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Spatial point pattern analysis of the Sumatran tiger (*Panthera tigris sumatrae*) poaching cases in and around Kerinci Seblat National Park, Sumatra

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Abstract.*Rifaie F, Sugardjito J, Fitriana YS. 2015.Spatial point pattern analysis of the Sumatran tiger (*Panthera tigris sumatrae*) poaching cases in and around Kerinci Seblat National Park, Sumatra. Biodiversitas 16: 311-319.*Wild Sumatran tigers are in a critical state with around 250 adult tigers remain in their habitat in Sumatra Island. Despite the fact that this subspecies is an elusive animal with very wide home range, Sumatran tigers are facing two serious threats, the depletion of its habitats and preys in one side and the increase of tiger hunt for illegal wildlife market. Improving the capacity and effectiveness of law enforcement in reducing poaching of tigers is an immediate priority protecting the remaining wild populations in their habitat. Enforcement monitoring was established under the Tiger conservation program. During their patrols, the anti-poaching team recorded various data including poaching incidents. We analyzed secondary data of Sumatran tiger poaching cases around Kerinci Seblat National Park that have been documented from 2000 to 2012. Georeferencing process was performed to transform locality data of 87 poaching cases into geographic position. The Nearest Neighbor (NN) analysis suggested a strong clustering pattern with the observed mean distance was 4.9 km, much lower than the expected mean distance (10.9 km).Similarly, The Ripley's K analysis also showed the aggregation of the points along the observed distances. On the other hand, about 35.6% of points were located outside the standard deviational ellipse. The pattern indicated that poaching incidents were spread in all corner of the region but excessive cases were observed in the center of the park.

Keywords: Kerinci Seblat National Park, *Panthera tigris sumatrae*, poaching, spatial statistic, Sumatran tiger

INTRODUCTION

Sumatran tiger (*Panthera tigris sumatrae*) is the only tiger subspecies that live outside the continent (Tilson et al. 1994), following the extinction of the Bali tiger (*P. t. balica)* in 1940s and the Javan tiger (*P. t. sondaica)* in 1980s (Seidensticker et al. 1999). Similar to its relatives in the mainland, this subspecies existence is threatened and the International Union for Conservation of Nature (IUCN) has categorized it as critically endangered (Tilson et al. 1994). Indonesian government has passed Law No.5/1990, Government Regulation No.7/1999 and Government Regulation No.8/1999 which stipulated that Sumatran tiger is a protected animal. Although its presence is still observed across the Sumatra Island (Wibisono and Pusparini 2010), but the exact population has never been revealed since it is almost impossible to census this solitary, cryptic animal. The latest assessment estimated that at least there are 250 adult tigers inhabit Sumatra Island (Wibisono and Pusparini 2010).

The fundamental impediment for Sumatran tiger survey is the secretive nature of this animal combines with the low density and very large home range (Wibisono et al. 2011). This makes the detection of its presence a very difficult task. The tiger existence was mostly exposed by their scats, tracts, urine smell and growl (Tilson and Nyhus 2010). Sumatran tiger population assessments have been conducted by mean of questionnaire surveys (Wibisono et al. 2011), occupancy surveys and camera trap surveys (Linkie et al. 2010).

Twelve Tiger Conservation Landscapes (TCL) have been recognized across Sumatra Island to determine habitats that support tiger populations (Wikramanayake et al. 1999; Sanderson et al. 2010; Seidensticker 2010). However, there are only two landscapes (Kerinci Seblat and Bukit Tigapuluh) that are included in global priority TCL, while three other landscapes, i.e. Leuser, Sibolga and Berbak, are categorized to class IV TCL (insufficient information) due to lack of data (Sanderson et al. 2010). Furthermore, Wibisono and Pusparini (2010) evaluated 33 forest patches in Sumatra to understand their distribution and revealed that tigers present in 27 forest patches. Those patches are mainly located in the western parts of the island that have mountainous terrain. Only several patches are expanding eastward, reach the east coast of Sumatra Island in Riau and Jambi Provinces. These forests are covering area of 140,226 km^2, where only 29% are protected (Wibisono and Pusparini 2010).

Despite their elusive behavior, Sumatran tigers are facing two serious threats, the depletion of its habitats and preys in one side and the increase of tiger hunt due to body parts trade or retaliation of predation cases (Nyhus and Tilson 2004; Nugraha and Sugardjito 2009; Wibisono et al. 2009). The habitat loss and fragmentation in Sumatra

Island have reached an alarming rate, varied between 0.8% and 9.8% per year (Wibisono et al. 2011). O'Brien et al. (2003) found numerous types of poaching signs in Bukit Barisan Selatan National Park (BBSNP), such as snares, cartridges, discarded batteries, gunshots, bush meat and wildlife parts market. One hundred and seventy two snare traps that were mainly targeted for muntjac, mouse deer, sambar and serow, were also spotted in Kerinci Seblat National Park (KSNP) (Linkie et al. 2003).

This top predator actually has no natural enemy, only human beings that disproportionately hunt and kill them to sell their body parts or to take revenge. The pressure of their habitats creates conflicts between human and tigers across the island. Between 1978 and 1997, the conflicts caused 146 people died, 30 people injured and more than 870 cattle became prey (Nyhus and Tilson 2004).During these 20 years period, 265 tigers were killed and 97 others were captured as a result of the retaliation (Nyhus and Tilson 2004). Additionally, 16 others became victims of retaliation between 2000 and 2004 in which later investigations revealed the involvement of professional hunters/poachers on some cases (Nugraha and Sugardjito 2009). This big cat is also hunted due to their body parts value (Plowden and Bowles 1997) and a police officer was involved in an organized poacher (Tilson and Nyhus 2010). More importantly, these poaching activities took place inside national park and almost no law enforcement for the offenders (Linkie et al. 2003; O'Brien et al. 2003; Tilson and Nyhus 2010).

This illicit act has long been recognized as the most imminent threat for tiger survival and appropriate measures could halt the declining trend of tiger populations (Galster and Elliot 2000; Damania et al. 2003; Gopal et al. 2010).In Sumatra, anti-poaching unit has been established in KSNP since 2000 (Hartana and Martyr 2001; Linkie et al. 2003), named the Tiger Protection and Conservation Unit (TPCU). The main objective of this unit is to assist the national park management to detect, prevent and deter tiger poaching activities in and around KSNP (Hartana and Martyr 2001). This unit also records tiger signs, arrests illegal loggers and wildlife poachers, confiscates chainsaws and dismantles wildlife traps (Linkie et al. 2003).

Most studies about tiger poaching investigated the relation of this illicit activity with tiger population or its survival. There has not been any research about the tiger poaching incidents related to their spatial context. The location where poaching cases occur can be plotted into map. The arrangement of the points can be studied spatially. One method for the study of spatial configuration of observed events within a two-dimensional space is point pattern analysis (Gatrell et al. 1996; Loosmore and Ford 2006).

This analysis has been widely utilized for epidemiology studies (Gatrell et al. 1996; Siqueira et al. 2004; Ngowi et al. 2010; Liebman et al. 2012; Simarro et al. 2012). This technique was successfully applied to understand clumping pattern of morbidity and mortality, spatial and temporal dynamic and modeling the raised incidence of diseases (Gatrell et al. 1996). This method is also popular in studies of spatial patterns of plant communities (Haase 1995; Loosmore and Ford 2006; Perry et al. 2002, 2006). Applications range from seed dispersal (Seidler and Plotkin 2006), plants coexistence (Liu et al. 2014), plants competition (Gray and He 2009) and plant disease (Dallot et al. 2003). Even though almost all animals are non-sedentary, but this analysis has been used to study the occurrences, lethal incidences and stationary constructions such as ant hills or birds' nests (Ramp et al. 2005; Hengl et al. 2009; Cogălniceanu et al. 2013; Iosif et al. 2013). Other disciplines that harness benefits from this method include soil science (Huo et al. 2012), volcanology (Bishop 2007) and urban studies (Zhang et al. 2014).

With the increasing awareness of importance of spatial pattern in biology, a variety of statistical tests have emerged (Haase 1995, Perry et al. 2006). Researchers with limited experience must carefully explore suitable approaches base on the characteristic of their data and the relevant questions regarding the spatial information (Perry et al. 2002, 2006). Consequently, it is a good practice employing different techniques so that they will complement each other and avoid partial conclusion about the spatial data (Perry et al. 2002, 2006). Edge effects are other pitfalls in spatial statistic and needs some form of correction. The cause of the edge effect is the assumption of an unbounded area for spatial point distributions, but observed distributions are calculated from a defined region (Dixon 2002a; Wiegand and Moloney 2004; Perry et al. 2006). Edge effects should not be neglected because can lead to overestimation and alter the conclusion (Dixon 2002a). The addition of a buffer zone around the plot is a popular method to account for edge effects (Dixon 2002a; Haase 1995).

This paper aimed to investigate the tiger poaching pattern by analyzing the spatial point pattern of the tiger poaching incidents in KSNP and surrounded area. The main objective of this study was to evaluate the capability of spatial analysis in exploring the pattern of tiger poaching cases.

MATERIALS AND METHODS

Tiger poaching data

The tiger poaching data were obtained from the Fauna & Flora International (FFI), a non-governmental organization focus on biodiversity conservation across the globe. They compiled tiger poaching incidents in and around KSNP reported monthly by the field manager of TPCU to the head of KSNP. The data was stored in a spreadsheet file format and contains date of the incident, location, poaching methods, detail of the case and enforcement actions. There were 87 incidents recorded between October 2000 and September 2012. The record only reported the administrative locations of the incidents. Twenty-six cases revealed the locations up to village level, 59 records only reported the sub district and two others only mentioned the name of the district.

Georeferencing spatial data

The process of transforming text base locality information into geographic coordinates is called georeferencing (Garcia-Milagros and Funk 2010). Common sources of reference of geographic coordinates for georeferencing process include gazetteers and maps. However, assigning a single point to a locality is commonly neglecting the quality of the representation of a point over actual locality (Wieczorek et al. 2004). Wieczorek et al. (2004) proposed point radius method to calculate the potential errors or uncertainties adhered to descriptive localities.

Georeferencing locality data is time consuming particularly on the error checking and correcting processes. Numerous tools have been developed to make this process become less tedious. Garcia-Milagros and Funk (2010) proposed the use of Google Earth© to georeference biological specimen locality data. Google Earth displays high-resolution satellite imagery with WGS84 datum as the coordinate system and NASA Shuttle Radar Topography Mission (SRTM) data as Digital Elevation Model (DEM). The advantage of utilizing this application is that the interface allows overlying maps, drawing paths, adding information marks, measuring distances, checking the elevation of a point and moving a point to another position (Garcia-Milagros and Funk 2010).

In order to determine the position of a poaching incident and calculate the uncertainty, administrative map of the study area was first uploaded into Google Earth. The administrative map was only up to sub-district level because the lack of reliable village map. The determination of the position of a poaching incident was done by following steps. Firstly, the point was placed in the middle of an administrative region if the locality was a sub district or district. Next, the case were located near or on the point of a village indicated by Google Earth when the locality indicates the name of a village. Lastly, the position of the poaching was placed in a forested area when the data specifies the habitat is the national park or the tiger conservation landscape.

The uncertainty calculation on the Google Earth application was adapting Garcia-Milagros and Funk (2010) based on steps described by Wieczorek et al. (2004). The points was then exported into shapefile format and processed into open source GIS software, QGIS (QGIS Development Team 2014).

Spatial point pattern analysis

Every point process has a basic property called intensity *(λ(s))*. It can be described as the expected number of events per unit area at the point *s* (Perry et al. 2006; Stoyan and Penttinen 2000).The simplest spatial process is complete spatial randomness (CSR), named the homogeneous Poisson Process with intensity *λ*. CSR is commonly used as null model, and a disproving event would exhibit either (i) clustering (aggregation in the bivariate case), or (ii) regularity (segregation) (Wiegand and Moloney 2004; Perry et al. 2006).

The behavior of a general spatial stochastic process can be characterized in terms of its first-order and second-order properties (Gatrell et al. 1996; Wiegand and Moloney 2004; Perry et al. 2006). First-order properties are described in term of intensity of a point pattern, in which intensity is defined as the mean value of the distribution at locations throughout the region of interest (Gatrell et al. 1996; Zhang et al. 2014). On the other hand, second-order properties of a spatial point process define the small-scale spatial correlation structure of the point pattern and they are based on the distribution of distances of all pairs of points (Gatrell et al. 1996; Wiegand and Moloney 2004; Perry et al. 2006; Zhang et al. 2014).

Numerous spatial statistic methods have been developed to study the point pattern characteristic. Perry et al. (2006) compared six types of univariate analyses in order to provide a guidance concerning the appropriate selection and use of each method. Each analysis has its own strengths and weaknesses, and the application of these tests should complement each other (Perry et al. 2006). They also added that the tests generally could be divided into first-order and refined for those derived from Nearest Neighbor (NN) and second-order summary statistics.

NN test is a simple first-order analysis that determined the intensity based on distances between two closest points (Stoyan and Penttinen 2000; Perry et al. 2006). This test represents a logical first step in analysis and useful for analyzing spatial point patterns (Perry et al. 2006). However, this method has limitation to the scale in which events beyond nearest neighbors are ignored (Stoyan and Penttinen 2000). Nearest neighbor index (r) can be explained with the following formula:

$$r = \qquad [1]$$

Where is the observed mean distance to nearest neighbor and is the expected mean distance to nearest neighbor for a random distribution. Furthermore, the observed and expected mean nearest distances can be explained as follow:

$$d_o = \Sigma \qquad [2];$$

$$d_e = \frac{}{\sqrt{}} \qquad [3]$$

Where, Σ is total distance to nearest neighbor, n is the number of points and A is the size of the area. Finally, the Z score of the observed mean distance to nearest neighbor is:

$$Z = \frac{d_s}{} \qquad [4]$$

where SE is the standard deviation. The index will show a statistically significant at level 5% when the Z score is less than -1.96 or bigger than 1.96.

On the contrary, Ripley's K function is one of most commonly use second-order statistic which able to detect mixed pattern due to difference of the distance scale. This test considers all inter-point distances and produces more information on the scale of the pattern (Wiegand and Moloney 2004). The K function represents the expected number of points within radius r from a randomly chosen point (Dixon 2002b; Zhang et al. 2014), and is defined as:

$$K(r) = \lambda^{-1}E \qquad [5]$$

Where, λ is the density (number per unit area) of points, and E is the expected other points within distance *r* of a randomly chosen event. The expected other points within distance r from a randomly chosen point in a process with no spatial dependency is also expressed as $\lambda\pi r^2$, K(r) for a homogeneous Poisson process can be defined as:

$$K(r) = \qquad [6]$$

In addition, the empirical function $\hat{K}$ is a ratio of numeration and the density of events, λ. The density of events is the ratio between the number of events and the size of the area. The estimation of numerator should consider the edge effects. These effects appear when the numerator does not consider points outside the boundary. One of commonly used estimator that count in the edge correction (Haase 1995; Dixon 2002b; Zhang et al. 2014) is:

$$\hat{K}(r) = n^{-2} A \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j \neq 1}}^{n} \omega_{ij}^{-1} I(\qquad [7]$$

This study examined the applicability of these two spatial statistic tests for tiger poaching incidents. QGIS and R spatstat (Baddeley and Turner 2005; R Development Core Team 2012), were used to perform these analyses. Most freeware are modular where new additional packages can be attached to the main program as a library, add on or plug-in. Two different free programs can also be combined performing a series of operations as has been demonstrated by Hengl et al. (2010). Unlike their work, which optimized a scripting language, this study used a combination between QGIS as the main software and R packages as plug-ins so that all the work can be done in a graphical user interface (GUI) environment.

RESULTS AND DISCUSSION

There have been 87 poaching cases recorded by the TPCU between 2000 and 2012. Most cases were dominated by snare traps (72 cases) in which 166 tiger snares were found and destroyed. This record revealed that there were 33 tiger casualties because of poaching activities. While most of the active traps were found and destroyed by the team, around thirteen traps took victims. In addition, one tiger were poisoned in 2000 and three other were shot in 2010 and 2012. On the contrary, body parts (smoked flesh, skeleton, pelts or skins) from 16 tigers were discovered during investigations, either on poaching sites or in poachers stash houses, without exact information about how the tigers were killed. However, when the TPCU found the tiger body part from a poacher, their investigation revealed where the location of the poaching was. For example, on January 2005 the team observed tiger skins and skeleton from poachers in Batang Merangin, Kerinci. Nevertheless, the TPCU team revealed that the poaching took place in Gunung Raya, Kerinci. Unfortunately, most of the identified poachers could not be arrested. Table 1 shows the summary of poaching cases reported by the TPCU team.

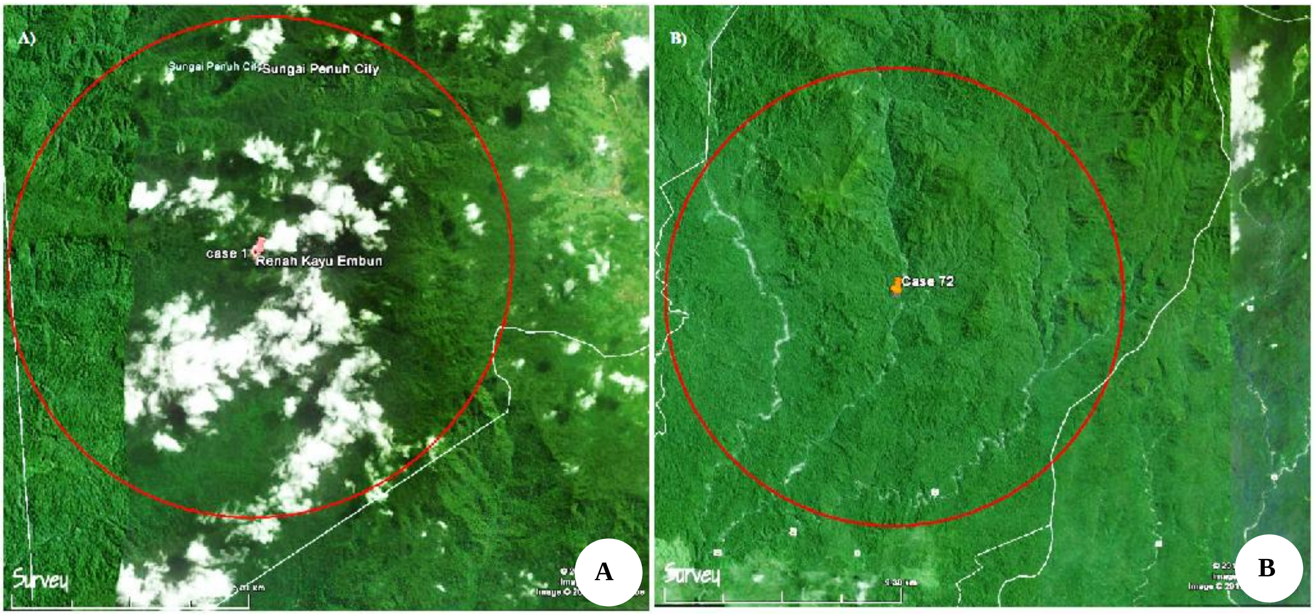

Figure 1. A. Case number one (October 2000) was placed on the Renah Kayu Embun Village indicated by Google Earth with uncertainty of 5 km. B. The record only indicates that case number 72 (January 2010) occurred in Malin Deman Sub district and the habitat is the national park. It was then placed in the forested area of this sub district and shows uncertainty of 9.2 km. The bright lines are sub district's boundaries.

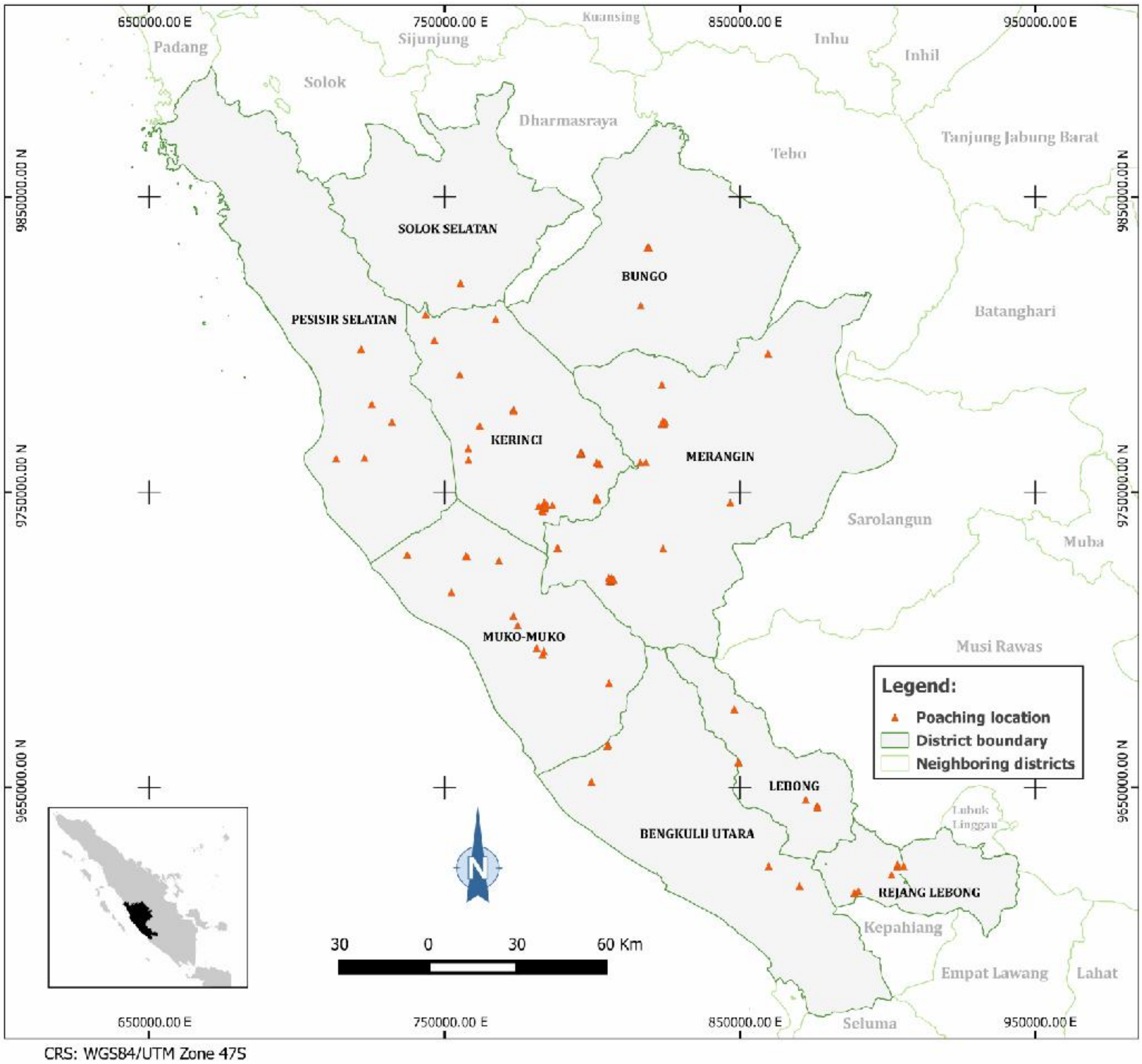

Figure 2. The distribution map of tiger poaching incidents between 2000 and 2012 in Kerinci Seblat National Park and surrounding area. The coordinate reference system (CRS) of the map is WGS 84/UTM zone 47S.

Table 1. Tiger poaching incidents recorded by the TPCU between 2000 and 2012 and compiled by TRAFFIC.

Year	Poaching cases	Snares found	Tiger poisoned	Tigers shot	Tigers killed
2000	1	0	1	0	1
2001	12	27	0	0	6
2002	3	0	0	0	4
2003	8	4	0	0	6
2004	8	21	0	0	1
2005	8	21	0	0	3
2006	9	31	0	0	0
2007	5	6	0	0	0
2008	4	7	0	0	0
2009	12	18	0	0	2
2010	9	11	0	1	2
2011	5	12	0	0	6
2012	3	8	0	2	2
Total	**87**	**166**	**1**	**3**	**33**

The georeferencing of all 87 poaching locations were successfully done by using the Google Earth. Almost all locality names listed in the report were easily found and plotted; only several locations could not be determined promptly. For example, the report mentioned several incidents were occurred in Lempur area, Gunung Raya Sub District, Kerinci. However, there are four localities started with Lempur found from Google Earth website, i.e. Lempur Danau, Lempur Tengah, Lempur Hilir and Lempur Mudik. Since these villages were closely located, the points were located in the middle of these villages. The inclusion of a more specific locality detail was another example that made Google Earth could not identify the exact position. One case was reported to take place in an area that belongs to a government institution property in Curup, Bengkulu. Two other incidents happened in a concession forest belong

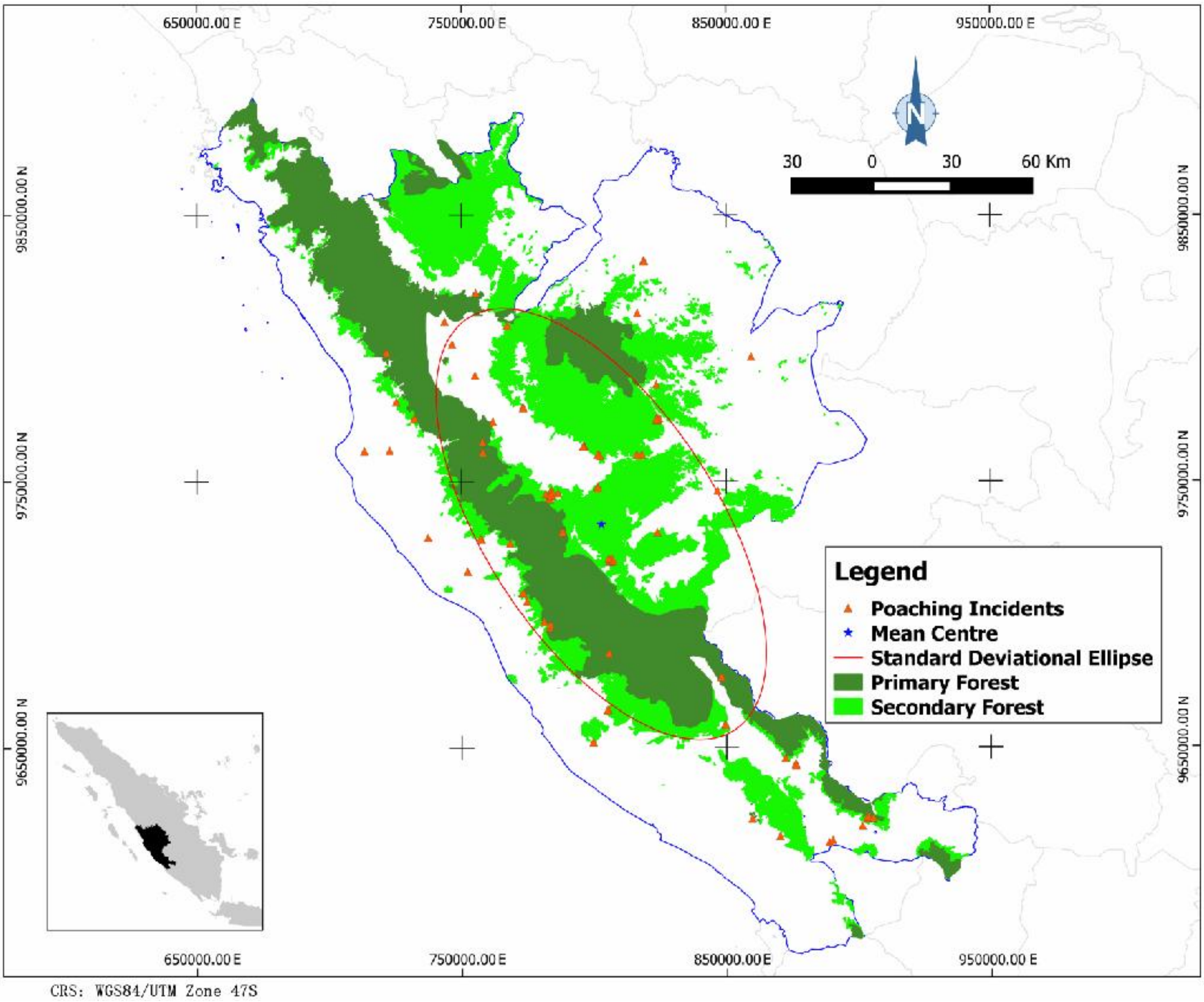

Figure 3. The mean center and standard deviational ellipse of the tiger poaching cases showing that the poaching incidents were occurred along the national park, and there were many outliers especially in the southeast and northwest of the ellipse. This forest cover map in 2011 was obtained from the Ministry of Forestry GIS website (http://appgis.dephut.go.id/appgis/download.aspx).

to a private company. When a locality was unsuccessfully determined based on the most specific location, it would be plotted based on the higher administrative region. The uncertainty of points determination were varied between 5 and 20 km and mostly caused by the extent of administrative boundaries. Uncertainty in mapping is something that cannot be avoid due to the complexity of the nature and measurement methods and should be taken into account (Rocchini et al. 2011). Figure 1 illustrates two examples of points determination and uncertainty calculation.

Garcia-Milagros and Funk (2010) demonstrated the use of expedition map to decrease the uncertainty from 7.5 km to only 0.85 km. unfortunately, such data could not be obtained because of concerns that tiger occurrence will be exposed to hunter syndicates. Other spatial data that could decrease the uncertainty are village maps. However, accurate village maps have not been readily available in Indonesia. The uncertainties may seem showing low accuracy of point mapping, but these values indicate overestimation (Wieczorek et al. 2004). Moreover, the uncertainties are relatively small figures when it is compared to the study area which extent about 39.000 km^2. It is more likely that the statistical analysis would not change significantly when more precise positions can be identified. Figure 2 shows the distribution of the points where tiger poaching incidents in KSNP area occurred.

The tiger poaching incidents took place in 9 out of 13 districts that surround KSNP. The districts where incidents were found were distributed in three provinces of West Sumatra, Jambi and Bengkulu. The mean center of the 87 points were located at 101° 43' 21.62"E and 2° 24' 16.45" S, with the standard distance of 71.7 km. This center point is located in Jangkat, Merangin, Jambi only about 55 km South East of Sungai Penuh where the national park office is situated. Standard deviational ellipse (SDE) calculated from the poaching incidents indicates the main orientation

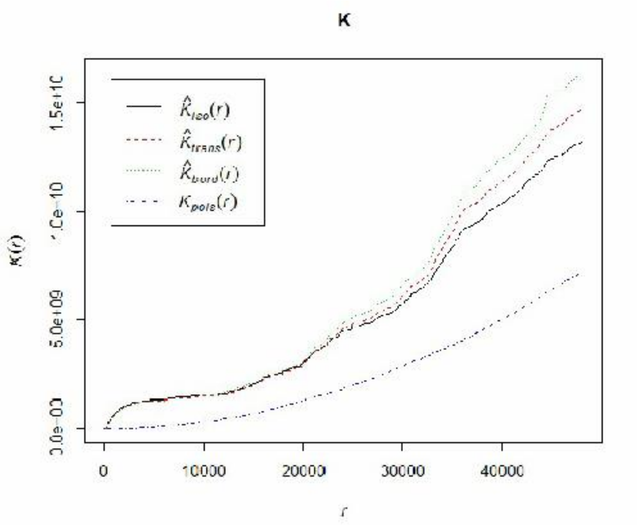

Figure 4. Plot of $\hat{K}(r)$ versus distance up to 50 km for all poaching locations. The difference between $\hat{K}(r)$ values and K(r) rise as the distance increases.

Table 2. The cumulative poaching cases recorded in each districts

District	Total incidents
Bengkulu Utara	5
Bungo	5
Kerinci	28
Lebong	6
Merangin	20
Mukomuko	11
Pesisir Selatan	5
Rejanglebong	6
Solok Selatan	1

of the poaching distribution (Gong 2002). The bearing of the major axis of this ellipse was 147° South East with the length of 184.3 km. There were 56 points or only 64.4% of total points that were situated inside the SDE area. Most of outliers (16 points) were located in Bengkulu Province (see Figure 3).

The NN test applied to this data showed that the distribution of tiger poaching incidents had the NN index of 0.451973869542. The observed mean distance was 4,967.646 m, while the expected mean distance was 10,991.003 m, with the Z-score -9.77893987179 far less than the critical value of -1.96. This suggested that the cases distribution were significantly clustered. The second order test, Ripley's K, verified this clustering pattern. Figure 4shows that the empirical K function (solid line) was constantly higher than the expected value representing a homogenous Poisson process (dashed blue line). It can be viewed that the K value soared significantly from the finest scale (0-20 km). The slope was then noticeably ascending as the distance rose. This rise can be observed at the medium scale (about 25 km) and at the longer scale (35 km).

The spatial statistic analysis of secondary data of Sumatran tiger poaching incidents in and around KSNP area showed the extent and pattern of the tiger poaching. This vast extent of areas where this illicit activity took place can be seen from the outlier points and administrative distribution. The furthest outlier point in Air Duku, Rejang Lebong District was 62 km away from the SDE boundary. The outliers were not only scattered in both ends of the SDE but also in northwest and northeast of the standard deviational area. The hunt for tigers by poachers were stretched from Sangir Sub district, Solok Selatan, West Sumatra in the north to Air Duku, Bengkulu in the south, and Muara Sako Village, Pancung Soal, Pesisir Selatan in the west to Tabir Hulu, Merangin, Jambi in the east. This vast extent of outliers illustrated how pervasive the threat of Sumatran tiger in this region.

On the other hand, both NN and Ripley's K tests that represent first and second-order spatial statistic analyses indicated that the poaching incidents were significantly clustered. There were three reasons why this pattern was appeared in this region. First, the georeferencing procedure was merely based on the administration data. This made some data were georeferencing in the same or very close position. The clustering points were visibly apparent in some districts with several incidents found. Secondly, the limited resources forced the TPCU to manage their patrol carefully (Linkie et al. 2003). The TPCU teams put more focus on areas that have been recognized as the prime tiger habitat and area with imminent threat of illegal logging and encroachment (Fauna & Flora International 2008). Several sub-districts, Gunung Raya and Jangkat sub-districts in Jambi for instance, were areas where TPCU teams seized more poaching activities than any other regions. Finally, the conspicuous clustering point pattern in this area was as a result of the poachers activities pattern. They commonly set tiger traps on the animal trails and on certain time when they think the anti-poaching team did not guard the park intensively (Fauna & Flora International 2008). On August 2004, TPCU team recorded two snares have been replaced by poachers in Tapus, Lebong, Bengkulu. One of previously found snares (July 2004) in the same area took one tiger life. Moreover, the aggregation of the poaching cases was also clearly observed from the districts level. Table 2 shows the accumulation of the recorded poaching in each district during this 12 years period. This table shows that there were three districts, which had high poaching incidents. There were 28, 20 and 11 cases recorded in Kerinci, Merangin and Mukomuko districts respectively. These administrative regions are located in the center of this national park. In contrast, administrative regions that are located in the fringe of the protected park such as Solok Selatan, Pesisir Selatan, Bungo and Bengkulu Utara had very low poaching cases.

As can be seen, statistical analysis performed in this paper suggested that rampant poaching activities occurred in the heart of this national park. Even though the anti-poaching team has been established since 2000 and actively patrolling the park, this has not been stopping poachers hunting Sumatran tigers. Strengthening the TPCU is an urgent measure. Two simple mechanisms of the TPCU enhancement are adding more personnel and increasing the frequency of patrols. The addition of patrolling team members will expand the area covered with regular patrol. Correspondingly, the intensification of patrols will reduce the possibility of tigers being trapped, poisoned or shot. However, it is more critical improving the law enforcement for any illegal act toward wildlife in Indonesia. Very weak law enforcement and government commitment to conservation made Indonesia fell far behind than other developing countries in term of protecting wildlife (Meijaard 2014).

This study has shown the applicability of two spatial point pattern analyses for Sumatran tiger poaching pattern study. Both first-order (NN) and second-order (Ripley's K) tests were chosen among other spatial statistics based on their simplicity and popularity to use (Perry et al. 2006). Perry et al. (2006) elaborated the strengths and weaknesses of both techniques. The employment of different tests in a study is not only to combine various results but also to avoid false deduction due to the weakness of a method (Perry et al. 2002, 2006). These two purposes of applying different tests have been reflected by the congenial results from the two statistics.

As shown above, spatial statistics are robust tools for animal ecology study especially in Indonesia. Nevertheless, the collection of point position is the first major problem that scientists must deal with (Stoyan and Penttinen 2000). Enormous species occurrences which can be gathered from museum collections, published data or field records (Cogălniceanu et al. 2013) have assorted level of locality precision. Even with most recent locality data acquired with GPS devices, certain amount of uncertainty occurred because of GPS inaccuracy, unknown datum and coordinate imprecision (Wieczorek et al. 2004). This most likely happened when biologists with limited GPS knowledge copy coordinates data manually, ignoring the datum information.

Correspondingly, the exploration of statistical tests to answer different questions will advance the adoption of this method in Indonesia. New approaches have also gained significant consideration to link the spatial structure to process (Perry et al. 2006).Perry et al. (2006) suggested that we should use a priori hypotheses and generate testable hypotheses as an outcome of the spatial analyses. More importantly, a good multidisciplinary teamwork between ecologists and spatial statisticians must be established to attain the goals (Stoyan and Penttinen 2000).

Two spatial point pattern analyses performed in this paper showed a significant clustered pattern of Sumatran tiger poaching. Although the points were generated from georeferencing process and have some degree of uncertainty, they represent the position of the poaching incidents quite well. The aggregation of the tiger poaching demonstrates the enormous pressure to this subspecies especially in the central parts of the park. On the contrary, the extent of the points suggests that poachers were lurking for any opportunity to catch and kill this majestic animal.

While the subject of this study is the poaching activity of an endangered species, the occurrence of a species itself should become the target of investigations in the future. It would be very valuable to perform point pattern analysis of Sumatran tiger presence based on their scats, scratch marks, tracks and other signs. In addition, species occurrence records from museum collections provide immense opportunity to be explored. Finally, the point pattern analysis is multivariate in nature, therefore bivariate and multivariate analyses are potential approaches to study inter-species coexistence or competition.

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REFERENCES

Baddeley A, Turner R. 2005. Spatstat: an R package for analyzing spatial point patterns. J Stat Softw 12: 1-42.

Bishop MA. 2007. Point pattern analysis of eruption points for the Mount Gambier volcanic sub-province: a quantitative geographical approach to the understanding of volcano distribution. Area 39: 230-241.

Cogălniceanu D, Székely P, Samoilă C, Ruben I, Tudor M, Plăiaşu R, Stănescu F, Rozylowicz L. 2013. Diversity and distribution of amphibians in Romania.ZooKeys296: 35-57.

Dallot S, Gottwald T, Labonne G, Quiot JB. 2003. Spatial pattern analysis of Sharka disease (Plum pox virus strain M) in peach orchards of southern France. Phytopathology 93: 1543−1552.

Damania R, Stringer R, UllasKaranth K, Stith B. 2003. The economics of protecting tiger populations: linking household behavior to poaching and prey depletion. Land Econ 79: 198-216.

Dixon PM. 2002a. Nearest neighbour methods. In: El-Shaarawi AH, Piegorsch WW (eds) Encyclopedia of Environmetrics, vol. 3. John Wiley & Sons, New York, USA.

Dixon PM. 2002b.Ripley's K-function. In: El-Shaarawi AH, Piergorsch WW (eds). Encyclopedia of Environmetrics, vol. 3.John Wiley & Sons, New York, USA.

Fauna & Flora International. 2008. Protection and Conservation of Sumatran Tigers in and around Kerinci Seblat National Park, Sumatra, Indonesia. Sungai Penuh.

Galster S, Elliot V. 2000. Roaring back: Anti poaching strategies for the Russian Far East. In:Seidensticker J,Christie S, Jackson P (eds). Riding the Tiger: Tiger Conservation in Human-dominated Landscapes.Cambridge University Press, Cambridge.

Garcia-Milagros E, Funk VA. 2010. Improving the use of information from museum specimens: Using Google Earth© to georeference Guiana Shield specimens in the US National Herbarium. Front Biogeogr 2: 71-77.

Gatrell AC, Bailey TC, Diggle PJ, Rowlingson BS. 1996. Spatial point pattern analysis and its application in geographical epidemiology. Trans Inst Br Geogr 21: 256-274.

Gong J. 2002. Clarifying the standard deviational ellipse.Geogr Anal 34: 155-167.

Gopal R, Qureshi Q, Bhardwaj M, Jagadish Singh R,Jhala YV. 2010. Evaluating the status of the endangered tiger *Panthera tigris* and its prey in Panna Tiger Reserve, Madhya Pradesh, India. Oryx 44: 383-389.

Gray L, He F. 2009. Spatial point-pattern analysis for detecting density-dependent competition in a boreal chronosequence of Alberta. For Ecol Manage 259: 98-106.

Haase P. 1995. Spatial pattern analysis in ecology based on Ripley's K-function: introduction and methods of edge correction. J Veg Sci 575−582.

Hartana AT, Martyr DJ. 2001. Kerinci Seblat Tiger Protection Project - PelestarianHarimau Sumatera Kerinci Seblat - Report on activities and progress 2000-2001.Kerinci Seblat National Park and Fauna & Flora International, Sungai Penuh.

Hengl T, Heuvelink G,Van Loon E. 2010. On the uncertainty of stream networks derived from elevation data: the error propagation approach. Hydrol Earth SystSci 14: 1153-1165.

Hengl T, Sierdsema H, Radović A, Dilo A. 2009. Spatial prediction of species' distributions from occurrence-only records: combining point pattern analysis, ENFA and regression-kriging. Ecol Mod 220: 3499−3511.

Huo XN, Li H, Sun DF, Zhou LD, Li BG. 2012. Combining geostatistics with Moran's I analysis for mapping soil heavy metals in Beijing, China. Int J Environ Res Public Health 9: 995-1017.

Iosif R, Rozylowicz L, Popescu VD. 2013. Modeling road mortality hotspots of Eastern Hermann's tortoise in Romania. Amphibia-Reptilia 34: 163-172.

Liebman KA, Stoddard ST, Morrison AC,Rocha C, Minnick S, Sihuincha M, Russell KL, Olson JG, Blair PJ, Watts DM. 2012. Spatial dimensions of dengue virus transmission across interepidemic and epidemic periods in Iquitos, Peru (1999-2003). PLoSNegl Trop Dis 6: e1472. DOI: 10.1371/journal.pntd.0001472

Linkie M, Guillera-Arroita G, Smith J, Rayan DM. 2010. Monitoring tigers with confidence. Integr Zool 5: 342-350.

Linkie M, Martyr DJ, Holden J, Yanuar A, Hartana AT, Sugardjito J, Leader-Williams N. 2003. Habitat destruction and poaching threaten the Sumatran tiger in Kerinci Seblat National Park, Sumatra. Oryx 37: 41-48.

Liu Y, Li F, Jin G. 2014. Spatial patterns and associations of four species in an old-growth temperate forest. J Plant Interact 9: 745-753.

Loosmore NB, Ford ED. 2006. Statistical inference using the G or K point pattern spatial statistics. Ecology 87: 1925−1931.

Meijaard E. 2014. Why Is Conservation So Much Harder in Indonesia Than Elsewhere? Jkt. Globe.http://thejakartaglobe.beritasatu.com/opinion/conservation-much-harder-indonesia-elsewhere/ [December 15, 2014].

Ngowi HA, Kassuku AA, Carabin H, Mlangwa JE, Mlozi M, Mbilinyi BP, Willingham AL. 2010. Spatial clustering of porcine cysticercosis in Mbulu district, northern Tanzania.PLoSNegl Trop Dis 4: e652.

Nugraha RT,Sugardjito J. 2009. Assessment and Management Options of Human-Tiger Conflicts in Kerinci Seblat National Park, Sumatra, Indonesia. Mammal Study 34: 141-154.

Nyhus PJ, Tilson R. 2004. Characterizing human-tiger conflict in Sumatra, Indonesia: implications for conservation. Oryx 38: 68-74.

O'Brien TG, Kinnaird MF, WibisonoHT. 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. AnimConserv 6: 131-139.

Perry GL, Miller BP, Enright NJ. 2006. A comparison of methods for the statistical analysis of spatial point patterns in plant ecology. Plant Ecol 187: 59-82.

Perry J, Liebhold A, Rosenberg M, Dungan J, Miriti M, Jakomulska A, Citron-Pousty S. 2002.Illustrations and guidelines for selecting statistical methods for quantifying spatial pattern in ecological data.Ecography 25: 578-600.

Plowden C, Bowles D. 1997. The illegal market in tiger parts in northern Sumatra, Indonesia. Oryx 31: 59-66.

QGIS Development Team. 2014. Quantum GIS Geographic Information System. Open Source Geospatial Foundation Available at: http://qgis. osgeo. org [September 3, 2014].

R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.r-project.org/. [August 6, 2016]

Ramp D, Caldwell J, Edwards KA, Warton D, Croft DB. 2005. Modelling of wildlife fatality hotspots along the snowy mountain highway in New South Wales, Australia. BiolConserv 126: 474−490.

Rocchini D, Hortal J, Lengyel S, Lobo JM, Jimenez-Valverde A, Ricotta C, Bacaro G, Chiarucci A. 2011. Accounting for uncertainty when mapping species distributions: the need for maps of ignorance. ProgPhysGeogr 35: 211−226.

Sanderson E, Forrest E, Loucks C, Ginsberg J, Dinerstein E, Seidensticker J, Leimgruber P, Songer M, Heydlauff A, O'Brien TG, Bryja G, Klenzendorf S, Wikramanayake E. 2010. Setting priorities for the conservation and recovery of wild tigers: 2005-2015.In: Tilson P, Nyhus PJ (eds). Tigers of the World: The Science, Politics and Conservation of *Panthera tigris*. Academic Press, London.

Seidensticker J, Christie S, Jackson P. 1999. Preface. In: Seidensticker J, Christie S, Jackson P, Editor. Riding the Tiger: Tiger Conservation in Human Dominated Landscape. Cambridge University Press, Cambridge.

Seidensticker J. 2010. Saving wild tigers: a case study in biodiversity loss and challenges to be met for recovery beyond 2010.IntegrZool 5: 285-299.

Seidler TG, Plotkin JB. 2006. Seed dispersal and spatial pattern in tropical trees. PLoSBiol 4: e344. DOI: 10.1371/journal.pbio.0040344.

Simarro PP, Cecchi G, Franco JR, Paone M, Diarra A, Ruiz-Postigo JA, Fèvre EM, Mattioli RC, Jannin JG. 2012. Estimating and mapping the population at risk of sleeping sickness. PLoSNegl Trop Dis 6: e1859. DOI: 10.1371/journal.pntd.0001859.

Siqueira JB, Martelli CM, Maciel IJ, Oliveira RM, Ribeiro MG, Amorim FP, Moreira BC, Cardoso DD, Souza WV, Andrade ALS. 2004. Household survey of dengue infection in central Brazil: spatial point pattern analysis and risk factors assessment. Am J Trop Med Hyg 71: 646−651.

Stoyan D, Penttinen A. 2000. Recent applications of point process methods in forestry statistics. Stat Sci 61-78.

Tilson R, Nyhus PJ. 2010. The biology and politics of Sumatran tigers: Crash of the Conservation Garuda. In:Tilson P, Nyhus PJ (eds).Tigers of the World: The Science, Politics and Conservation of *Panthera tigris.* Academic Press, London.

Tilson R, Soemarna K, Ramono W, Lusli S, Traylor-Holzer K, Seal US. 1994. Sumatran Tiger Populations and Habitat Viability Analysis. Indonesian Directorate General of Forest Protection and Nature Conservation, and IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Wibisono HT, Figel JJ, Arif SM, Ario A, Lubis AH. 2009. Assessing the Sumatran tiger *Panthera tigris sumatrae* population in BatangGadis National Park, a new protected area in Indonesia. Oryx 43: 634-638.

Wibisono HT, Linkie M, Guillera-Arroita G, Smith JA, Pusparini W, Baroto P, Brickle N, Dinata Y, Gemita E, Gunaryadi D. 2011. Population status of a cryptic top predator: an island-wide assessment of tigers in Sumatran rainforests. PloS One 6: e25931. DOI: 10.1371/journal.pone.0025931.

Wibisono HT, Pusparini W. 2010. Sumatran tiger (*Panthera tigris sumatrae*): A review of conservation status. IntegrZool 5: 313-323.

Wieczorek J, Guo Q, Hijmans R. 2004. The point-radius method for georeferencing locality descriptions and calculating associated uncertainty. Int JGeogrInfSci 18: 745−767.

Wiegand T, Moloney KA. 2004. Rings, circles, and null-models for point pattern analysis in ecology. Oikos 104: 209-229.

Wikramanayake ED, Dinerstein E, Robinson JG, Karanth KU, Rabinowitz A, Olson D, Matthew T, Hedao P, Conner M, Hemley G. 1999. Where can tigers live in the future? A framework for identifying high priority areas for the conservation of tigers in the wild. In: Seidensticker J, Christie S, Jackson P (eds). Riding the Tiger: Tiger Conservation in Human Dominated Landscape. Cambridge University Press, Cambridge.

Zhang Z, Xiao R, Shortridge A, Wu J. 2014. Spatial point pattern analysis of human settlements and geographical associations in eastern coastal China - a case study.Int J Environ Res Public Health 11: 2818-2833.