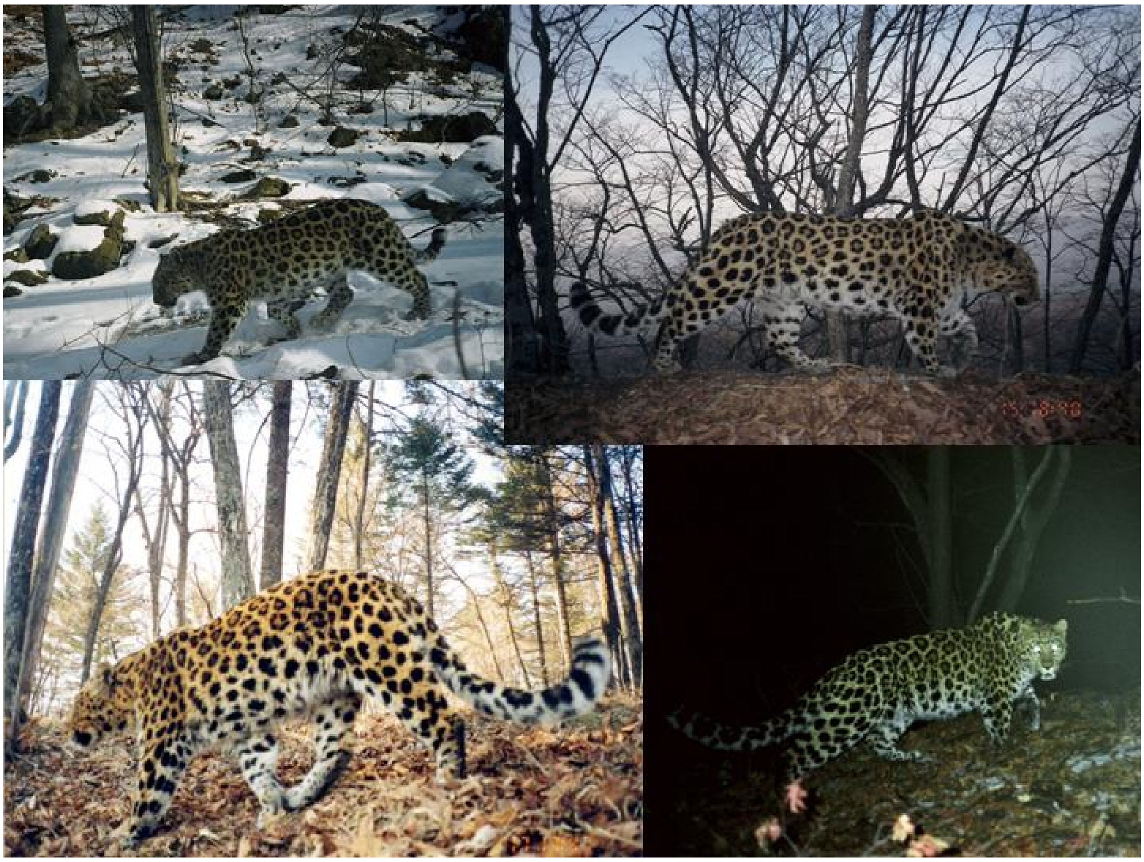
RESULTS OF CAMERA TRAP SURVEY OF FAR EASTERN LEOPARD POPULATION IN SOUTHWEST PRIMORSKI KRAI, WINTER 2002-2003

A.V. Kostyria[1]*, A.S. Skorodelov[2], D.G. Miquelle[1],
V.V. Aramilev[2], D. McCullough[3]

[1] Wildlife Conservation Society (New York, USA)
[2] Institute of Sustainable Use of Nature Resources (Vladivostok, Russia)
[3] Berkeley University (California, USA)
* post-graduate student of Institute of Biology and Soil Science FEB RAS



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Introduction

Far Eastern leopard (*Panthera pardus orientalis*) is the northernmost of 9 recently existent leopard subspecies (Miththapala et al. 1996; Uphyrkina et al. 2001). It is unique because inhabits temperate zone with low temperatures and snow cover in winter, which are extremal conditions for *P. pardus* species. Far Eastern leopards occur in southernmost part of Russian Far East (southwest Primorye). In 1998 in China only 5-7 leopards were found in the territory along Russian border (Jilin Province) (Yang et al. 1998). No evidence of leopards were found in Heilongjiang Province in China and Paektusan Mountains in North Korea (Sun et al. 1999; Kim Jin Rak et al. 1998). Far Eastern leopard along with Anatolian (*P.p. tulliana*), Arabian (*P.p. nimr*) and Barbary (*P.p. panthera*) species is on the verge of extinction and is listed in IUCN Red List (Nowell & Jackson, 1995).

As well as other representatives of *Panthera* family leopards are secretive and territorial animals. When density of ungulates (their prey species) is low, leopards have large home ranges (home range of Far Eastern leopard can be up to 100 km^2 (Ogastin et al. 1996)). At that, isolation of Far Eastern leopard range, degradation and shrinking of suitable habitat because of logging, decrease of ungulate numbers due to ineffective management of hunting leases and poaching as well as illegal shots of leopards have destructive impact on leopard population. Additionally, recent molecular genetic analysis of leopard DNA collected from the remaining RFE population using mitochondrial gene sequences plus 25 nuclear microsatellite loci has revealed a marked depletion of population genetic diversity that means extreme vulnerability of the population and potential loss of its viability (Uphyrkina, et al. 2002).

To date estimations of Far Eastern leopard number in Russia varied: different scientists gave different suggestions about leopard population size - from 25-31 (Pikunov et al. 1997) and 22-27 individuals (Pikunov et al. 2000) up to 48-50 individuals (Aramilev, Fomenko, 2000). Estimates of Far Eastern leopard population size (as well as Amur tiger (*Panthera tigris altaica*) population size) are based on information about size and distribution of predator tracks collected during winter season, when snow cover is present throughout the range of these animals (Matyushkin et al. 1996). However such methods may give considerable estimation error (Miquelle, Smirnov, unpubl.) and do not have significant statistical power (Karanth & Nichols, 1998). It can result in subjective estimations and discrepancy in analysis and interpretation of the same primary data by different experts (Miquelle, 2000). "Unique trackers" are needed to conduct winter track count. The lack of such trackers and appropriate methodology result in incorrect identification of animal tracks, absence of standard approach to track measurements and their age assessment. All these factors also lead to biased survey results. Based on mentioned above we can conclude that today one of the foreground tasks is to implement new survey methods to estimate Far Eastern leopards abundance and density as well as to monitor population status.

Color pattern of each leopard and tiger is unique, therefore it gives the possibility to identify animals using photographs. This characteristic was used in India to develop new survey methods, which use automatic camera traps and "capture-recapture" ("mark-recapture") statistical models (Karanth & Nichols,1998). Despite the fact that camera trap survey was approved in India, where tiger density is high (4-16 tigers per 100 km^2), camera traps were also successfully used to estimate Amur tiger abundance in Ussuriisky Reserve, where tiger density was low (1,6 individuals per 100 km^2 (Kostyrya et al. 2003)).

In this report we present results of the first survey of Far Eastern leopard population in southwest Primorye, which was conducted using camera traps.

METHODS

Organisation of field work

The most appropriate time for conducting camera trap survey is winter season (Kostyrya et al. 2003) therefore our survey was conducted between the 20th of November and the 10th of April. Before that, in October, southern part of Borisovskoe Plateau Zakaznik and Nezhinskoe Hunting Lease were investigated to find potential sites for camera trap sets.

We used camera traps CamTracker of passive system (Forestry Suppliers, Jackson, MS, USA), which are activated by changing of temperature. The colour patterns of different flanks of Far Eastern leopard body are asymmetrical (Fig. 1 in Attachment), therefore to identify individuals correctly two camera traps were set opposite to each other to insure that animal is photographed from both flanks simultaneously (Karanth, 1995; Karanth and Nichols, 1998). Camera traps were fasten to trees within 3.5-4 m from assumed animal motion path and their infrared sensors were at a height of 45-50 cm above the trail (Karanth et al. 2002). To insure the simultaneous activation, camera traps were aimed at one point but at the same time were placed at the angle to each other to avoid the impact of photoflashes from two opposite cameras to exposition of snapshots. Additionally we used bait to attract animals and hold them up between cameras.

For placing camera traps we chose animals' trails on southern edges of plateau-shaped ridges or on narrow ridges and spurs. Trails were considered suitable for placing camera traps if there were leopard signs on them, especially scrapes. Total 44 units (pairs of cameras) were set during the survey, the average distance between them was 3.7 km (min = 1 km, max = 6.5 km) (Fig. 2 in Attachment). Based on radiotelemetry data on home range size of females (45-65 km^2) such design, in our opinion, suggests placing minimum 2-3 camera traps within one leopard female home range . All spatial data on camera traps location were entered in GIS database using ArcView 3.2a. This program was also used for further spatial data analysis.

Camera traps were checked every 5-6 days and the number of taken frames was recorded. Cameras automatically imprinted date and time when photos were taken. Unfortunately we could not measure tracks of photographed leopards because study area was free of snow during our survey.

Leopards were identified using pictures by comparing the shape, size and topography of rosettes on both flanks of captured animals (Fig. 3 in Attachment).

Statistical conceptions

Because of lack of camera traps the study area was divided into two territories - Northern and Southern (Fig. 2 in Attachment). Northern territory includes Nezhinskoe Hunting Lease and southern portion of Borisovskoe Plateau Zakaznik. Southern territory includes Kedrovaya Pad reserve and northern portion of Barsovy Zakaznik. Survey was conducted in each territory separately: in Northern - from November 24, 2002 through January 28, 2003 and in Southern - from February 2 through April 8, 2003. These two time spans were divided into 5 day-intervals, which were designated as sampling occasions (Karanth, 1995). There were 13 sampling occasions for each territory.

The history of "captures" and "recaptures" was made up for each photographed animal i, it is series of t records, where t is the number of sampling occasions. Each record in the history was represented as X_{ij} for animal i during sampling occasion j and was denoted as "1" if the animal was photographed during this period and as "0" if it was not photographed. (Karanth & Nichols, 1998). Such design of capture history was mentioned as X-matrix (Otis et al., 1978) and can be used as input format for modelling of animal abundance using CAPTURE computer program (Rexstad & Burnham, 1991).

Program CAPTURE models animal abundance in "closed" populations (those populations, in which number of individuals is constant during overall study period). For abundance modelling we used models $M_{(0)}$ and $M_{(h)}$ included in this program. Model $M_{(0)}$ assumes that every animal *i* shows the same capture probability for each sampling occasion *j* during study period,. Whereas model $M_{(h)}$ permits different probability for each individual to be caught in subpopulation of our interest. Nevertheless this probability do not differ over all sampling occasions .

Far Eastern leopards are territorial animals. They have home ranges, which vary in size among individuals of different sex and age classes (Pikunov, Korkishko 1992, Ogastin et al. 1996). Since we do not have enough information about spatial structure of subpopulation inhabited study area then different number of camera trap units may be set inside of each leopard home range that may result in capture probability variations among captured animals. In this case $M_{(h)}$ model is considered to be more appropriate to estimate leopard abundance (Karanth & Nichols, 1998).

To compile overall leopard capture history we combined the results obtained during each time span. To do this we combined captures from different time spans by sampling occasions, i.e. "captures" for the first combined occasion include all "captures" from the first occasions of each time span. Similarly, "captures" and "recaptures" for the second combined occasion includes all "captured" and "recaptured" animals from the second occasions of each time span, etc. (Nichols & Karanth, 2002) (Table 1).

Table 1. Procedure of combining hypothetical X-matrices of two time spans to compile overall capture history

Animal # (*i*)	**Occasion (*j*)**			
	1	**2**	**3**	**4**
L1	1	0	0	1
L2	1	1	0	0
L3	1	1	1	1
L4	0	0	1	0

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Animal # (*i*)	**Occasion (*j*)**			
	1	**2**	**3**	**4**
L5	1	1	1	1
L6	0	1	1	0
L7	0	0	0	1
L8	1	0	0	0

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Animal # (*i*)	**Combined occasion (*j*)**			
	1	**2**	**3**	**4**
L1	1	0	0	1
L2	1	1	0	0
L3	1	1	1	1
L4	0	0	1	0
L5	1	1	1	1
L6	0	1	1	0
L7	0	0	0	1
L8	1	0	0	0

Animal density is of great interest to researchers because this parameter is used for comparison and analysis of status of populations and subpopulations inhabited different ranges or different parts of one range. When large territorial mammals are counted using traditional methods (WTC), study area, used in calculations, is determined by a researcher and is often limited by borders of hunting lease, zakaznik, reserve or river basin, which usually include only part of suitable habitat. Therefore animals, counted in study area, may use larger territory, i.e. study area may include only parts of animals' home ranges. Use of such approach may result in overestimated animal density. To determine the effective area for estimating density we used the method suggested by Wilson and Andersen (1985) and adapted for camera trap survey of tigers by Karanth and Nichols (1998). This method is based on estimation of additional buffer strip, which may include parts of captured animal home ranges. Classically density can be calculated as : $D = \frac{N}{A}$, where N is the number of animals and A is the area. In our case total or effective area *A(W)* includes area of minimum concave polygon, which was defined by the outermost camera trap locations, and area of additional buffer strip with width W (Fig. 2 in Attachment).

Denote maximum distance between two locations of consecutive captures of animal i as d_i, and the number of animals that were caught at least twice during the study as m. Then maximum average distance $\overline{d}$ and its variance can be computed as :

$$\overline{d} = \frac{\sum_{i=1}^{m} d_i}{m} \quad (1);$$

$$\hat{\mathrm{var}}(\overline{d}) = \frac{\sum_{i=1}^{m} (d_i - \overline{d})^2}{m(m-1)} \quad (2)$$

Buffer strip width W and its variance can be estimated as:

$$W = \frac{\overline{d}}{2} \quad (3);$$

$$\hat{\mathrm{var}}(W) = \frac{\hat{\mathrm{var}}(\overline{d})}{4} \quad (4)$$

Then leopard density $\overline{D}$ and its variance can be calculated according to:

$$\overline{D} = \frac{\overline{N}}{A(W)} \quad (5);$$

$$\hat{\mathrm{var}}(\overline{D}) = D^2 \left[\frac{\hat{\mathrm{var}}(A(W))}{\left[A(W)\right]^2} + \frac{\hat{\mathrm{var}}(\overline{N})}{\overline{N}^2} \right] \quad (6);$$

where: $$\hat{\mathrm{var}}(A(W)) = 4\pi A(W)\,\hat{\mathrm{var}}(W) \quad (7),$$

and $$\hat{\mathrm{var}}(\overline{N}) = \left[SE(\overline{N})\right]^2 \quad (8),$$

where $SE(\overline{N})$ is standard error which was calculated by program CAPTURE for each model separately, and standard error $SE(\overline{D})$ is $\sqrt{\hat{\text{var}}(\overline{D})}$.

Distribution of non-captured animals is log-normal (Rexstad & Burnham, 1991). Therefore lower bound of 95% confidence interval, calculated by program CAPTURE, may be equal or exceed the number of photographed animals (M_{t+1}), and upper bound may be significantly higher than that on calculating confidence interval of normal distribution (Karanth 1995).

The next important stage in the survey is estimation of animal abundance and density within the entire range. To provide the ground for comparison we extrapolate data in two ways, each of them was based on the specific hypothesis:

1. leopard distribution is uneven and densities are not equal in entire range;
2. leopard density is the same within the entire range.

To estimate leopard abundance under first hypothesis we used the results of leopard survey, conducted in February 2003 using traditional methods (Pikunov et al. 2003), as an index. Assuming that there is a direct relationship between density of leopard tracks per 10 km of survey routes and leopard density, to extrapolate data we used the ratio with known leopard density in our study area. For this purpose all suitable habitats (see Murzin and Miquelle 2001) were divided into 5x5 km quadrants. Total length of survey routes and total number of encountered leopard tracks were counted for each quadrant. Quadrants without survey routes were excluded from the analysis. Then track density per 10 km of survey routes was calculated for each quadrate. Based on distribution of quadrates with similar density estimates we stratified suitable habitats outside of our study area to 5 strata *k* (Fig. 5).

Denoting leopard density in each strata as $\overline{D}_k$, mean leopard track density per 10 km of survey routes in each strata as $\overline{a}_k$ and mean track density on survey routes in study area *A(W)* as $\overline{a}$ we have the following equation for calculating leopard density for each strata *k:*

$$\overline{D}_k = \frac{D\overline{d}_k}{\overline{a}} \qquad (9),$$

where *D* is leopard density in area *A(W)*. Applying inverse function for calculating density through numbers we calculated leopard abundance for each strata and then for the entire range.

On the assumption of the second hypothesis we calculated leopard numbers using ratio:

$$\hat{N} = \frac{N\hat{A}}{A(W)} \qquad (10),$$

where $\hat{N}$ is total leopard numbers in entire area and $\hat{A}$ is total area of leopard range calculated by adding/combining areas of strata *k* used for analysis in the first case and study area *A(W)*.

In both cases total numbers were calculated for minimum, average and maximum estimates based on analysis of data obtained during camera trap survey.

RESULTS

Testing of camera traps

At a temperature below 20^0 C (at night) functioning of camera traps was estimated as bad. Leaves of camera's shutter became frozen, it resulted in increased exposure and we got several light-struck takes. Additionally at low temperatures working life of lithium batteries in cameras decrease sharply therefore it is necessary to check camera traps as often as possible. Despite all mentioned above, such low temperatures are rare in southwest Primorye and equipment failure did not influence on survey results.

We noticed that infrared sensors differ in sensibility (tuning) therefore it is necessary to set up camera trap carefully and pay special attention to the angle of its vertical inclination (it should be at angle of 90^0 to assumed animal motion path). Sensors become less sensible at low temperatures. If camera is inclined (even slightly) and the distance between camera and assumed animal motion pass is 2-2.5 m sensors function badly (despite the fact that manufacturer guarantee the work within 20 m) and it results in "omissions". We observed several cases of involuntary actuation of camera traps due to direct sunrays influence.

We believe the main disadvantage of passive camera traps is the delay (20 seconds) for preparing infrared sensor for work after each shooting. The advantages of such systems are small weight of monoblocks (one person can carry up to 10 monoblocks) and short time needed for their set up.

Leopard numbers and density in study area

During survey in Northern unit 1136 camera-days were spent, in Southern unit -1254 and total 2390 camera-days in entire study area. 112 pictures of 16 different leopards were obtained (53 "captures") (Table 2).

Table 2. The number of snapshots and leopard "captures" obtained during the survey

Area	Number of pictures	Number of "captures"	Number of captured leopards M_{t+1}
Northern	65	30	9
Southern	47	23	8
Total	112	53	16*

* Total number of photographed leopards is less than sum of individuals photographed in two units because one individual was registered in both units.

However if one individual i was captured more than once during one sampling occasion j only one capture was recorded in capture history for this occasion. Capture history of leopards is shown in Table 3. Animals were recaptured for 1-6 times.

Table 3. Capture history of leopards in study area

Animal # (*i*)	**Occasions (*j*)**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
L1	0	1	0	0	1	0	1	0	0	1	1	0	0
L2	1	1	1	0	0	0	1	1	0	0	1	0	0
L3	0	1	1	0	1	0	0	1	0	1	0	1	0
L4	0	1	0	0	0	0	0	0	0	0	0	0	0
L5	0	0	0	0	0	1	0	0	0	1	1	0	1
L6	0	0	0	0	0	0	0	1	0	1	0	0	0
L7	0	0	0	0	0	0	1	0	0	0	0	0	0
L8	0	0	0	0	0	0	0	0	0	0	1	0	0
L9	0	0	0	0	1	1	1	0	0	1	1	0	0
L10	1	0	0	0	1	0	0	0	1	1	0	0	1
L11	0	0	1	0	0	0	0	1	0	0	0	0	0
L12	0	1	0	0	1	0	0	0	0	0	0	0	0
L13	0	0	0	1	0	0	0	1	0	0	0	0	1
L14	0	0	0	0	0	0	0	0	1	0	0	1	0
L15	0	0	0	0	0	0	0	0	0	1	0	0	0
L16	0	0	0	0	0	0	0	1	0	0	0	0	0

Long-duration survey and large number of "capture" occasions may led to concern about closure assumption of studied leopard subpopulation (Karanth & Nichols, 1998). However the closure test for Northern, Southern territories and for the total study area, supported by program CAPTURE, showed positive result (Table 4). It gives us the possibility to use the models for "closed" population to estimate leopard abundance..

Table 4. The leopard abundance in Northern and Southern territories and in the total study area

Area	**"Closeness" test**		**Model**							
			M_0				***M_h***			
	z	***P***	$\overline{N}$	***SE***	***95% CI***	***p ****	$\overline{N}$	***SE***	***95% CI***	$\hat{p}$ ********
Northern unit	-1,026	0,153	9	0,5	9-9	0,231	11	3,3	10-28	0,189
Southern unit	0,195	0,578	8	0,7	8-8	0,202	10	1,9	9-18	0,162
Total area	-0,282	0,389	16	0,8	16-20	0,225	18	3,1	17-34	0,201

* M_0 model capture probability for sampling occasion *j*
** M_h model average capture probability for sampling occasion *j*

Average number of leopards in territories varied from 8 to 11 depending on used model. However, as it was mentioned above, one leopard was "captured" in both territories therefore the total number of leopards in these territories is more than in total study area, where average number of leopards, calculated using M_h model, was 18 individuals (Table 4). In spite of high values of upper bound of model M_h 95% confidence interval and based on interval values of model M_o we suppose that maximum number will be closer to $\overline{N} + SE$ calculated under model M_h. Based on this we can suggest that leopard number in study area is 16-21 individuals, where lower limit corresponds to M_{t+1} value.

Maximum distances between "recaptures" of some individuals varied from 2.8 to 15.2 km. Average value $\overline{d_i}$ for study area was 9.7 km and width of buffer strip W - 4.85 km (Table 5). Consequently effective area $A(W)$ in our survey was 1,548 km^2 and mean leopard density in study area was 1.2 individual per 100 km^2 (under M_h model) (Table 5).

Leopard numbers and density in entire range

Based on the first hypothesis, after analysing data of WTC the following results were obtained: average route length per 25 km^2 varied among strata and study area from 7 to 9.6 km (Table 6) with minimum 0.04 km and maximum 23.6 km. The most surveyed area was situated in the northern part of range (Fig. 4 in Attachment). Mean track density per 10 km also varied greatly - from 0.23 in south of range (South 2 plot) to 1.54 in study area (Fig 5 in Attachment). Based on these results we estimated average number of leopards in entire range - 33 individuals (min=29, max=38) (Table 6).

After extrapolating the data (assuming that leopard density is equal in entire range) we estimated average number of leopards - 50 individuals (min=44, max=58).

24-hours activity

Assuming that there is a direct correlation between frequency of leopard "captures" in specific time of the day and activity we simulated the 24-hours activity curve. To do this we divided 24 hours into 6 periods (4 hours in each) (Fig 1). Then we counted the number of "captures" for each period. As a result we ascertained that 24-hours activity of Far Eastern leopard is described by bimodal curve with peaks in the morning (8 a.m. - 12a.m.) and in the evening (4 p. m - 8 p.m.) (Fig. 1).

Besides leopards 6 Amur tigers were photographed (16 pictures). Total number of "captures" is seven. Tigers number was not simulated because of lack of information.

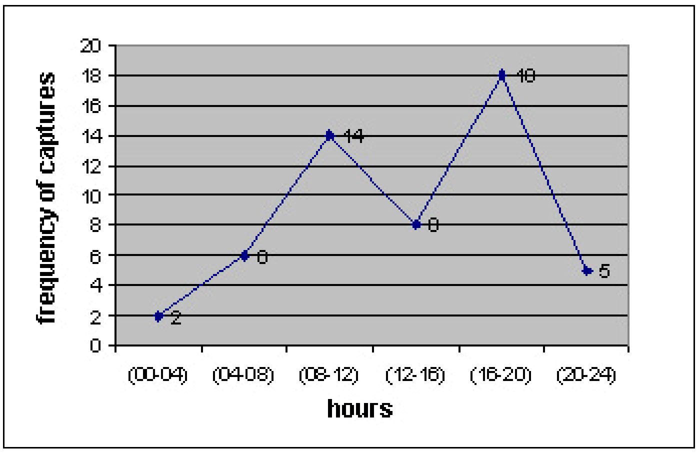

Figure 1. Curve of 24-hour activity of Far Eastern leopards (n=53)

Table 5. Sizes of effective areas and leopard densities in survey units and in total study area

Territories	**Area of polygon with camera traps (km^2)**	**Maximum average distance between captures (km)**	**Buffer strip width (km)**	**Effective area (km^2)**	**Leopard density (individuals per 100 km^2)*** $\bar{D} \pm S$	
		$\bar{d} \pm S$	$W \pm S$	$A(W) \pm S$	$M_{(0)}$	$M_{(h)}$
Northern	274	11,2±1,2	5,6±0,6	808±62	1,1±0,1	1,4±0,4
Southern	357	8,5±1,9	4,25±0,9	772±94	1,03±0,2	1,3±0,3
Total study area	765	9,7±1	4,85±0,5	1548±66	1,1±0,8	1,2±0,2

* Average number of Far Eastern leopards were used to calculate densities

Table 6. Total number of Far Eastern leopards in southwest Primorsky Krai

Territory	**Area (km^2)**	**Average density of survey routes per 25 km^2**	**Average track density per 10 km**	**Leopard density**			**Leopard numbers**		
				D_{min}	$\overline{D}$	D_{max}	N_{min}	$\overline{N}$	N_{max}
Study area	1,548*	9,6	1,58	1,03	1,2	1,4	16	18	21
Strata North 1	678	9,3	0,71	0,46	0,52	0,61	3,1	3,5	4,1
Strata North 2	282	7,0	1,32	0,86	0,97	1,14	2,4	2,7	3,2
Strata East	90	7,6	1,21	0,79	0,89	1,04	0,7	0,8	0,9
Strata South 1	863	8,9	0,95	0,62	0,70	0,82	5,3	6,0	7,1
Strata South 2	780	7,5	0,23	0,15	0,17	0,20	1,2	1,3	1,5
All suitable habitats	***4,151*****	***----***	***----***	***0,70***	***0,78***	***0,92***	***~ 30***	***~ 33***	***~ 39***

* area corresponds to $A(W)$

** area corresponds to $\hat{A}$

DISCUSSION

In spite of sceptical forecast, use of camera traps for leopard survey in areas with low leopard densities was successful.

Previous studies showed low probability of "capture" of young animals ((Karanth, 1995; Karanth & Nichols, 1998). We faced the same result: 20 second pause between consecutive shots excludes the chance to take photographs of two animals travelling together (Kostyrya et al. unpubl. data). Previous winter transect counts showed that the average number of litters is not high and the number of kittens is low: 4 individuals (Pikunov et al. 1997), 1-3 individuals (Pikunov et al. 2000), 5 individuals (Aramilev, Fomenko, 2000). Likely that juvenile cubs, which stay in dens and do not follow females, are not registered at all. Based on this assumption we believe that comparative analysis of data obtained using camera traps and during previous surveys could be done.

Average population size extrapolated on the basis of the second hypothesis is twice higher than that estimated during the most of previous surveys. Our study area included territories with highest leopard densities therefore our results are overestimated and probably indicate optimum leopards number in suitable habitat with conditions favourable for these predators. Results of assessment of habitat carrying capacity based on radiotelemetry data on structure of leopard subpopulation in Kedrovaya Pad Reserve (Ogastin et al. 1996) were similar to our estimates of habitat carrying capacity in southwest Primorye. The same results were obtained by other researchers, who finally determined not the actual number of leopards but carrying capacity of suitable habitat (Aramilev, Fomenko, 2000). As for extrapolation of our results on the basis of the first hypothesis we can mention that mean number of animals (33) also exceed the results of previous surveys and is closer to bottom limit of our estimates (29). Thus 21-28 adult leopards were registered in 1997 (Pikunov et al. 1997), and only 21-25 animals in 2000 (Pikunov et al. 2000). The reason of this difference is underestimation, which is typical for winter transect counts (Miquelle, Smirnov, unpubl. data). Additionally, partial overlap of track size of adult females and subadult males and track deformation rate due to isolation (Miquelle, Smirnov, unpubl. data) may influence on final field data interpretation results. Definitely it is very important to concern about track deformation during sweep surveys, when it takes about a month to conduct such survey and long time may pass after last snowfall. In India camera trap surveys also showed higher tiger numbers and density in comparison with other methods (track counts, radiotelemetry and visual counts) (Karanth & Nichols, 1998).

It is supposed that competition between tigers and leopards first of all depends on densities of prey species of different sizes classes in territories, where these two predators are sympatric (Rabinowitz, 1989; Seidensticker, and McDougal, 1990; Karanth and Nichols, 1998). Leopards are more vulnerable and tigers can eliminate them if densities of prey species of large and medium sizes are low. Habitats where only small prey species occur are more favorable for leopards. In southwest Primorye tigers and leopards prey on various animals. Though we do not have enough information about the diet of both predators especially in summer we may suppose that competition between them decrease in summer, when small prey species are more available. In winter conditions are less favorable for leopards and the extent of trophic niche overlap with that of Amur tigers probably reaches its peak. Nevertheless, in winter the overlap of trophic niches of these predators probably decreases because of difference in habitat use. It is confirmed by small number of Amur tigers "captures" (7 versus 53 "captures" of leopards) by camera traps set on leopard trails. Additionally, the reduction of niches' overlapping can be explained by difference in activity rhythms, which are described for leopard by bimodal curve with peaks in the morning and in the evening. Besides it may be supposed that in southwest Primorye, where snow depth is small, leopards successfully compete with lynxes occupying the same econiche and eliminate them.

Location of leopard "captures" showed that in Northern study territory the highest number of leopards was "captured" in Nezhinskoe Hunting Lease (Fig. 6 in the Attachment). It may be supposed that the main abiotic factor, which limits expansion of leopards into northern parts of southwest Primorye (Borisovka and Krounovka river basins, upper Nezhinka river), is the depth of snow cover. Though this factor in southwest Primorye does not influence on Amur tigers, which are more adapted for snow and therefore occupy Borisovskoe Plateau Zakaznik that includes all territories mentioned above. It is also necessary to mention low productivity of fir-spruce forests prevailing in this zakaznik and their insignificant trophic role for ungulates, whose densities are low in such habitat types. Nevertheless, as it was mentioned above, Amur tigers may be more adapted to such conditions than leopards and successfully use these habitats. The most valuable forests for ungulates and consequently for predators are pine-deciduous forests and oak forests. Mixed Mongolian oak-pine forests on southern slopes are the most productive (data on pine and oak productivity in Sikhote-Alin Reserve, Smirnova, Gromyko, unpubl. data). Such forests cover middle reaches of rivers south of Borisovskoe Plateau, where Nezhinskoe Hunting Lease is situated. With the exception of oak forest 2-3 km wide, extending along Razdolnoe-Khasan road, degraded by fires every year.

Most probably Barsovy Zakaznik does not function well to protect leopards. Thus in Southern unit 6 of 8 photographed leopards were "captured" in Kedrovaya Pad Reserve (one of them was also "captured" in Barsovy Zakaznik) and only two leopards were photographed outside the reserve. At that one of these leopards was photographed also in Nezhinskoe Hunting Lease in the middle reaches of Amba river. Perhaps the Reserve plays a key role as leopard population source for Barsovy zakaznik. In future it is necessary to pay special attention to status and support of Kedrovaya Pad Reserve when developing leopard conservation programs.

Finally we would like to mention that successful use of modern technologies brings researches on populations dynamics to the next qualitative level. In long-term monitoring programs the application of statistical methods is especially important, as it provides a standardized approach to assess numbers and densities and make them independent from subjective expert estimates. Additionally, camera trap surveys with using of statistical models for "open" populations when applied to long-term monitoring programs can give valuable information on such important population characteristics as mortality and recruitment rates, which are the basis for development of population models and prognosis of population status.

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LITERATURE

Aramilev, V.V., Fomenko, P.V. Simultaneous survey of Far Eastern leopards and Amur tigers in Southwest Primorski Krai, winter 2000. In: A Survey of Far Eastern Leopards and Amur Tigers in Southwest Primorye Krai, in 2000. Vladivostok. 2000

Karanth K.U. and Nichols J.D. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79: 2852-2862., 1998.

Karanth K.U. Estimating tiger populations from camera-trap data using capture-recapture models. Biological Conservation 71: 333 – 338, 1995

Kim Chen Rak, Miquelle D.G., Pikunov D.G. A survey of tigers and leopards and prey resources in the Paektusan area, North Korea, in winter 1998. (unpubl.)

Kostyrya, A.V., Belozor, A.A., Miquelle, D.G., Aramilev, V.V., Kotlyar, A.K. Use og cameratraps for Amur tiger survey. Theriofauna of Russia and adjacent territories (VII Conference of Theriological Society). Proceedings of International Conference, February 6-7, 2003. Moscow. 2003. Pp. 176-177.

Matyushkin, E.N., D. G. Pikunov, Y. M. Dunishenko, D. G. Miquelle , I. G. Nikolaev, E. N. Smirnov, G. P. Salkina, V. K. Abramov, V. I. Bazylnikov, V. G. Yudin, and V. G. Korkishko. 1996. Numbers, distribution, and habitat status of the Amur tiger in the Russian Far East: “Express-report”. Final report to the USAID Russian Far East Environmental Policy and Technology Project.

Miquelle D.G. Counting tigers in the Russian Far East: “How many are there?” Versus “Is There a Change // Russian Conservation News, No 23, Moscow. 2000.

Miquelle, D.G., Murzin, A.A. Spatial distribution of Far Eastern leopard in southwest Primorski Krai, and recommendations for their conservation. Vladivostok. 2000

Miththapala S., Seidensticker J., O’Brien S.J. Phylogeographic subspecies recognition in leopards (*Panthera pardus*): molecular genetic variation // Conservation Biology 10: 1115-1132. 1996.

Nichols J.D. and Karanth K.U. Statistical concepts: estimating absolute densities of tigers using capture-recapture sampling. Pages 125-137 in Monitoring tigers and their prey. Center for Wildlife Studies, India. 2002

Nowell K., Jackson P. New Red List Categories for Wild Cats // Cat news 23: 21-27. 1995.

Ogastin, J., Miquelle, D.G., Korkishko, V.G. Leopard is on the air. Zov Taigi, vol. 4(27), Vladivostok. 1996. Pp. 6-11.

Otise D.L., Burnham K.P., White G.C. and Anderson D.R. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62: 1-135. 1978.

Pikunov D.G., V.V. Aramilev, P.V. Fomenko, D.G. Miquelle, V.K. Abramov, V.G. Korkishko, I.G. Nikolaev. Leopards number and its habitat structure in the Russian Far East. A final report to The Wildlife Conservation Society. 1997

Pikunov, D.G., Abramov, V. K., Korkishko, V.G., Nikolaev, I.G., Belov, A.I. “Sweep” survey of Far Eastern leopards and Amur tigers in Southwest Primorski Krai, winter 2000. In: A Survey of Far Eastern Leopards and Amur Tigers in Southwest Primorye Krai, in 2000. Vladivostok. 2000

Pikunov, D.G., Korkishko, V.G. Leopard of the Far East. Moscow. Nauka. 1992. P. 191.

Pikunov, D.G., Miquelle, D.G., Abramov, V.K., Nikolaev, I.G., Seredkin, I.V., Belov, A.I., Korkishko, V.G. Surveys of leopards (*Panthera pardus orientalis*) in the Russian Far East (February 2003) (unpubl.)

Rabinowitz A.R. The density and behavior of large cats in dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. Natural History Bulletin of the Siam Society 37: 235-251. 1989.

Rextad E. and Burnham K.P. User's guide for interactive program Capture. Abundance estimation of closed animal populations. Colorado State University, Fort Collins, CO, USA. 1991.

Seidensticker J., and McDougal C. Tiger predatory behavior, ecology and conservation. Pages 105 – 125 *in* N. Dunstone and M.L. Gorman, editors. Mammals as predators// Clarendon press, Oxford, UK. 1993.

Sun B., Miquelle D.G., Xiaochen Y., Zhang E., Hiyai S., Goshen G., Pikunov D.G. Dunishenko Y.M. and Nikolaev I.G., and Daming L. 1999 survey of Amur tigers and Far Eastern leopards in eastern Heilongjiang Province, China, and recommendation for their conservation. A final report to The Wildlife Conservation Society. 1999, pp. 56.

Uphyrkina O., Johnson W., Quigley H., Miquelle D., Marker L., Bush M., O'Brien S. J. Phylogenetics, genome diversity and origin of modern leopard, *Panthera pardus* // Molecular Ecology. 2001. V. 10. pp. 2617-2633.

Uphyrkina O., Miquelle D., Quigley H., Driscol C., O'Brien S. J. Conservation Genetics of the Far Eastern leopard (*Panthera pardus orientalis*) // J. Heredity. 2002.

Willson K.R. and Anderson D.R. Evaluation of low density estimators of small mammal population size. Journal of Mammalogy 66: 13-21., 1985.

Yang S., Jiang J., Wu Z., Li T., Yang X., Han X., Miquelle D.G., Pikunov D.G., Dunishenko Y.M., and Nikolaev I.G. Report on the Sino-Russian joint survey of Far Eastern leopards and Siberian tigers and their habitat in the Sino-Russian boundary area, eastern Jilin Province, China, winter, 1998. A final report to the UNDP and The Wildlife Conservation Society. 1998. 42 p.

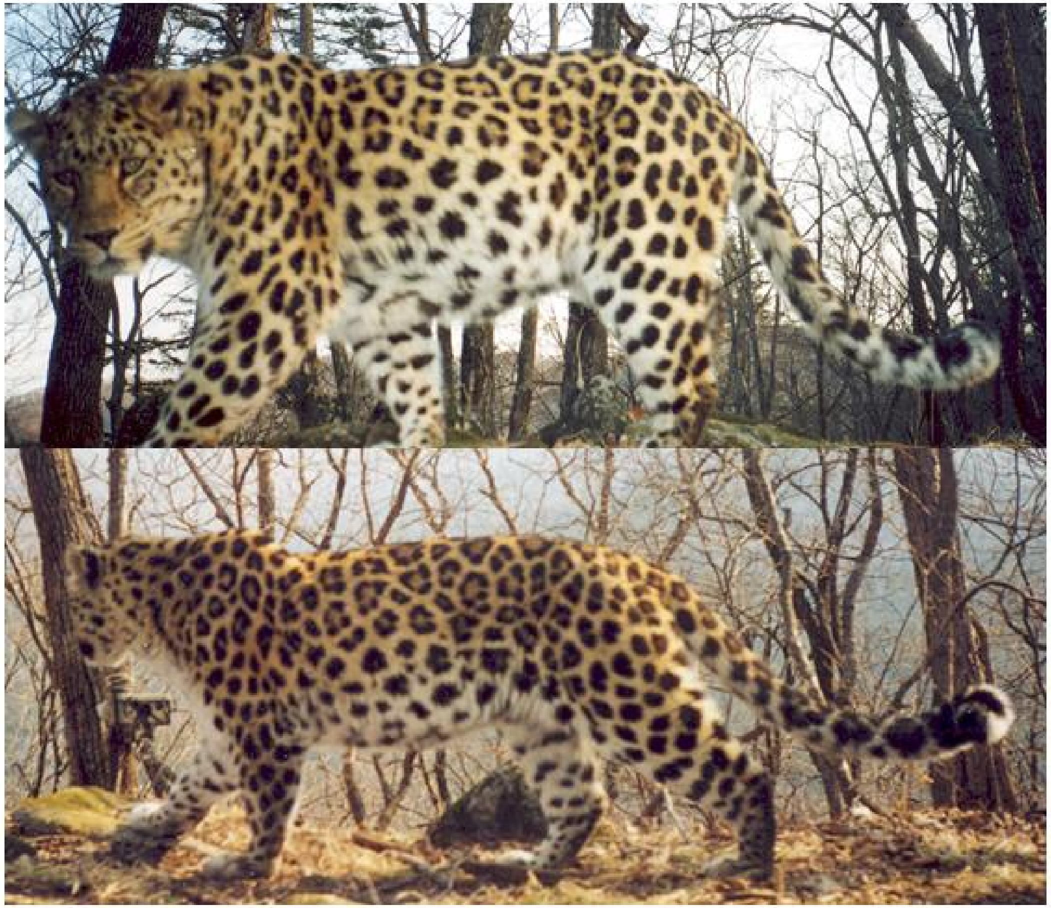

Figure 1. Coloration of leopard is asymmetrical on different sides (one leopard photographed from both sides)

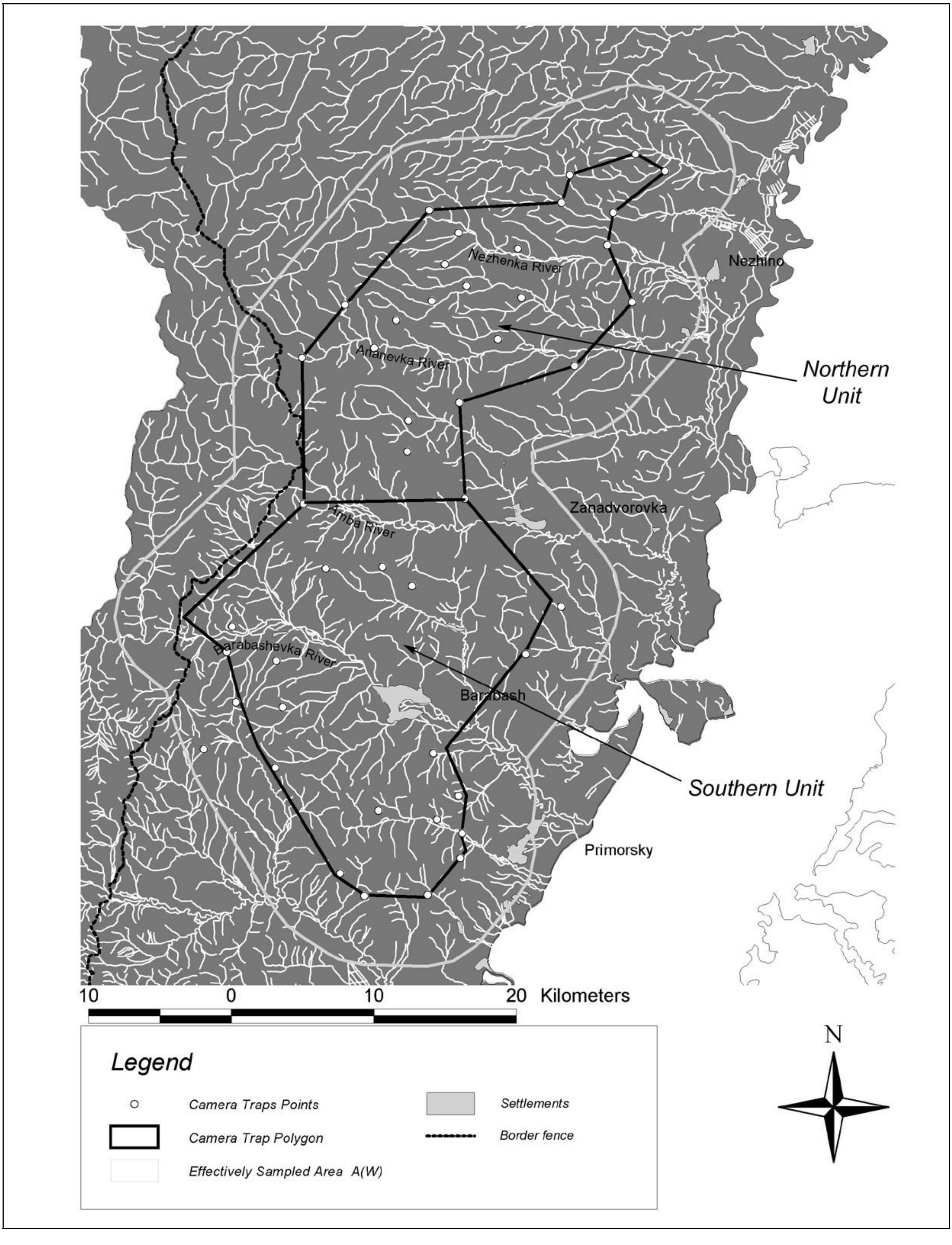

Figure 2. Study area and camera trap locations in Northern and Southern units

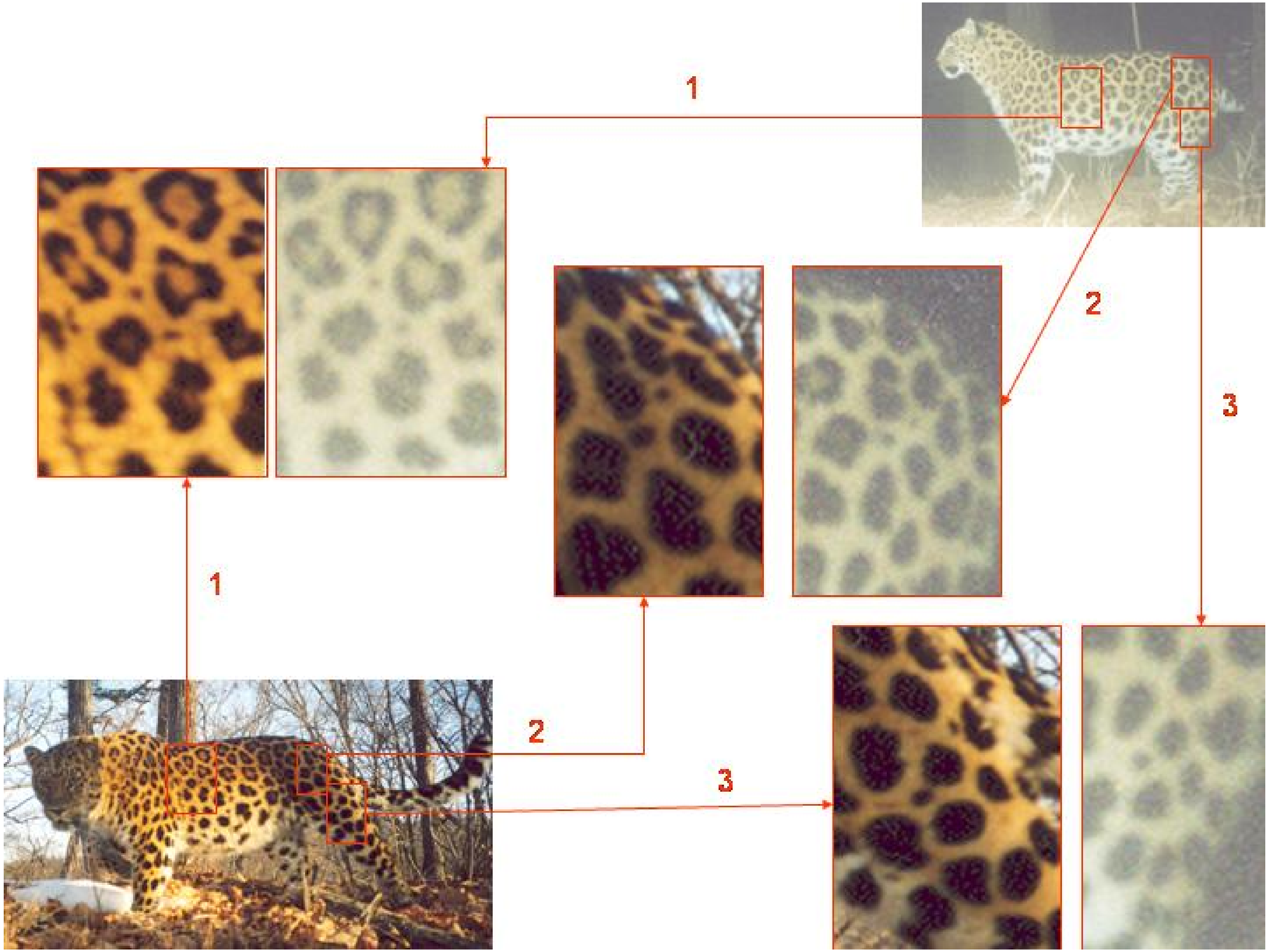

Figure 3. Identification of Far Eastern leopard by shape and topography of rosettes

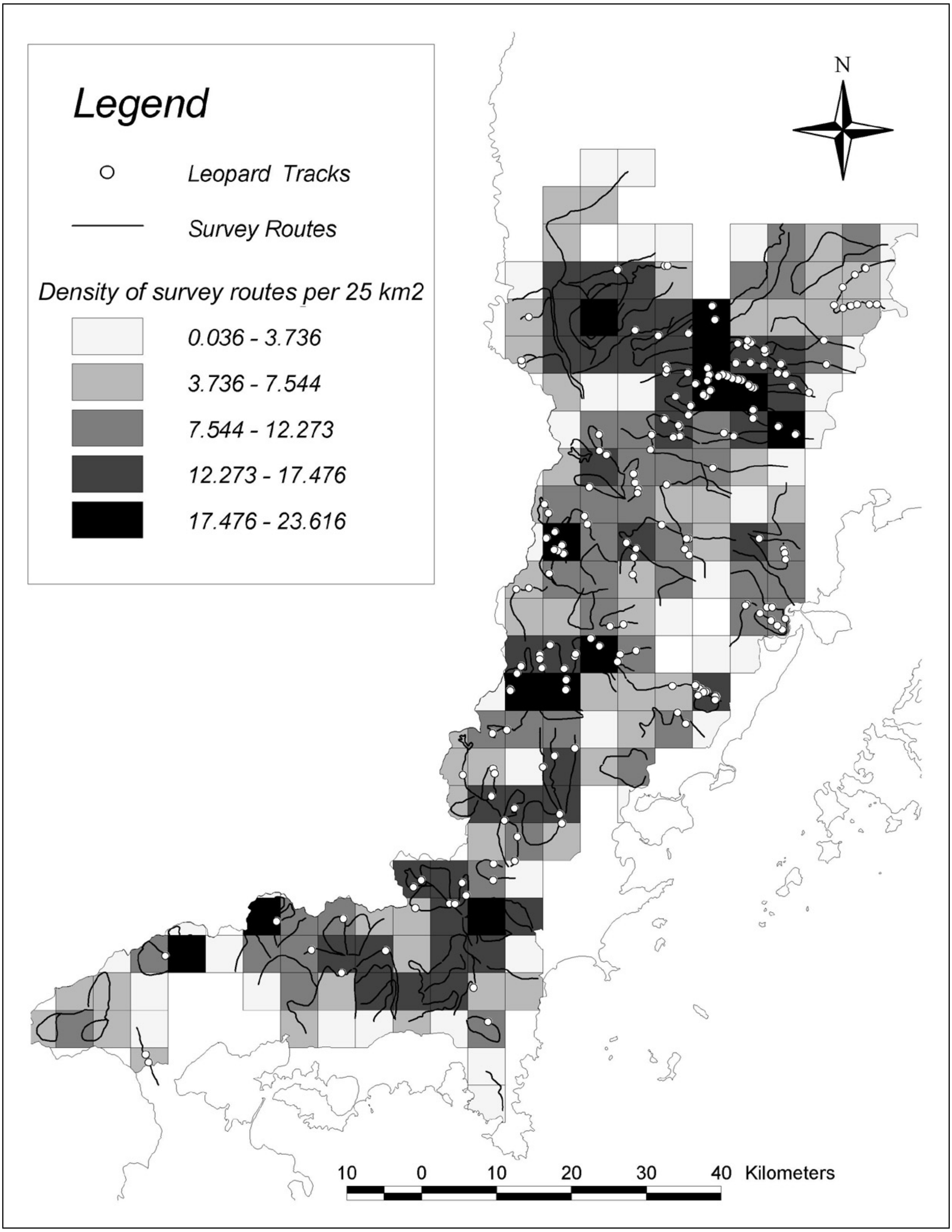

Figure 4. Density of survey routes in suitable leopard habitat, survey 2003 (Pikunov et al. 2003)

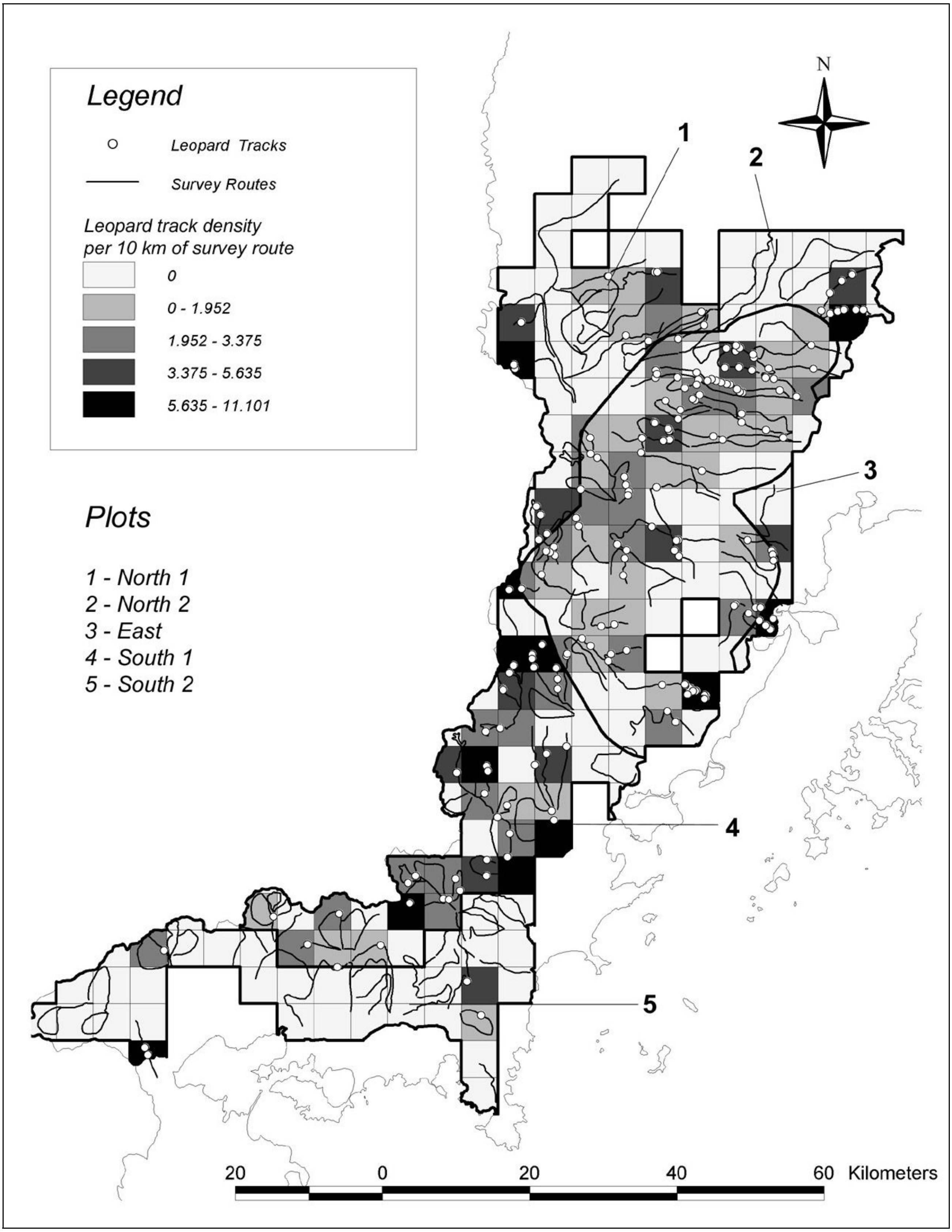

Figure 5. Leopard track density per 10 km of survey routes

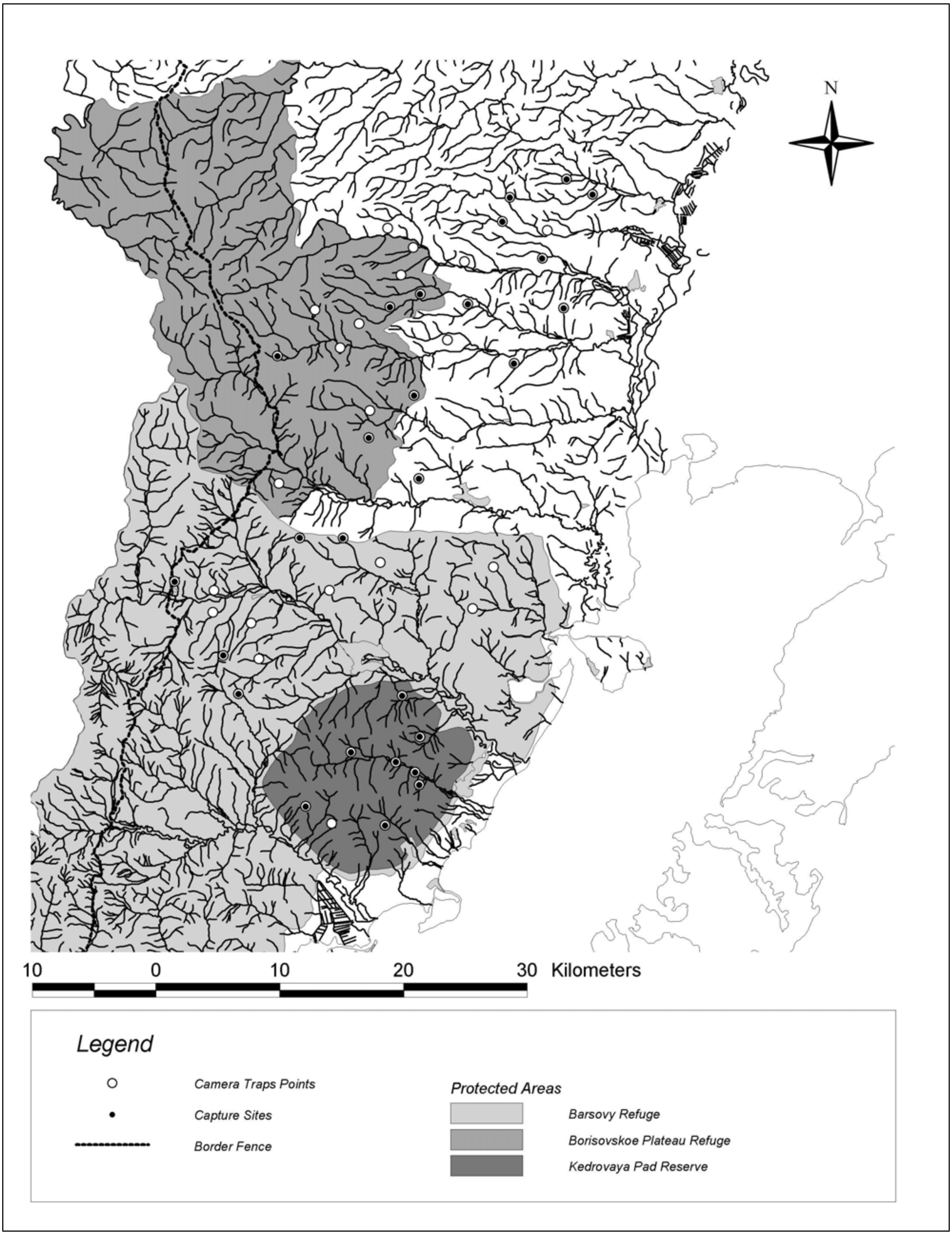

Figure 6. Location of leopard “captures”