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Estimation of Population Size and Density of the Far Eastern Leopard (*Panthera pardus orientalis*) in the Southwest of Primorsky Krai

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ABSTRACT

Monitoring of the critically endangered Far Eastern leopard is crucial for understanding population status and trends to assess the effectiveness of conservation interventions. This study provides an up-to-date assessment of the Far Eastern leopard population in the southwest of Primorsky Krai, Russia. Population parameters were derived from camera trap monitoring data conducted in the protected areas in 2022. The analysis of population size and density was carried out using the spatially explicit capture-recapture method. A total of 116 individuals were identified: 104 adults and 12 cubs. The estimated population size was 118 individuals (95% CI: 115–121), with a population density of 2.46 individuals/100 km^2, which is 20% higher than previously published estimations for 2020 and doubled since 2014. A reassessment of the global population of Far Eastern leopards will require a combination of data from both Russia and China, as was done in 2014 and 2015.

1 | Introduction

Wildlife monitoring is crucial for understanding the patterns of ecosystem dynamics and the complex biotic factors associated with them. One of the key components of this monitoring is the regular assessment of species abundance and spatial distribution (Kuzyakin 2017). Regular monitoring and standardized data collection on populations of endangered or threatened species are particularly important to assess status and the effectiveness of conservation interventions. Furthermore, monitoring the status of animal populations and assessing their abundance and density is crucial for studying animal ecology and the animals' unique biology. Currently, the conservation of biodiversity is one of the leading global issues, relevant both at the species and ecosystem levels. The rarest species (and at the same time the most vulnerable) are those that, by their role in ecosystems and their biological characteristics, cannot be widespread, but play the key regulatory roles in maintaining balance within ecosystems.

The Far Eastern leopard (*Panthera pardus orientalis*), also known as the Amur leopard, is one of the rarest subspecies of large felids and is recognized as a critically endangered subspecies (IUCN Red List; Stein et al. 2025). It is also included in the Red Data Book of the Russian Federation (2021), which is a national analog of the IUCN Red List. The Far Eastern leopard is characterized by its high mobility, large home ranges (up to 300 km^2), and elusive behavior, which pose significant

Summary

Practitioner Points

- This study indicated continued growth of the Far Eastern leopard population in Russia due to effective conservation measures.
- The estimated population size and density parameters using SECR provide precise results relative to point estimates from previous years due to methodological improvement.
- Further assessment of the global population across the subspecies' range is essential, given the cross-border distribution.

challenges to population monitoring (Pikunov and Korkishko 1992; Kuzyakin 2017). From 1972 to 2003, the status of this remnant population in Russia was estimated using a track count methodology that was initially developed for Amur tigers (*Panthera tigris altaica*) (Abramov 1961; Yudakov and Nikolaev 1987; Matyushkin et al. 1996). This method attempted to distinguish individuals based on track size and distribution surveyed along predetermined survey routes (Pikunov and Korkishko 1992). However, the accuracy of such surveys is subject to many limitations, including measurement errors in track dimensions, the subjective interpretation of track age by different observers, and the assumption that individuals of each sex have nonoverlapping home ranges (Sutyrina et al. 2013; Lukarevsky et al. 2021). In addition, this methodology is contingent on the availability of snow cover to ensure the presence of tracks, but snow is unevenly distributed and unpredictable in the southwest of Primorsky Krai and may be entirely absent on southern slopes (Vitkalova et al. 2023).

The monitoring of animal populations and/or assessing their relative abundance using various noninvasive tools, such as the long-term deployment of camera trap networks, has become increasingly prevalent (Jansen et al. 2014; Harmsen et al. 2017; Djekda et al. 2020; Kays et al. 2020; Zuleger et al. 2023). Camera traps provide significant advantages over traditional track-based methods, including reduced dependence on weather conditions and the ability to conclusively identify individuals by unique spot patterns. Furthermore, camera trap networks yield more reliable and comprehensive information beyond basic population metrics (e.g., density/size), enabling the assessment of key biological parameters such as litter size, reproductive frequency, sex ratios, and survival rates. In addition, this method facilitates detailed observations of individual physical condition and behavior, as well as the reliable identification of distinct individuals. The annual application of this method for evaluating the population status of a target species provides insights into population trends and the spatial utilization patterns for that species.

The original range of the Far Eastern leopard included the Korean peninsula, Northeast China, and the southern half of Primorsky Krai, Russia (Heptner and Sludski 1972). However, by 1985, the last remaining wild population was isolated from the species' main range and was confined to southwest Primorsky Krai (Pikunov and Korkishko 1985), with estimates of its population size ranging from just 24–32 individuals (Pikunov and Korkishko 1992; Aramilev et al. 1999; Pikunov et al. 2009). Timely conservation measures were implemented for the Far Eastern leopard, including the establishment of Land of the Leopard National Park. This park unified and expanded existing regional protected areas and provided federal-level habitat protection within the Russian portion of the subspecies' current range (Ministry of Environmental Resources and Ecology of the Russian Federation 2014), which encompasses approximately 70% of its current range in Russia (Hebblewhite et al. 2011). With strong antipoaching efforts within the protected area, the population began to gradually recover.

Recent studies indicate that the Far Eastern leopard has now expanded across nearly all suitable habitats in the southwest of Primorsky Krai (Vitkalova et al. 2023). It has also expanded into adjacent areas along the Russian border with China (Jiang et al. 2015; Wang et al. 2016), and up to the border with the Democratic People's Republic of Korea. This expansion has resulted in a nearly threefold increase in the subspecies' range distribution since 1974 (Pikunov and Korkishko 1992; Vitkalova et al. 2018).

Recently, numerous studies have been published regarding the population size and status of the subspecies, including long-term assessments (Vitkalova and Shevtsova 2016; Lukarevskiy and Lukarevskiy 2019; Vitkalova et al. 2018, 2023). However, the most recent published population estimates are available only through 2020 and are not statistically robust. The IUCN Red List Assessment for Far Eastern leopards is currently based on the minimum number of individuals recorded in 2020, with an adjustment for total population size based on expert opinion rather than rigorous analysis (Stein et al. 2025), whereas the latest robust estimation dates back to 2014 (Vitkalova and Shevtsova 2016).

The aim of this study is to provide statistically robust estimates of population parameters for the Far Eastern leopard for the year 2022, thereby providing an updated assessment of the status of the Russian portion of the population. While there is evidence of population recovery in recent years, current management decisions rely on outdated information dating back to 2014. To address this critical knowledge gap, we conducted the first robust population assessment since 2014 (Vitkalova and Shevtsova 2016). The evaluated parameters included minimum and estimated population size, density, sex ratio, number of litters, and number of cubs per litter.

2 | Materials and Methods

The study was conducted within the Kedrovaya Pad State Nature Biosphere Reserve, the Land of the Leopard National Park, and its buffer zone, which together constitute the total study area, hereafter referred to as LLNP (Figure 1). The research area is located in southwest Primorsky Krai in the Russian Far East, bordering the Northeast Tiger Leopard National Park in China, specifically in the Jilin and Heilongjiang provinces (coordinates 42.54°–43.73° N, 130.43°–131.79° E). The total study area covered 3620 km^2. Vegetation types within the study area belong to the

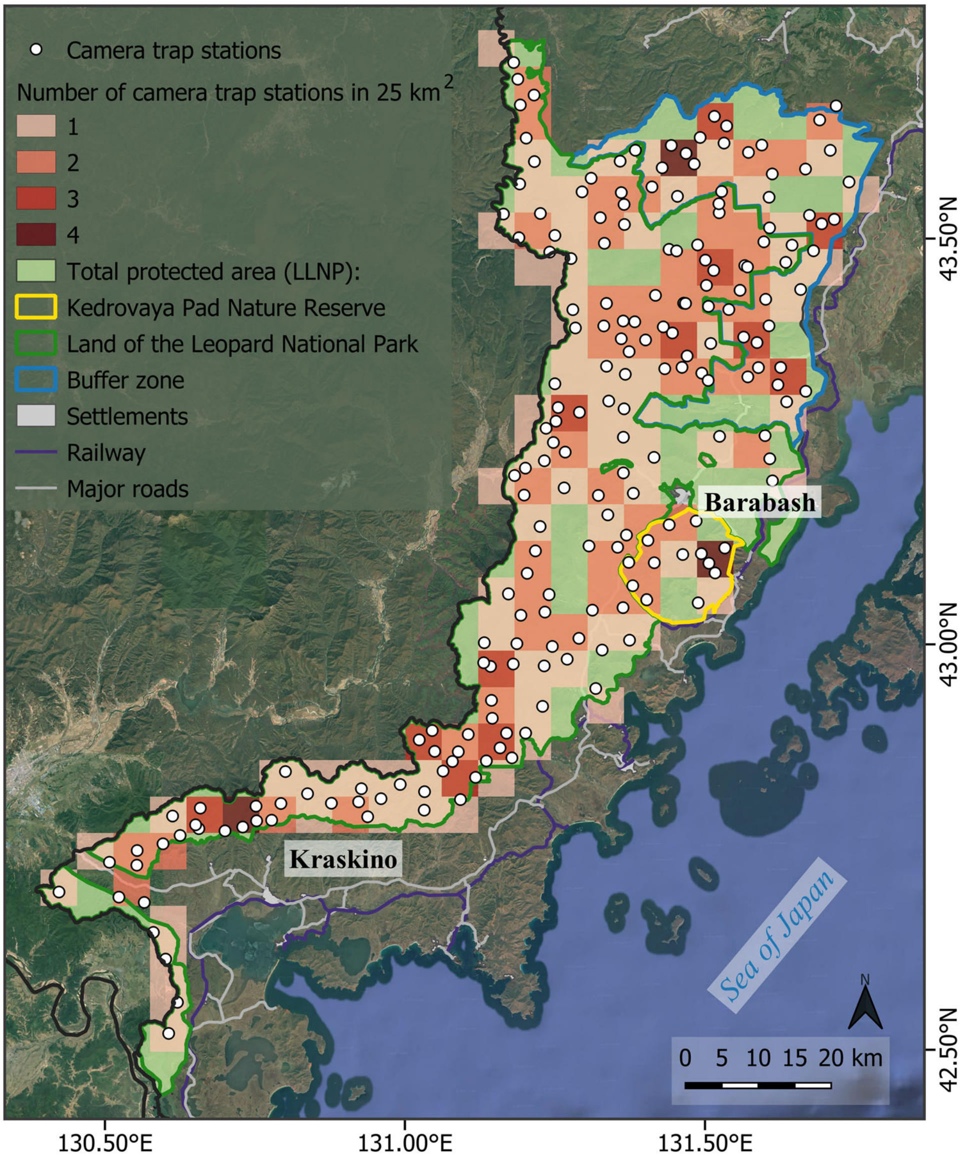

FIGURE 1 | Study area with camera trap locations. Projection: WGS84/UTM52N. Basemap source: Google Satellite.

East Asian floristic region (Manchurian flora type) and include a diverse mix of subtropical, tropical, and temperate species, which is typical for regions with a sharply continental climate (Takhtajan 1978).

Apart from the leopard, other carnivores found in LLNP include the Amur tiger (*P. tigris altaica*), leopard cat (*Prionailurus bengalensis*), brown bear (*Ursus arctos*), Asiatic black bear (*Ursus thibetanus*), yellow-throated marten (*Martes flavigula*), raccoon dog (*Nyctereutes procyonoides*), Asian badger (*Meles leucurus*), and red fox (*Vulpes vulpes*). The major prey species include sika deer (*Cervus nippon*) and roe deer (*Capreolus capreolus*), alongside other ungulates such as musk deer (*Moschus moschiferus*), water deer (*Hydropotes inermis*), long-tailed goral (*Naemorhedus caudatus*), and wild boar (*Sus scrofa*) (Kachur et al. 2012). No settlements or railways are located within LLNP boundaries; one road runs along the LLNP border between Land of the Leopard National Park and Kedrovaya Pad Nature Reserve. There is no agricultural activity or grazing of livestock within LLNP, except for occasional intrusions of livestock from border villages.

Camera trap monitoring was conducted in LLNP during the winter-spring seasons of 2022, following the protocols established by prior monitoring in LLNP (Vitkalova et al. 2023). The winter-spring period was chosen to allow for the continuation of long-term observation series dating back to the first snow track survey in 1972. Locations were chosen to maximize the detection probability of individuals by deploying camera traps on animal trails located along ridges or spurs (Vitkalova et al. 2023). Paired cameras were placed on each side of the trails to photograph both sides of an animal for individual identification. An even distribution of stations was ensured by placing at least one station in each 25 km² grid square across LLNP (Figure 1). The grid size was estimated to be one-quarter the average home range size of female leopards, based on analysis of winter pugmark and radio-collar tracking data (Pikunov et al. 2003; Salmanova 2012; Rozhnov et al. 2015). One to four stations were deployed within each grid cell depending on relief heterogeneity. The average distance between neighboring stations was 2.72 km (SD = 1.94). A total of 202 paired camera trap stations were deployed, supplemented by four additional unpaired stations, resulting in a total of 206 camera trap stations (408 camera traps).

The exact study period was defined post hoc as a 90-day period when all camera trap stations were operational simultaneously, with this duration selected to ensure a sufficient number of detections for capture-recapture analysis while reducing the chances of violating the assumption of population closure, in accordance with a previous study (Vitkalova et al. 2023).

The initial data processing was conducted following the protocols described earlier, which include photo-based organization, photo processing and sorting, and species identification (Marchenkova 2021). The unit of information obtained from each camera trap was a *photo-capture*—an instance where a single individual was photographed at a single station (referred to hereafter simply as a *capture*). Identification was carried out according to previously developed protocols (Vitkalova et al. 2023). For each capture, two photographs (one for each side) were chosen where the spot pattern on the leopard's coat was most clearly visible. For each capture, the following information was included in the database: date, time, number of camera trap stations and their coordinates, age class of the individual, photographs of the leopard's right and left sides, and additional comments. Individual identification was carried out using the ExtractCompare software version 1.27 (http://conservationresearch.org.uk/). The program-based identification was independently validated by two researchers. After individual identification, the database was updated with information on the sex, individual identification number, and distinctive features of the animal. Details of co-occurrence with other individuals were included in the database if more than one animal was present in a capture.

Individuals were categorized by age into two groups: adults (independent) and cubs. Young dispersing individuals after leaving their natal group (older than 1 year) were classified as "adults" and included in the corresponding sample for analysis. Individuals were classified as cubs if they were in association with an adult female, and had physical characteristics of a cub (e.g., small size, coat characteristics) in any capture during the study period, or if their age could be determined by their habitus when registered alone (Vitkalova et al. 2023). To understand the breeding history of females, we referred to the long-term database to determine whether females had produced litters earlier, and if so, when.

The spatially explicit capture-recapture (SECR) method was used to estimate density and population size (Efford 2004). This method accounts for the spatial structure of the population and the spatial nature of the capture process, where the parameter λ0 represents the baseline probability of capture. This differs from traditional capture-recapture (CR) methods, which do not consider the influence of spatial components on the probability of detecting animals (Borchers and Efford 2008). A population closure test was performed using the "closure.test" function from the secr package in the R environment (Efford 2023).

The area of integration was defined by the locations of camera trap monitoring stations arranged in a regular grid, with a mesh spacing of 1 km—approximately half the average distance between stations, as recommended by Royle et al. (2013). Around each location, a buffer was plotted equal to 4σ (radius of activity) for males. We used this buffer to ensure optimal coverage of the state space, based on the male activity radius, as they maintain larger home ranges than females. Following Borchers and Efford (2008), a 4σ buffer was used to account for individuals whose activity centers lie outside the trap array but whose movements extend into the sampling area. The initial estimate of σ was obtained from a model incorporating sex as a covariate for σ. We tested masks with different buffer sizes (16, 20, 32, 50 km) to define the optimal outer limit of the integration area, capturing sufficient habitat while minimizing error. Buffers were tested starting from 50 km, corresponding to the maximum home range radius of males (Salmanova 2012); subsequently, buffers corresponding to 4σ from previous studies (32 and 20 km) (Vitkalova and Shevtsova 2016; Vitkalova et al. 2023), and a buffer equal to 4σ derived from the current study. The difference in results and calculated errors between models constructed for different buffer zone values was negligible, amounting to less than 0.01 for density and less than 0.001 for the σ value. Consequently, the final buffer zone size for modeling population density was set at 16 km (Table 1).

Differences in the home range size between sexes of big cats (Sunquist and Sunquist 2002) can potentially influence the probability of capture (Efford and Mowat 2014), so we evaluated four models incorporating sex as a covariate for σ and λ0 (Table 2). Akiake's information criterion (Akaike 2011) was used to select the final model that best explained our data. In addition, we used sex to compute derived density and sex ratio parameters from the best SECR model.

Population size was calculated using the "region.N" function from the secr package. Since data from the Chinese side of the territory were unavailable, population size was estimated exclusively for the protected area within the Russian part of the range. We defined permanent residents as individuals who met the following criteria: activity centers located within LLNP

TABLE 1 | Results of null model (D~1, g0~1, σ~sex, pmix~1) to estimate optimal size of buffer for the spatially explicit capture-recapture (SECR) analysis.

		σ (km) (±SE)	
Buffer (km)	**Average density (±SE)**	**Females**	**Males**
16	2.46 (< 0.01)	1.97 (0.12)	4.07 (0.13)
20	2.46 (< 0.01)	1.97 (0.13)	4.07 (0.15)
32	2.46 (< 0.01)	1.97 (0.15)	4.07 (0.19)
50	2.46 (< 0.01)	1.97 (0.16)	4.07 (0.21)

TABLE 2 | Model selection statistics of tested models for the spatially explicit capture-recapture (SECR) analysis.

Model	AIC	Delta AIC	AIC weights	logLik	N parameters
D~1, λ_0~sex, σ~sex	2059.638	0	0.8237	−1024.819	5
D~1, λ_0~sex + b, σ~sex	2062.467	3.083	0.1763	−1025.234	6
D~1, λ_0~1, σ~sex	2088.327	28.481	0	−1040.164	4
D~1, λ_0~1, σ~1	2334.009	273.999	0	−1164.005	3

Abbreviations: b, learned response; D, density; λ_0, probability of capture; σ, radius of activity.

boundaries, repeated location-specific detections, and consistent recording throughout the study period (and often in previous years).

We calculated the capture rate as the number of identified individuals per camera trap location during the survey period. For the leopard capture history database, Microsoft Office (Access) was used. Data processing and analysis were conducted using R version 4.3.2 (R Core Team 2014) with the following packages: secr (Efford 2023), data.table (Dowle et al. 2019), wiqid (Meredith 2020), raster (Hijmans et al. 2013), ggplot2 (Wickham et al. 2016). Maps were created using QGIS version 3.14.13.

3 | Results

A total of 18,372 camera trap days were sampled during the 2022 survey period (from February 2 to May 2). Out of 206 camera trap locations, 202 operated successfully, with leopard detections recorded at 137 locations (67.8% of stations). A total of 5439 leopard photographs were obtained, representing 570 captures. Among these, 544 captures provided high-quality images suitable for individual identification based on spot patterns, while the remaining 26 captures could not be identified due to low-quality images.

We identified 104 adult individuals and 12 cubs. Among the adults, 53 were identified as females, 44 as males, and the sex of 7 individuals could not be determined. Leopard capture rate varied from 1 to 5 individuals per location (mean = 1.98, SD = 1.04; SE = 0.09), with slightly higher capture rates along the Russian–Chinese border. The population was considered demographically closed based on the population closure test ($Z = -0.69$; $p = 0.25$).

The estimated population size of Far Eastern leopards within the LLNP using SECR was 118 individuals (95% CI: 115–121) (Table 3). The average population density was 2.46 individuals per 100 km^2 (SE = 0.002). The distribution of leopard density within the protected area was uneven, ranging from 0.82 to 7.21 individuals per 100 km^2 (Figure 2). The population density of females was significantly higher than that of males, despite females having a capture probability and activity range radius half that of males (Table 3). Of the 104 individuals recorded in total, 69 were identified as resident individuals (66.35% of the total population).

Females were twice as common as males (estimated sex ratio at 2:1, Table 3). Over the survey period, 12 cubs from 8 litters were recorded. All cubs were observed with their mothers. Four females had two cubs each, while the other four females had one cub each. Based on our long-term database, for six females, this was their first recorded litter, while for two females, it was their second. One female had a 5-year interval between recorded litters, and another had a 2-year interval. The age of females recorded with offspring during this period ranged from 3 to 8 years.

4 | Discussion

We conducted the first statistically robust population analysis of the Far Eastern leopard population in Russia since 2014 (Vitkalova and Shevtsova 2016). The 2022 population estimate of 118 individuals (95% CI: 115–121) represents the largest estimate since the beginning of regular camera trap monitoring in 2014 (Vitkalova et al. 2023). This figure represents a dramatic increase from the earlier estimates of 20–40 individuals based on track counts (Pikunov et al. 2003; Aramilev et al. 1999), reflecting both more accurate monitoring methods and analyses and a genuine population recovery. The 2022 estimates are 1.6 times greater than the 2014–2015 estimate made using the same methodology (Vitkalova et al. 2018). The difference between the minimum counted population size and the estimated size can be explained by the behavior of reproductive females. During the period of raising offspring (particularly with cubs under 3 months old), females significantly reduce their home ranges and may not be detected during the survey period (Rozhnov et al. 2015). This behavior has also been observed in Amur tigers (Petrunenko et al. 2020). For instance, in previous years, up to 50% of females with cubs recorded annually were not detected during the formal survey period but were recorded outside of it (Vitkalova et al. 2023).

While our findings do not represent a global population estimate for Far Eastern leopards, their numbers are exceptionally low compared to other subspecies (Jacobson et al. 2016; Stein et al. 2025). They are comparable only to the geographically and genetically close North Chinese population, previously described as subspecies *Panthera pardus japonensis* (Laguardia et al. 2017; Yang et al. 2021), exceeding solely the population of the Arabian subspecies *Panthera pardus nimr* (Al Hikmani et al. 2023). Although density has also increased in Southwest Primorye, it remains quite low compared to most other leopard subspecies (Kumar et al. 2019; Stein et al. 2025). These relatively low densities likely reflect lower prey biomass compared to other areas that retain leopards, and more severe ecological conditions under which they persist. Nonetheless, both population size and density have increased dramatically over the past 15 years due to both population recovery and expansion into China (Jiang et al. 2015).

TABLE 3 | Results of population size and density estimations of the Far Eastern leopard population in the protected areas based on the spatially explicit capture-recapture (SECR) method and minimum count.

Method	Population size (±SE)	Average density (±SE)	Sex	Sex ratio (%)	Density by sex (±SE)	σ (km) (±SE)	λ_0 (±SE)
SECR	118 (1.36)	2.46 (< 0.01)	Females	62.4	1.61 (< 0.01)	1.97 (0.12)	1.74 (0.03)
			Males	37.6	0.71 (< 0.01)	4.07 (0.13)	3.27 (0.02)
Minimum count	104	—	Females	54.5	—	—	—
			Males	45.5	—	—	—

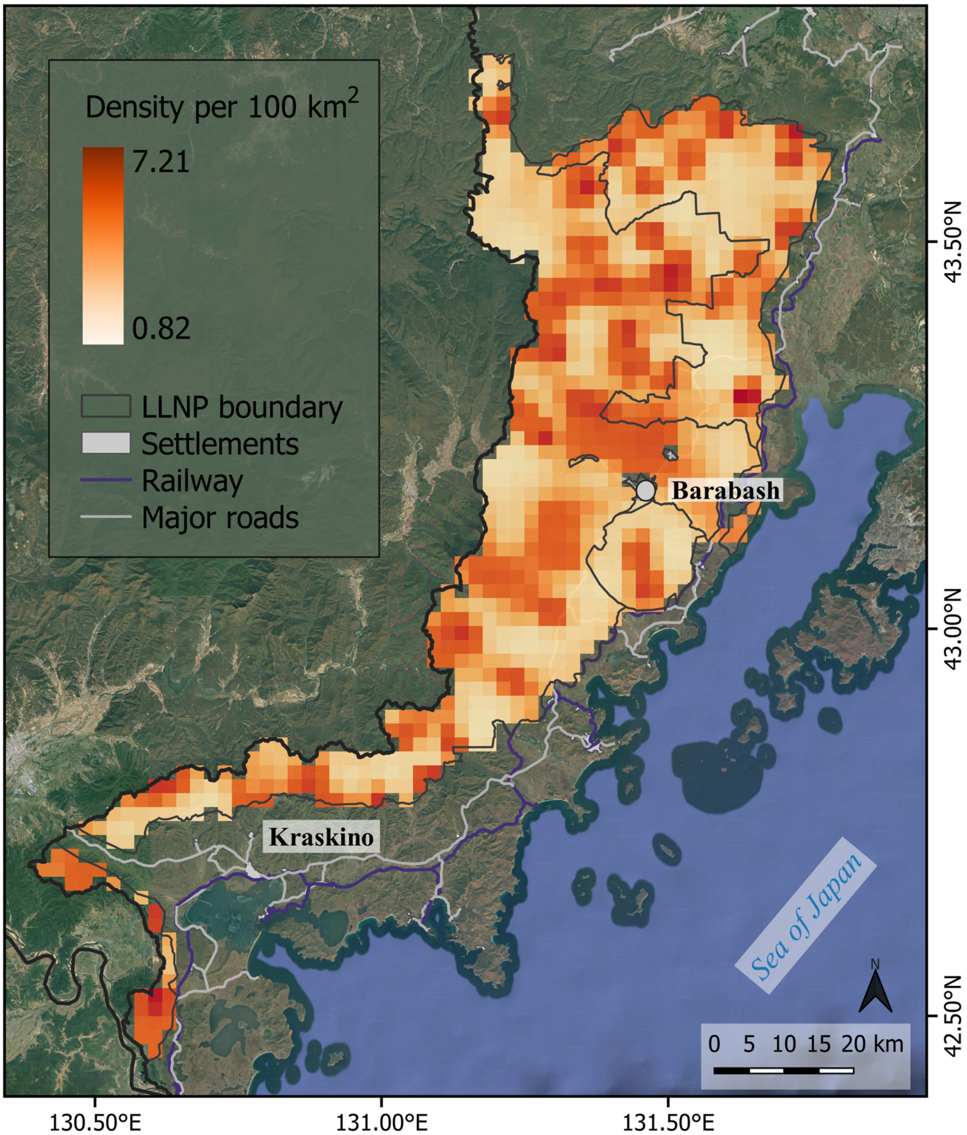

FIGURE 2 | Distribution of the Far Eastern leopard density in the protected area. Projection: WGS84/UTM52N. Basemap source: Google Satellite.

The number of leopard detections across monitoring stations was unevenly distributed. High detection rates observed in the border zone adjacent to China suggest higher densities there, with a large number of individuals using both sides of the border, as previously reported by Vitkalova et al. (2018). The absence of leopards at 30% of the stations could be attributed to various factors, including snow cover conditions (presence, distribution, and depth), the spatial distribution of ungulates, the presence of females with cubs, and individual behavioral patterns of certain leopards. However, we suggest that leopard distribution is not affected by a shortage of ungulates, as the study area maintains high densities of all primary prey species (Petrov et al. 2025). Furthermore, anthropogenic pressure appears negligible given the absence of human settlements and major roads within the research area. Importantly, leopards were detected at most stations outside the survey period (unpubl. data), suggesting that they are distributed across the entirety of LLNP. Therefore, the absence of detections during the survey period simply reflects a low probability of detection rather than true absence.

A high number of different individuals detected at a single station does not necessarily indicate that all are permanent residents. Instead, it may reflect the movement paths of young, dispersing individuals or individuals whose core home range lies on the Chinese side of the border, resulting in only sporadic detections on the Russian side (Vitkalova et al. 2018). Furthermore, the increased diversity of recorded individuals may be explained by leopards that utilize habitats in both countries equally, which is supported by the higher detection rates observed in the border zone adjacent to China. However, this cross-border movement has a negligible effect on the density estimates, with only a slight underestimation observed when using data solely from the Russian side, as evidenced by a previous joint Russian-Chinese study (Vitkalova et al. 2018). Nevertheless, a comprehensive analysis requires further research based on combined data from both Russia and China.

Young dispersing individuals cover large distances while establishing their home ranges. This behavior may increase their likelihood of detection at a larger number of locations. Dispersal is more commonly observed in males, as they travel further than females (Fattebert et al. 2015). The detection rate may vary among individuals depending on their age and social status (e.g., resident, dispersing individual, female with offspring, or older individual), which is a potential source of variability in capture probability (Efford and Mowat 2014). A high number of detections often belonged to the same individual, typically males, who have a photo-capture frequency nearly twice that of females, as reflected in their potential capture probability (Table 3).

The average litter size and number of cubs were smaller in 2022 compared to previous years. According to Vitkalova et al. (2023), the average litter size was previously 1.7. This difference may indicate that the surge in birth rates observed between 2016 and 2018 has subsided, and population growth rates may be slowing (Vitkalova et al. 2023). However, another possible reason for the lower number of females with cubs could be a shift by these females toward the periphery of the park and outside protected areas, which requires further investigation. For instance, a similar situation was described for the *Panthera pardus fusca* in Kanha National Park, India (Kumar et al. 2019), where a growing tiger density forced leopards to the edges of the protected area. This is particularly impactful for females with cubs, which, due to competitive pressure and situational vulnerability, face greater exposure to human-induced disturbances, negatively affecting their survival rates and those of their offspring (Kumar et al. 2019). Given that tiger numbers are increasing in LLNP concurrently with leopards (Darman and Matiukhina 2025), a similar effect could be occurring. Furthermore, limited geographical space saturated with leopards, combined with the increasing population density, may lead to a reduction in individual home range sizes. This issue is further compounded by the restricted mobility of females during cub rearing, a phenomenon also observed in Amur tigers (Petrunenko et al. 2020).

Another contributing factor could be the cumulative effects of ongoing inbreeding (Marchenkova et al. 2021; Cho et al. 2022), previously documented health issues (Lewis et al. 2020), and the presence of abnormal spermatozoa (Naidenko 2016). Hence, it cannot be ruled out that the smaller number of recorded cub sightings may also stem from genetic problems within the population and a direct reduction in the reproductive fitness of individuals. However, based on the data presented here, it is still not possible to confidently assert that population reproductive success is declining, and further long-term assessment is needed.

For a comprehensive assessment of the current status of the Far Eastern leopard population, an analysis across the entire range of the subspecies is required, including the northeastern regions of China, as was done previously (Vitkalova et al. 2018). In addition, an extensive demographic analysis of the population is necessary. Such studies are rare for leopards as a species overall. A complete demographic analysis has been conducted in full only for the Indochinese subspecies *Panthera pardus delacouri* (Rostro-García et al. 2023) and only partially for the Far Eastern leopard (Vitkalova et al. 2023). For instance, the demographic analysis of the Indochinese subspecies revealed an 82% decline in population size and density over 11 years, low population recruitment rates, and a low survival rate of adults (58%), with female survival being lower than that of males (Rostro-García et al. 2023). Preliminary estimates for the Far Eastern leopard, however, indicate a doubling of the population size, with an average adult survival rate of around 80% (ranging from 72% to 85% across years) (Vitkalova et al. 2018; Vitkalova et al. 2023). The contrasting trends in the status of these subspecies' populations are most likely due to differences in the effectiveness and timeliness of conservation measures, highlighting the success of the efforts undertaken in Russia to protect the Far Eastern leopard, and differences in anthropogenic pressure and land use. Nevertheless, many demographic parameters for the Far Eastern leopard, such as recruitment, sex-specific survival rates, population growth, resident composition, and their distribution across the territory, remain unknown.

This study provides updated information on the population parameters of the Far Eastern leopards in southwest Primorsky Krai and reflects a continuing positive trend for this subspecies, serving as a basis for future revisions of its status, for example, for the IUCN Red List. These updated metrics provide the evidence needed to justify continued protection efforts and establish a scientifically rigorous baseline for future assessments based on monitoring data. For a detailed understanding of the population recovery process and successful population management, the next critical steps should include targeted demographic studies and strengthening international collaboration. Such efforts would also validate the timeliness and success of previously implemented conservation measures for these rare big cats and are essential for a comprehensive analysis that includes data from both Russia and China to fully assess the current status of the global population.

Author Contributions

Taisiia V. Marchenkova: conceptualization (lead), formal analysis (lead), investigation (equal), methodology (equal), visualization (lead), writing – original draft (lead). **Alexander N. Reebin:** data curation (equal), investigation (equal), methodology (equal), validation (equal), writing – review and editing (equal). **Dina S. Matiukhina:** data curation (equal), investigation (equal), methodology (equal), validation (equal), writing – review and editing (equal). **Ekaterina Y. Blidchenko:** data curation (equal), investigation (equal), writing – review and editing (equal). **Darya A. Maksimova:** data curation (equal), investigation (equal), writing – review and editing (equal). **Viktor B. Storozhuk:** data curation (equal), investigation (equal), writing – review and editing (equal). **Alexey S. Titov:** data curation (equal), investigation (equal), writing – review and editing (equal). **Anna A. Yachmennikova:** supervision (equal), validation (equal), writing – review and editing (equal). **Dale G. Miquelle:** funding acquisition (equal), project administration (equal), supervision (equal), validation (equal), writing – review and editing (equal).

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Camera trap monitoring data are not publicly shared due to the threat of poaching.

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