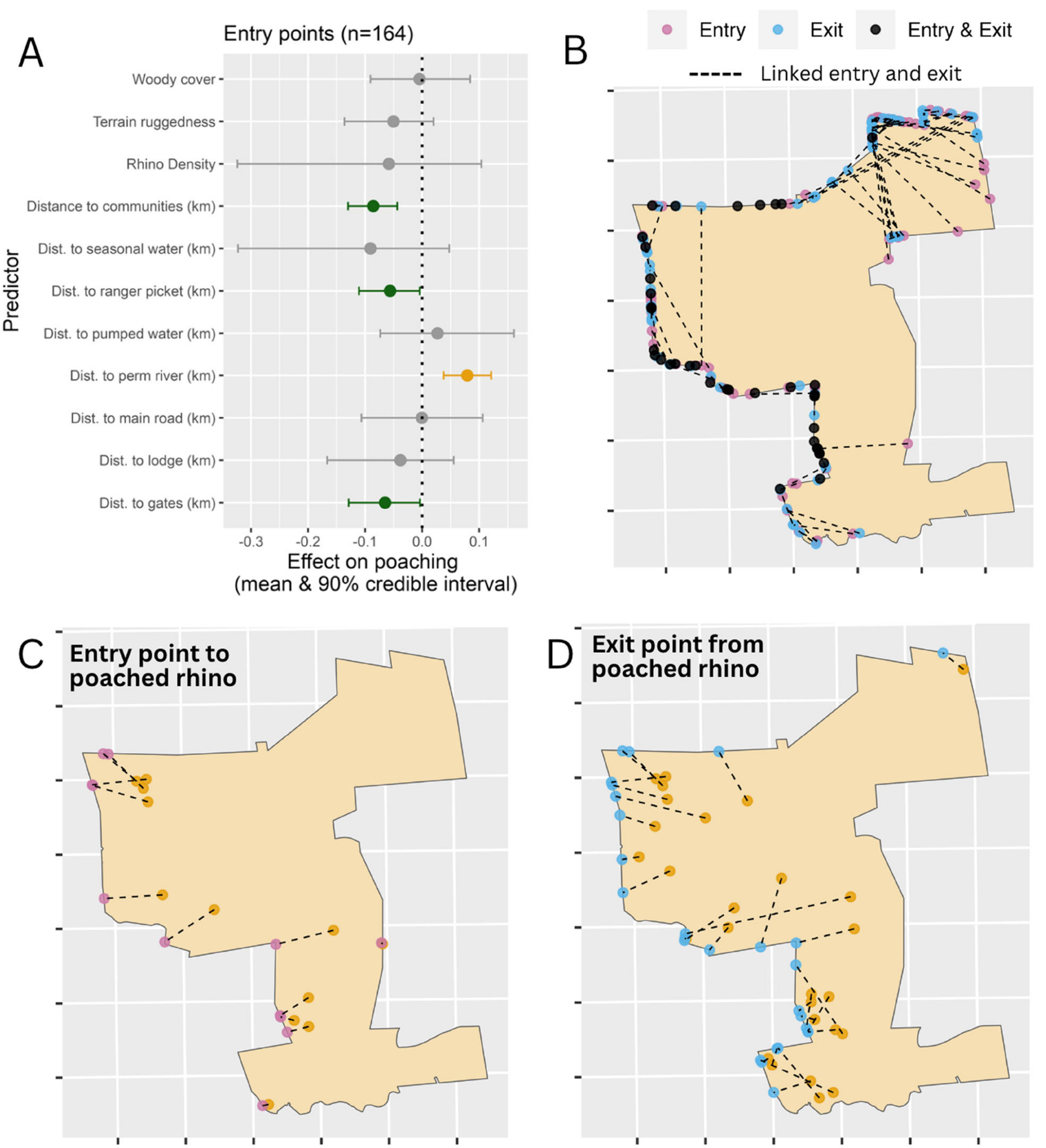


FIGURE 6 | (A) Spatial predictors of poacher entry points, (B) pathways between entry and exit points, (C) pathways between entry and poaching, and (D) pathways between poaching and exit.

crime across geographies and species (Moreto et al. 2015; Wyatt et al. 2018). In our Greater Kruger study system, a fragile socioeconomic environment and predatory criminal syndicates combine to make rangers particularly vulnerable to corrupting influences (Rademeyer 2023).

One alternative explanation of the ranger camp effect may be that rhino poaching events are more detectable near ranger camps, but we estimate that very few if any rhino carcasses are missed by ranger patrols (see Section 2). Another explanation is that ranger camps were established in high-risk poaching areas. However, these camps were fixed throughout the study, while our space–time modeling showed that hotspots change over time. Furthermore, Sabi Sand rangers are well-equipped and have had numerous hostile encounters with poachers, so one would expect displacement of poaching away from camps (Moore et al. 2018). The fact that poaching was still correlated with proximity to ranger camps thus lends further support to our ranger misconduct interpretation.

Finally, targeted polygraph tests are often conducted on rangers and other reserve staff who were on duty in the vicinity and time of the poaching incident. These incident-specific tests have resulted in greater failure rates than blanket polygraph testing on Sabi Sand, which provides further evidence that spatial patterns of poaching are influenced by spatial patterns in collusion between reserve staff and criminal syndicates.

4.4.1 | Complexity and Randomness

Despite multiple significant effects, the model AUC values were not very high (0.7–0.75), indicating that a fair amount of spatial variation in rhino poaching remained unexplained (as in similar previous analyses: Critchlow et al. 2015; Kuiper et al. 2020). This is both unsurprising and instructive: it is very difficult to accurately predict the complex and interactive behaviors of poachers and rangers. Many other unmeasured spatial factors likely shape their decisions, such as the location of conservation interventions like detection cameras, or unique opportunities to poach at specific times (Weekers et al. 2020).

4.4.2 | Conservation Implications

Predictive models like ours can help anti-poaching teams understand local poacher behavior and target resources accordingly. Indeed, our results are currently being used by reserve management to identify areas to deploy patrol, as well as priority areas for rhino dehorning (Kuiper et al. 2025). More broadly, our results point to the importance of contextual factors in driving patterns of crime and suggest that a situational crime prevention approach may help to reduce crime by making it harder, riskier, and less rewarding (Lemieux 2014). For example, the deterrent value of tourist activity could be more strategically utilized. Analogous to disease outbreaks, early detection of developing space–time poaching clusters can guide effective response (Kulldorff et al. 2005). The evidence for ranger misconduct presented here also points to the need to ensure stronger financial independence for rangers (through fair salaries, financial skills training, and debt counselling) to help buffer against corrupting influences (Moreto et al. 2015). Finally, many existing interventions target the symptoms of the illegal economy established by organized syndicates, rather than factors like corruption, weak institutions, and local poverty that allow these syndicates to thrive (Kuiper et al. 2025).

Author Contributions

Timothy Kuiper: conceptualization, data curation, formal analysis, investigation, methodology, writing – original draft, writing – review and editing. **Iain Olivier**: conceptualization, funding acquisition, project administration, resources, investigation, methodology, writing – review and editing. **Julie Gane**: conceptualization, funding acquisition, project administration, resources, investigation, methodology, writing – review and editing. **Res Altwegg**: formal analysis, investigation, methodology, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Given the sensitivity of the rhino poaching location data, it is protected by a data sharing agreement. We are able to upload the R code for the analysis, but access to the data will need to be restricted.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.