Original Study

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Activity patterns of the Yellow-throated marten *Martes flavigula* in the Far East of Russia revealed by camera traps

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Abstract: The Yellow-throated marten *Martes flavigula* is one of the least studied species within the genus Martes and there is contradictory information regarding its daily activity, spanning from diurnal to nocturnal or cathemeral. Our long-term studies of the daily and seasonal activity of the Yellow-throated marten were carried out in five protected areas of Primorsky Krai (Russian Far East) using a large-scale network of camera traps from 2010 to 2021. The aim of the study was to find out the pattern of daily activity of the species, its changes over the seasons and in different territories of the region. We found that the Yellow-throated marten had a pronounced diurnal activity pattern, including one or two detection peaks per day. The species is less active at dusk and almost inactive at night in this part of its range. Two clusters with different patterns of marten activity were identified in the protected areas of Primorsky Krai: with one pronounced peak around noon in the continental part with a more severe climate and smoothed activity in coastal areas with milder climatic conditions. Seasonal detection has two peaks in April-May and October, which corresponds to species biological requirements.

Keywords: activity patterns; camera trapping; daily activity; Russian Far East; Yellow-throated marten

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1 Introduction

Mammals exhibit great diversity and flexibility in their activity patterns that evolved in response to environmental changes that caused organisms to respond in physiological and behavioral aspects (Bennie et al. 2014; Daan 1981; Kronfeld-Schor and Dayan 2003). Activity patterns are often related to daily changes in the duration of dark and light times of the day and are thus dependent on the season of the year (Zielinski 2000). For most species of mustelids, there have been few autecological studies, including activity patterns in the wild and outside of urban (populated areas), and therefore activity patterns are poorly known. The peaks of activity in different species of the Mustelidae family vary in different locations and may also vary between seasons (Zielinsky 2000).

Despite its widespread distribution, studies on the activity patterns of the Yellow-throated marten are sparse compared with other members of the genus *Martes* (Grassman et al. 2005). Some researchers classify this marten as a species with cathemeral activity evenly distributing their activity between the light and dark periods of the day; others regard it as mostly nocturnal; and yet others – suggest that it is predominantly diurnal. However, the strong majority of studies performed in different parts of the species' range indicate daytime activity (Table 1).

The Yellow-throated marten *Martes flavigula* is distributed from the tropical forests of the Malay Archipelago in the south to the temperate forests of the southern Russian Far East, the Korean Peninsula, and northwest of China in the northern part of its range (Heptner and Naumov 1998; Pocock 1941). The northernmost part of the area is in Russia in a cold continental climate where average monthly temperatures below freezing stretch from November to April (Rikhter 1961), which in turn predetermines larger body size and greater degree carnivory (Heptner and Naumov 1998; Matyushkin 1993). We hypothesize that harsh climatic conditions (extreme air temperatures) affect the daily and seasonal activity of the Yellow-throated marten near the northern border of the species range.

Table 1: Types of daily activity patterns of the Yellow-throated marten reported in different parts of its distribution range.

Country (geographic area)	Type of activity (author y)		
	Diurnal activity	Cathemeral activity	Nocturnal activity
Russia	Matyushkin (1987), Kerley and Borisenko (2014)[a]	Kucherenko (1974), Yudin and Batalov (1982)	Astafiev and Zaitsev (1975), Matyushkin (1993)
China	Zhou et al. (2008)[a], Zhu et al. (2019)[a]	–	–
South Korea	Woo (2014)	–	–
Nepal	Appel and Khatiwada (2014)[a]	–	–
India	Mallick (2015)[a], Pocock (1941)	–	–
Thailand	Grassman et al. (2005)	–	–
Myanmar	Zaw et al. (2008)[a]	–	–
Lao PDR	Duckworth (1997)	–	–
Indonesian (Sumatra)	–	van Schaik and Griffiths (1996)[a]	–
Malaysian (Borneo)	Ross et al. (2017)[a]	–	–

[a]Studies performed using camera traps.

Currently, the species' range and population are diminished near its northern boundary, and it is classified as a rare species in the regional Red Data Books of Russia (Oleynikov et al. 2022). It is also included in the Korean Red List of Threatened Species (Kim 2014) and the Chinese equivalent (Wang et al. 2004). Thus, the Yellow-throated marten is a rare forest predator in the northern part of the range for which it is difficult to collect systematic and comprehensive data in the wild this predetermines the low level of knowledge of the ecology of the species.

It should be noted that while many researchers comment on 24 h activity patterns, those that consider year-round patterns are indeed rare (Bu et al. 2016; Zhu et al. 2019). This is an unavoidable consequence of the fact that most camera-trap studies last only a few months, or if longer, with interruptions for the monsoon season, etc. Environmental conditions – the weather, the duration of daylight and darkness time, the composition of feed, the presence of snow cover and many other factors that change cyclically throughout the year affect the daily activity of animals (Daan 1981; Stokes et al. 2011). Our comprehensive study looks at seasonal activity patterns also, which makes it different from most of the studies identified in the Table 1. This long-term study of the daily and seasonal activity of the Yellow-throated marten held in all seasons of the year is important for understanding its ecological niche and the characteristics of its behavioral ecology.

In order to understand whether the patterns of daily activity of the Yellow-throated marten differ, we conducted research in several protected areas located in different parts of Primorsky Krai (the maximum distance between protected areas is about 500 km in the latitudinal direction), which differ in natural and climatic conditions, the duration of day and night. In addition, there are two relatively isolated populations in the study area, one of which inhabits southwestern of Primorsky Krai adjacent to the border with China, and the other inhabits the range in the Sikhote Alin Highlands.

The objectives of this study are as follows: (1) determine the daily activity of the Yellow-throated marten in Primorsky Krai (Russia) and comparing its activity in some protected areas; (2) evaluate whether high and low temperatures affect the detection of the species; (3) detect changes in daily and seasonal activity patterns among seasons. In addition, we will consider fields related to feeding and daily activity, which will shed more light on the issues we are considering.

2 Materials and methods

2.1 Study areas

Our studies were conducted in six federal protected areas of Primorsky Krai, but for the convenience of analysis, we combined them into 4 sites. The association of sites is connected with their geographical and administrative position, so the united territory of the Land of the Leopard National Park and the Kedrovaya Pad Reserve represents a single reserve with slight differences in the regime of protection (LL). The territories of the Lazovsky Reserve (L) and the Zov tigra National Park (ZT) were also combined by us for analysis since they have compactly located 20 km from each other (LZT). The Ussuriysky Reserve (U) and the Bikin National Park (B) are located on the western macro-slope of the Sikhote-Alin at a considerable distance (Figure 1).

The L and the ZT are in the southeast of the region (L: 43°13′N; 133°24′E and ZT: 43°34′N; 134°16′E, Figure 1) in river basins flowing down the eastern slopes of the Sikhote-Alin and flowing into the Sea of Japan (East Sea). The topography of the area is composed by medium-altitude mountains (20–700 m above sea level) with a great slope gradient. There are two climatic micro-zones: coastal and continental. The average temperature in January in the coastal zone is −7.8 °C (Preobrajenie); in July is 18.2 °C. The duration of the snow cover period ranges from 1.5 to

Figure 1: Study areas in the Primorsky Krai (Russia). 1, Bikin National Park (B); 2, the united territory of the Land of the Leopard National Park and the Kedrovaya Pad Reserve (LL); 3, Ussuriysky Reserve (U); 4, Lazovsky Reserve (L); 5, Zov tigra National Park (ZT).

5.0 months (November–March). Forests cover 96 % of the territory, dominated by Mongolian oak *Quercus mongolica*, cedar-broad-leaved and dark coniferous trees (Zhivotchenko 1989). The size of the study area amounted to 121,000 ha for the L and 83,000 ha for the ZT.

The U is located on the eastern slopes of the southern part of the Sikhote-Alin Range (43°41′N and 132°33′E, Figure 1). The coldest month is January (average temperature of –17.5 °C), and the warmest months are July is 21.3 °C. The duration of the snow cover period in the U is about four months. The landscape is low mountain – the altitude of the hills does not exceed 300–500 m above sea level (Tarankov 1974). Forest covers 99 % of the reserve, dominated by Korean pine forests that cover 42 % of the territory. Other species that are widely distributed are the Ayan spruce *Picea jezoensis*, Khingan fir *Abies nephrolepis*, Manchurian fir *A. holophylla*, Mongolian oak and Amur lime *Tilia amurensis* (Zhabyko 2006). The size of the study area is approximately 17,000 ha for the U.

The B (Bikin River basin) is the largest natural ecosystem of cedar–broad-leaved forests in the south of the Russian Far East, located in the north of Primorsky Krai (46°38′N; 136°35′E, Figure 1). The Bikin River flows down the western slopes of the Sikhote-Alin Range and belongs to the Amur River basin. The altitude of the study area is 250–700 m above sea level. The average temperature in January is –22 °C; in July is 21.5 °C. The duration of the snow cover period in the basin of the Bikin River is 5.5–6.0 months (mid-November to mid-April). The main forest-forming species are Korean pine *Pinus koraiensis*, Ayan spruce, Mongolian oak, and larch *Larix dahurica*. The size of the study area is about 10,000 ha for the B.

The LL is located in the southwestern part of Primorsky Krai predominantly on the eastern slopes of the Changbaishan (Paektu) Mountains and represents mountain slopes with strongly dissected gorges, ravines, rock outcrops, plateaus and plain forest massifs along riparian zones with diverse plant communities from coniferous-broad-leaved forests to pyrogenically transformed complexes (43°00′ N; 131° 25′E, Figure 1). The area of the territory is about 362,000 ha. The altitude of the study area is 0–996 m above sea level. The average temperature in January was –10.0 °C, and in July – 19.5 °C. The duration of the snow cover period in the area is 1–4 months, but in some years, there is no permanent snow. The dominant vegetation consists of stands of Mongolian oak and mixed conifer–deciduous forests dominated by Korean pine, Manchurian fir, lime (*T. amurensis*, *T. mandshurica*) and birch (*Betula costata*, *B. lanata*).

The study areas have differences in climatic characteristics that may influence the patterns of Yellow-throated marten activity, which will be discussed below. In general, the protected areas of Primorsky Krai located in the sea impact zone (LL, L, ZT) have a relatively mild climate, while those located inland (B, U) have a more pronounced continental climate, which reflects well the high gradient of temperature differences between the warmest (July) and coldest (January) months (Figure 2). The division of the studied territories into two clusters is especially noticeable by the average temperatures in January.

2.2 Data collection

We conducted a camera-trap survey in the wild from January to December, between 2010 and 2021, and additional data were obtained from visual observations during the same period. In this study several models of camera traps were used. Material and data were presented according to general recommendations for camera trapping studies (Meek et al. 2014). The camera traps were operational throughout the year (Table 2). Their key indicators are given in Table 2.

The cameras were fastened to trees at a height of 50~70 cm above the ground at some angle to the surface of the earth. In summer, the space in front of the camera was released from the shrubbery, high grassy vegetation and objects capable of interfering with the quality of shooting of passing animals. No scent lure or another attractant was applied. The camera traps have been working continuously throughout the research period since they were activated and have been programmed to operate 24 h a day. Before work, all devices were set to shoot a series of three frames for each moment of motion fixation. The trigger speed of the cameras we used was 0.3–0.7 s and the resolution level was not lower than 1536 × 2048 pixels. The shooting sensitivity was set to the maximum; the trigger interval was set as 1 s.

The camera traps were placed relatively evenly spaced in valleys of watercourses, on the slopes and ridges along animal paths. In the LZT and the LL, camera traps were installed primarily to record tigers

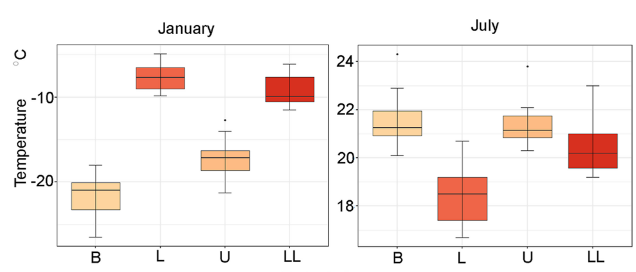

Figure 2: Average temperature of the coldest (January) and warmest months in four protected areas (minimum, maximum, median, first and third quartile and outliers).

Table 2: Summary of the camera-trap data in our four study areas in Far East Russia (2010–2018).

Study area	Period of surveys	Trap stations	Study area size (thousand ha)	Capture rate (per 100 trap-days)	Capture rate excluding stations where no marten was reported	Number of stations with marten records	Number of records
L	2010–2017	92	121	0.33 ± 0.12	0.95 ± 0.27	38	280
ZT	2015–2017	16	83	0.42 ± 0.51	1.69 ± 1.59	5	17
U	2010–2017	5	5	1.43 ± 0.40	1.43 ± 0.40	5	52
B	2015–2021	44	10	0.28 ± 0.15	0.75 ± 0.17	17	125
LL	2013–2020	204	362	0.18 ± 0.10	0.55 ± 0.12	86	476

Panthera tigris and leopards *P. pardus* at marking sites. These places were also located on the animal paths that were regularly used by other mammals, including the Yellow-throated marten. Images taken by camera traps were collected every one month. One registration case (trap event) equals the passage of individuals of one species along the camera trap, regardless of the number of frames and the time spent on the location. Consecutive photographs of the same species at the same site were deemed conditionally independent when there was at least a 30 min interval between them (O'Brien et al. 2003). The time stamp of the first picture was used in the subsequent daily activity analysis.

2.3 Data analysis

We calculated the capture rate, which was defined as the number of independent detections per 100 days of camera trapping for each species (Rovero et al. 2014). We used four intervals: morning twilight (1 h before and after sunrise), daytime (time between the end of the morning twilight and the start of the evening twilight), evening twilight (1 h before and after sunset) and night (time between the end of the evening twilight and the start of the morning twilight) (Ikeda et al. 2016; Romero-Muñoz et al. 2010). The duration of these periods was determined by sunrise and sunset times for each date, calculated for the geographic coordinates of each protected area Primorsky Krai using the website www.sunrisesunset.com; times of camera captures were converted to solar time. We divided the year into four periods based on the generally accepted calendar dates of the Gregorian calendar (winter (December–February); spring (March–May); summer (June–August); fall (September–November)). Additionally, we divided the year into cold (from November to March) and warm (from April to October) periods to analyze the possible correlation of activity with climate conditions. We took data on the lunar phases and moon illumination in percent for the place and time of registration from the site https://www.mooncalc.org.

To observe if marten activity was predominately categorized as crepuscular, diurnal, nocturnal or cathemeral, we calculated selection ratios of use to availability to each time period following Manly et al. (2002) by the formula:

$$W_i = o_i/\pi_i$$

W_i is the selection ratio for the period i; o_i is proportion of trap events in period i; π_i is proportion of length in period i to the length of all periods. $W_i > 1$ indicates that the time period is selectively used more than availability; $W_i < 1$ indicates the time period is avoided (Bu et al. 2016; Gerber et al. 2012).

We compared four studied territories (B, U, LL, LZT) in order to find out whether there are geographic differences in the activity patterns of the Yellow-throated marten in Primorsky Krai. Activity data present a circular distribution, so we compared the distributions of several samples of activity patterns among seasons using the nonparametric Watson-Wheeler test of homogeneity of means (Zar 2010). The Bonferroni correction was used when using multiple comparisons. This test indicates if there is a significant statistical difference between circular distributions, and it has been used to analyze data from 24 h activity patterns (Romero-Muñoz et al. 2010). To check the differences between samples the χ^2-test was implemented.

To assess the impact of low and high temperatures on Yellow-throated marten detection, we analyzed temperature readings obtained from camera traps during their registration. We used the Spearman Rank Order Correlation method, where each rank was considered as equivalent to a 5 °C temperature difference. For the winter period, we considered seven temperature intervals ranging from 0 °C to −35 °C, while for the summer period, we considered five intervals ranging from +10 °C to +35 °C. The number of registrations in each interval was taken as the yellow-throated marten's activity level. Due to insufficient registrations and similar climates, we merged study sites B and U.

We used the approach developed by Ridout and Linkie (2009) to estimate the activity patterns and seasonal activity of the Yellow-throated marten using kernel density analysis (Foster et al. 2013; Ikeda et al. 2016). This is a method for evaluating the probability density function of a random variable (time of capture). These procedures were implemented in R 3.4.3 software (R Development Core Team 2019). For the processing and analysis of camera trap data, we employed the "camtrapR" package, enabling the calculation of kernel density estimates (Niedballa et al. 2017). Additionally, to incorporate circular statistics, including the Watson-Wheeler test, we utilized the "circular" package (Lund et al. 2017). Other analyses were conducted using Statistica 10 (StatSoft 2011). To assess the physiological condition of the Yellow-throated martens during the cold season, anatomical dissection examinations were performed on seven individuals obtained from local hunters.

3 Results

The main results from the camera traps are presented in Table 2. As can be seen, most of the data were obtained from LL (50 %) and L (29 %). The total number of registrations of the Yellow-throated marten was 950 and the number of photographs was 2810.

A high daytime activity was observed for the Yellow-throated marten (80.13 % of registrations, Table 2). Manly selection ratio for daytime was high (W_i = 1.87) in this way species can be categorized as diurnal (Table 3). In twilight manly selection ratio was also greater than one. Comparison of manly selection ratios (W_i) throughout periods of the day for seasons showed that daily activity always prevailed. $W_i > 1$ for twilight was in winter and autumn, and nighttime activity was always minimal, especially in spring (0.95 % of registrations). Differences in daytime activity between seasons are not statistically significant, except for differences between winter and spring ($\chi^2 = 8.5$, $p = 0.014$) when daytime detection increased (from 75.7 to 85.5 %), but twilight and nighttime activity decreased.

We found a strong negative correlation between Yellow-throated marten activity and temperature decrease during winter at all three sites: LZT ($N = 40$, $R = -0.88$, $p < 0.05$), BU ($N = 26$, $R = -0.85$, $p < 0.05$), and LL ($N = 67$, $R = -0.89$, $p < 0.05$). For summer, a strong negative correlation between activity and temperature increase was observed at the LZT ($N = 68$, $R = -0.90$, $p < 0.05$) and BU ($N = 33$, $R = -0.89$, $p < 0.05$) sites. However, an average negative correlation was found between Yellow-throated marten activity and temperature increase during summer at the LL site ($N = 55$, $R = -0.60$, $p > 0.05$).

The general pattern of 24 h activity of the Yellow-throated marten reflects the generalized data on activity in all protected areas (Figure 3). According to our results, the main increase in detection occurred in the morning twilight, and its decline in the evening. At the same time, during the morning twilight, the activity increased by about 4 times, and during the evening, it decreased by 3 times. The high activity level was recorded approximately from 08:00 to 18:00, with no pronounced detection peaks. In the period from 23:00 to 01:00, there were no registrations of animals (Figure 3).

Within a year the activity pattern of an animal can vary for various reasons. The constructed kernel density plots of the activity of the species under consideration for four seasons allow one to visually assess the variability of the frequency of records at different times during the year (Figure 4). The activity of the Yellow-throated marten differed significantly between seasons ($W = 51.6$, $df = 6$, $p = 1.7e\text{-}9$; hereinafter Watson-Wheeler test).

Table 3: Frequency of registrations (TE, %) and Manly selection ratios (W_i) throughout periods of the day for seasons in the protected areas of Primorsky Krai (2010–2021).

	Nighttime		Daytime		Twilight		Category
	TE (%)	W_i	TE (%)	W_i	TE (%)	W_i	
All season	2.28	0.05	80.13	1.87	17.59	1.02	D/Cr
Winter	2.94	0.06	75.74	2.44	21.32	1.28	D/Cr
Spring	0.95	0.03	85.49	1.80	13.56	0.81	D
Summer	1.24	0.04	82.61	1.53	16.15	0.97	D
Autumn	2.97	0.06	78.81	2.09	18.22	1.09	D/Cr

D and Cr indicate diurnal and crepuscular activity, respectively.

In autumn, the activity type is bimodal with peaks in the daytime around 11:00 and 17:00. In winter, the activity has a unimodal type with a peak in the middle of the daylight at about 13:00. In spring, no peaks could be distinguished; activity was smoothed out during the daytime period. In summer, detection is higher in the afternoon with a maximum from 16:00 to 18:00. In all periods, the greatest changes of activity occurred at twilight (morning twilight – growth, evening – decline). The most significant differences were found between twilight periods ($W = 121.38$, $df = 6$, $p = 2.2e\text{-}16$), daytime differences were significant ($W = 75.98$, $df = 6$, $p = 4.5e\text{-}14$), differences between nighttime periods were not significant ($W = 9.89$, $df = 6$, $p = 0.12$).

When comparing four studied territories (B, U, LL, LZT) we found that daily activity had significant differences ($W = 21.16$, $df = 6$, $p = 0.002$). All the studied areas are characterized by a predominantly daytime pattern of marten activity.

In B and U, the patterns were similar and had a unimodal type of activity with an expressed peak in the middle of the day (Figure 5). The other two territories did not have clearly expressed peaks, however, there were differences in LL, more registrations were observed in the first half of the day, and in ZT and L in the second. We also compared activity variations for protected areas located in the zone of a pronounced continental climate (B, U) and in areas with a more temperate coastal climate (LL, LZT) (Figure 3). Differences were found between them ($W = 14.67$, $df = 2$, $p = 0.005$), while there were no differences between the territories within these groups ($W = 1.44$, $df = 2$, $p = 0.49$; $W = 5.30$, $df = 2$, $p = 0.07$). In the considered territories (B, U) with a continental climate, the differences in daily activity between the warm and cold seasons turned out to be significant ($W = 12.28$, $df = 2$, $p = 0.002$, Figure 6).

The highest seasonal activity level was observed in April–May. On the other hand, the lowest activity levels were observed in December–January and August. These results are presented in Figure 7.

4 Discussion

4.1 Daily activity and activity peaks

Information about activity patterns of the Yellow-throated marten in different parts of its range before the application of new methods was meager and antithetical (Table 1). The contradictions between the different types of daily activity

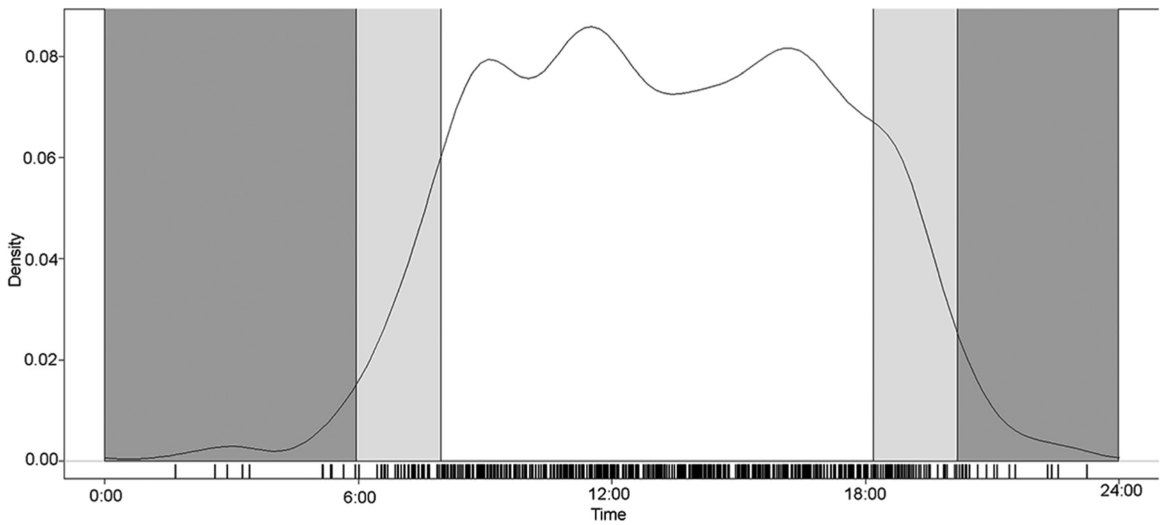

Figure 3: Kernel densities of daily activity of Yellow-throated marten (solid line) according to camera-trap data in the Primorsky Krai study areas (2010–2021). Individual records (n = 949) are shown as short vertical lines above the x-axis; dark gray shaded areas, light gray shaded areas and gray dashed lines represent the approximate night-time, twilight periods and time of sunrise and sunset, respectively.

patterns reported by researchers are likely associated with using different data collection and analysis methods. For example, the old Russian studies, which have reported different types of daily activity for this species, include information based on anecdotal observations in nature, survey data, and indirect signs (Astafiev and Zaitsev 1975; Kucherenko 1974; Matyushkin 1987; Matyushkin 1993; Yudin and Batalov 1982). Most studies performed using trail cameras instead showed diurnal activity of the Yellow-throated marten (Chiang et al. 2012; Ross et al. 2017; Zhu et al. 2019), except for one study in Indonesia (van Schaik and Griffiths 1996), where there were too little registrations (about 10) for reliable conclusions about the species' activity (Table 1). In some studies, such as Pocock (1941), Duckworth (1997) and Grassman et al. (2005), an unusually large database of direct observations was available, which was rare for that period. This is irrefutable evidence that previous generalized estimates of the daily activity of mustelid species were probably incorrect (Zielinsky 2000). The reason for this is that earlier estimates were largely based on direct observations, which have significant limitations in interpreting the data.

Results of our study show that the daytime activity of the Yellow-throated marten prevailed in all seasons of the year, the largest share of day registrations was noted in spring and summer (85.49 %, 82.61 % of registrations). Night activity was higher in autumn and winter (2.97 %, 2.94 % of registrations). We assume that in winter, due to the short period of daylight, the Yellow-throated marten lacked this time for activity related to feeding, which was necessary to replenish energy costs. Therefore, the animals were more often active at dusk. In spring, the duration of the day increased, and twilight activity decreased and, accordingly, daytime activity on the contrary, began to increase.

The comparison of the activity of the Yellow-throated marten in four protected areas of Primorsky Krai showed that, despite the widespread predominance of daytime activity, they had differences in activity patterns. At the same time, a statistical comparison of activity in these territories allowed us to distinguish two clusters: the first included B and U, the second – LL and LZT. The first cluster had a similar pattern of activity with one expressed peak in the middle of the day at 13:00 and 14:00 respectively. In the second cluster, activity in the middle of the day was lower than in morning hours and before evening twilight. In our opinion, this is primarily due to the climatic features of the territories. B and U are characterized by a sharply continental climate with low winter temperatures (Figure 2). Apparently, low winter temperatures are a serious stress for southern species, the impact of which it tries to offset by reducing activity in the coldest morning and evening hours (Churchfield 1982). A strong negative correlation between activity and the increase/decrease in air temperatures suggests that the Yellow-throated martens avoided extreme temperatures (probably remained in the shelter). They were more active in the comfortable temperature range. For instance, a telemetry study by Zalewski (2000) found that the activity of the European pine marten *Martes martes* was shorter in the coldest season of the year.

This thesis is confirmed by statistically significant differences in marten activity between warm and cold seasons

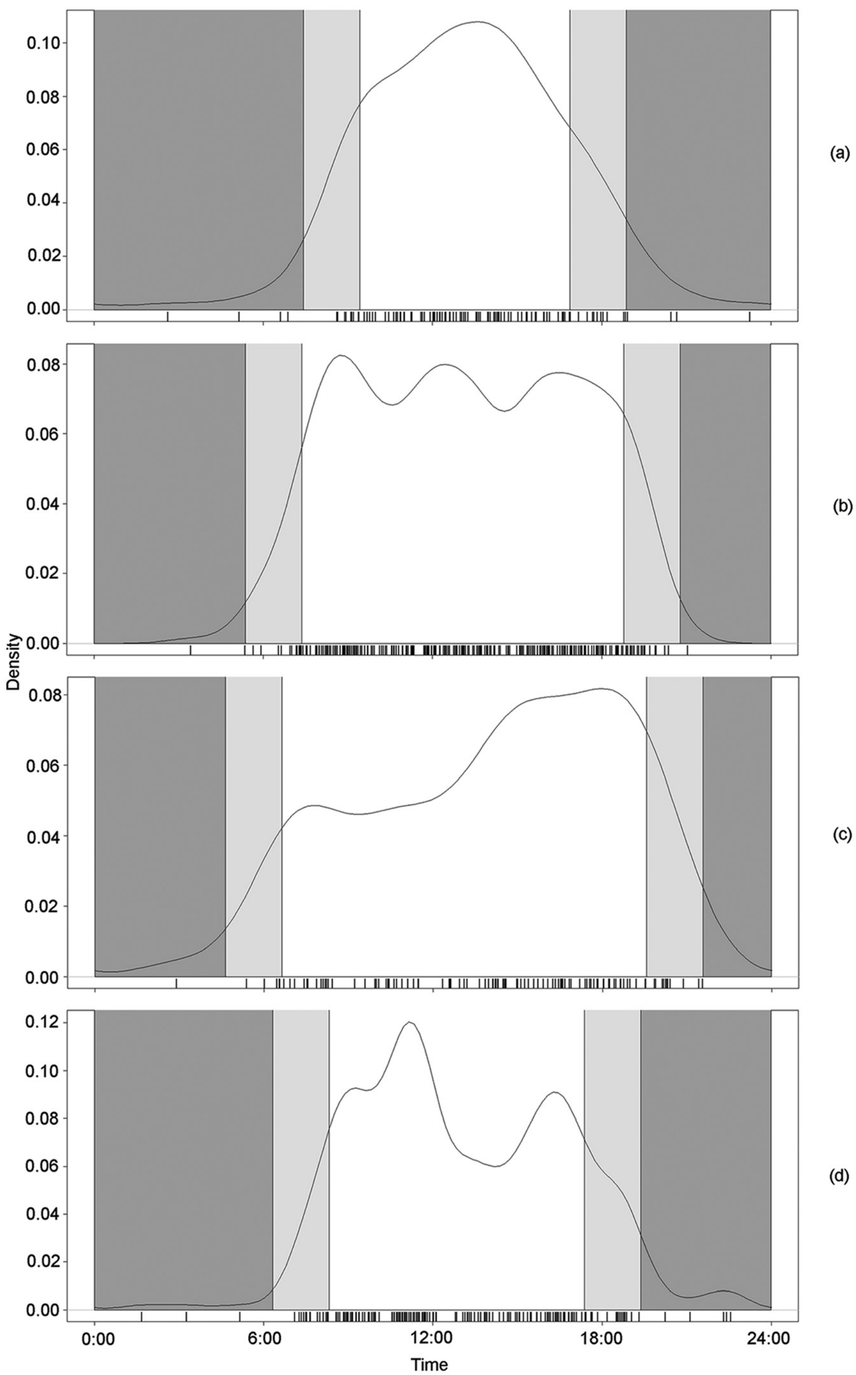

Figure 4: Kernel densities of daily activity of yellow-throated marten (solid line) according to camera-trap data in study areas of the Primorsky Krai by seasons (2010–2021). Individual records are shown as short vertical lines above the *x*-axis; dark gray shaded areas, light gray shaded areas and gray dashed lines represent the approximate night-time, twilight periods and time of sunrise and sunset, respectively. (a) Winter (n = 149), (b) spring (n = 364), (c) summer (n = 164), (d) autumn (n = 282).

in B and U (Figure 6). Activity in the middle of the day was more pronounced in winter, while in warm seasons it was weaker and prolonged from 10:00–14:00. In this study, the total period of diurnal activity was shorter during the cold season (11 h) than during the warm season (17 h), which is quite in line with the total duration of daylight hours in those periods. As for the differences in activity between LL and LZT, they were not significant, but possibly also related to the temperature regime. In LL, maximum summer temperatures were higher than in LZT and animals could shift their activity more to the beginning and end of the daylight period, thus avoiding the heat in the middle of the day (Figure 5).

Most studies show that the Yellow-throated marten expresses two detection peaks per day, occurring between 06:00 and 18:00 (Chiang et al. 2012; Grassman et al. 2005; Woo 2014; Zaw et al. 2008). In South Korea, the species instead expresses significant detection peaks, one around 8:00 after

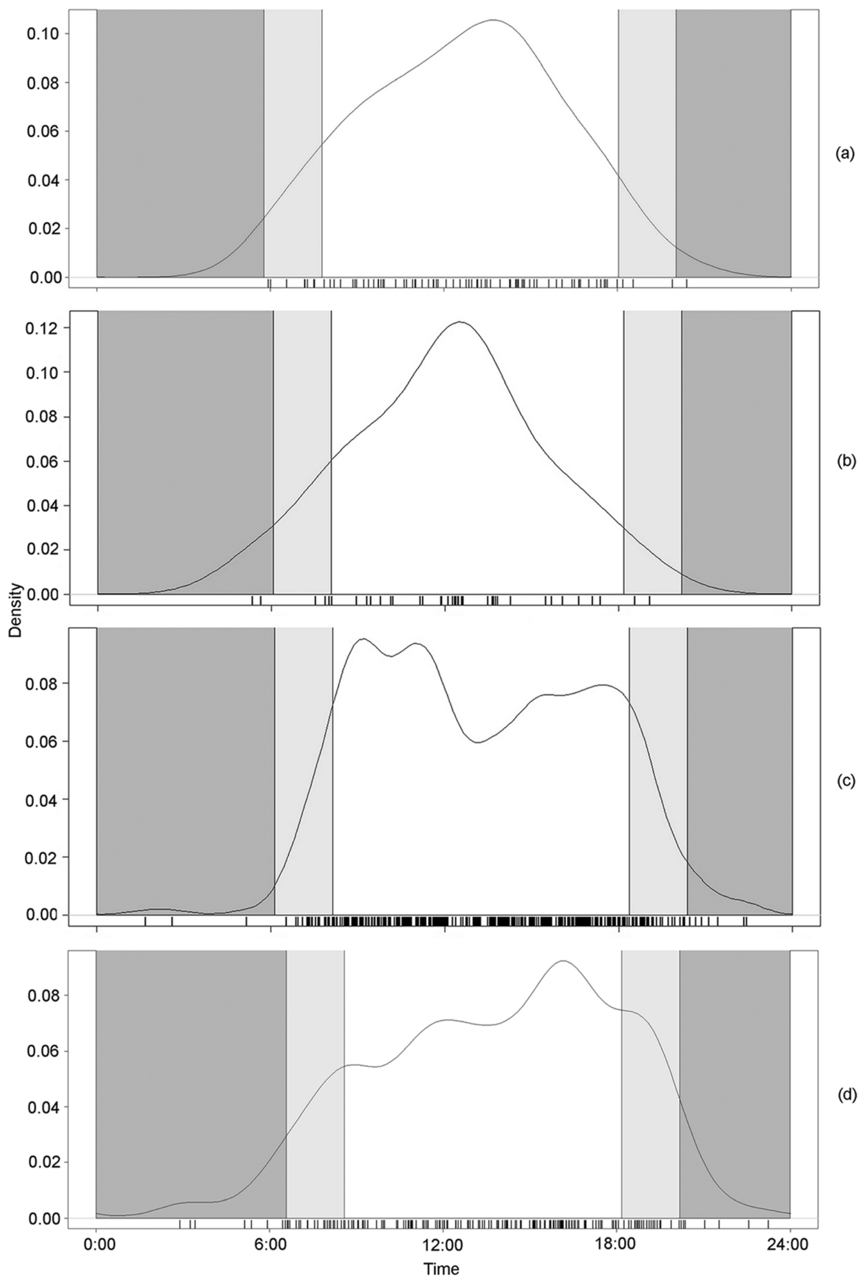

Figure 5: Kernel densities of daily activity of Yellow-throated marten (solid line) according to camera-trap data in the Primorsky Krai by four study areas (2010–2021). Individual records are shown as short vertical lines above the *x*-axis; dark gray shaded areas, light gray shaded areas and gray dashed lines represent the approximate night-time, twilight periods and time of sunrise and sunset, respectively. (a) B (n = 125), (b) U (n = 52), (c) LL (n = 476), (d) LZT (n = 297).

dawn and one in the afternoon around 17:00 (Woo 2014). A somewhat similar type of activity is noted in the LL, which is located closest to the Korean Peninsula, but the peaks are not so expressed here. Studies in China (Sichuan Province) and Malaysia (Borneo), there is one well-pronounced peak in the daily activity of the Yellow-throated marten occurring during the middle of the day (Ross et al. 2017; Zhu et al. 2019). Such activity was typical for the B and the U.

The character of daily activity of the species varied not only by territories but also by seasons of the year. In winter, there is one peak of activity in the middle of the day, which we associate with the warming of the surface air. In spring, animals are active throughout the day, without marked peaks, which can be explained by the need to restore spent energy reserves after winter (in detail below). In summer, the main daytime activity shifts to the second half of the day

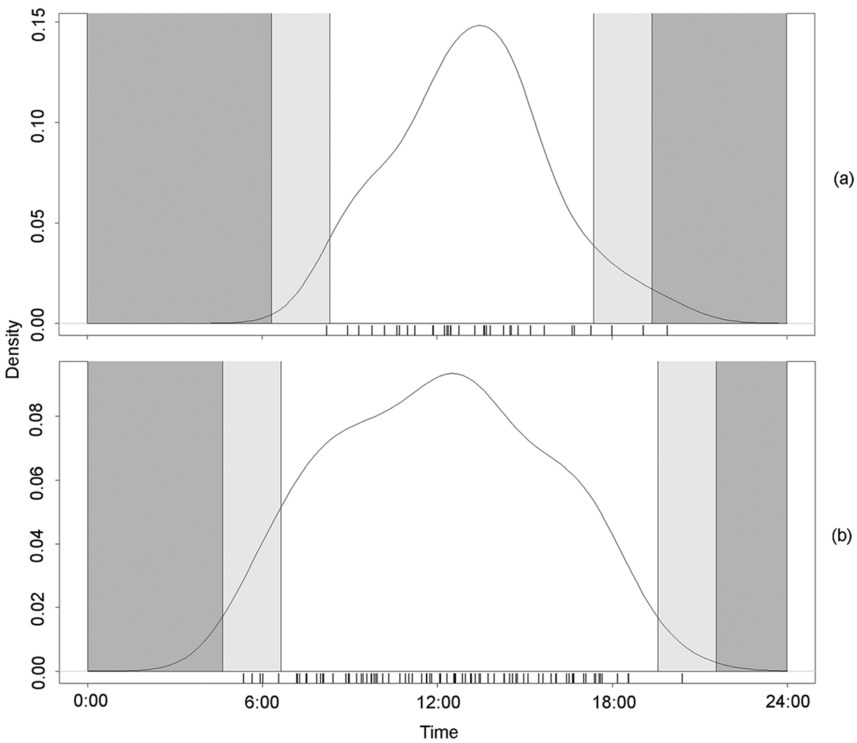

Figure 6: Kernel densities of daily activity of yellow-throated marten (solid line) according to camera-trap data in the continental part of Primorsky Krai (B, U) by cold and warm season (2010–2021). Individual records are shown as short vertical lines above the *x*-axis; dark gray shaded areas, light gray shaded areas and gray dashed lines represent the approximate night-time, twilight periods and time of sunrise and sunset, respectively. (a) cold season (n = 59), (b) warm season (n = 118).

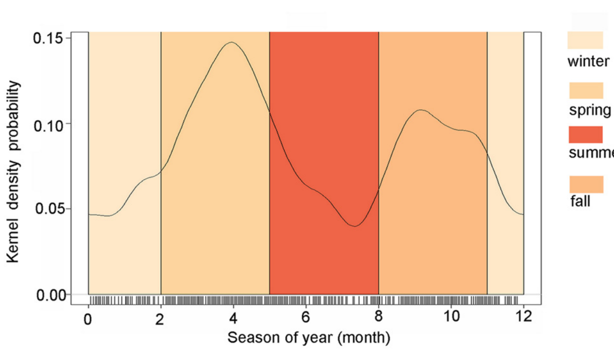

Figure 7: Kernel densities of seasonal activity of Yellow-throated marten (solid line) according to camera-trap data in the Primorsky Krai study areas (2010–2021). Individual records are shown as short vertical lines above the *x*-axis.

and closer to the evening twilight, when the air temperature begins to decrease. It allows marten avoids extremely high temperatures when the sun is at its zenith.

4.2 Seasonal activity

The records of Yellow-throated marten by seasons and months are distributed quite unevenly (Figure 7). High activity is well expressed in spring and autumn, while in winter and summer on the contrary, which corresponds to changes in climatic conditions and the basic physiological requirements of animals.

Low activity in the species during the cold period of the year would be expected since it is assumed that the animals spend most of their time in warm shelters during this period. This is probably due to the increase of energetic costs of movement and hunting/foraging, which are enhanced by deep and loose snow cover and extremely low air temperatures. The deep and loose snow cover undoubtedly hinders the movement of the yellow-throated marten, increases energy consumption, and shortens the duration of daily movement (Matyushkin 1987). In general, in winter, the detection level was lower than in other seasons. Consistent with this, we found that this species' active hours are shorter on winter days than during the warm period, and the largest number of registrations were observed during the warmest time of the day around noon (Figure 4).

In February and March, an increase in activity and occurrences of false mating, known as “false rut,” were observed in Sable *M. zibellina* and Pine marten (Heptner and Naumov 1998; Manteiffel 1948; Vladimirova 2011). The triggers for this phenomenon remain unclear, but we see similar signs in the yellow-throated marten. Further research is necessary to gain a more in-depth understanding of this phenomenon.

Increased activity of Yellow-throated martens in March-April in search for prey becomes energetically demanding, as it occurs against the background of its low fat reserves and even cachexia after the winter. We examined the bodies of seven dead specimens brought to us by hunters during

January–February. Out of these, six had a low or extremely low degree of body fat, and only one was in good condition. As confirmed by our snow tracking observations, in March-early April the Yellow-throated marten moves extensively on the snow crust and successfully hunts small and medium-sized mammals. On the other hand, during April–May, females give birth and must be secretive and sedentary (Shilo and Tamarovskaya 1989). The increase in detection in October coincides with the mating season that's quite natural (Figure 7).

In addition, comfortable air temperatures in the region, which is generally characterized by a sharply continental climate, contribute to increased activity of the marten in spring and autumn. During periods of extremely low (December–January) and high (July–August) temperatures, apparently, uncomfortable for the species, its activity level decreases. This is also consistent with the food consumption of predator mammals in temperate latitudes, which is lower in summer (Mautz and Pekins 1989; Prestrud 1991; Yudin 1992).

The Yellow-throated marten also shows variations in the seasonal activity pattern within its range. In the subtropical zone of China, the species is more active during the winter, with a peak in December and January, and the activity is also high in May and October (Bu et al. 2016). The minimum seasonal activity in China (central part of Sichuan Province) occurs in August (Bu et al. 2016), similar to our results in the Far East of Russia (Figure 7). Another study, conducted in the northern part of the Sichuan Province, China, found that the minimum activity was recorded during the winter months, which is similar to our data (Figure 7), and the highest activity was recorded in the autumn (Zhu et al. 2019).

Some researchers state that this species' activity is dependent on lunar cycles, reporting an increase in activity during moonlight nights that last for a few days after the full moon (Grassman et al. 2005). Unfortunately, behind the limited number of photographs taken at night in our study, we could not test this hypothesis statistically, but there is an interesting pattern. The largest proportion of activity (82 %) was observed in the quarters of the brightest (moon illuminance 76–100 %) and darkest (moon illuminance 0–25 %) nights. In further work, when additional material is obtained, an attempt should be made to elucidate the statistical influence of the phase of the moon on the nature of the activity of this species.

4.3 Foraging and daily activity

Foraging activity is one of the main types of mammalian activity. We analyzed all known cases of foraging activity the Yellow-throated marten in Russia to us and came to the conclusion that most of them belong to the daytime period (81 %). At the same time, martens often visit previously discovered food sources at night ($\chi^2 = 13.38$, $p < 0.05$). Despite the limited number, we will describe in detail the recorded cases, since such anecdotal observations in nature can be made episodically, but they allow us to get closer to understanding the ecological characteristics and behavior of animals.

In February 2020, in L a camera trap was installed near the corpse of a dead wild boar *Sus scrofa* on an open river spit. The first registration occurred here at 17:30 December 2 2020 the Yellow-throated marten stopped for a brief moment at the boar and ran away, at 23:15 this individual returned at night to the corpse and ate it for 22 min, then returned again at the end of the night at 5:09 December 3 and ate again for 26 min. In this case, it is possible that the animal came at night to avoid encounters with larger predators (tiger, bears, eagles) in an open area away from trees; this could be dangerous for it.

Foraging activity is typically observed in the Yellow-throated marten during daylight hours, which is consistent with the data relating to the southern part of its range (Pocock 1941; Pierce et al. 2014). We analyzed our own and literature data (11 cases) of hunting for musk deer *Moschus moschiferus* whereof nine were observed during the day and two at night (Abramov 1963; Matyushkin 1987). The pursuit of a young sika deer *Cervus nippon* was registered by a camera trap in the L on June 17, 2016, at 06:42 and 06:56.

We know of cases where Yellow-throated martens came at night to the remnants of prey known to them. Martens in the L have been registered at night by camera traps when revisiting the nest of Scaly-sided Merganser *Mergus squamatus* (pers. com. Solov'yova D.V.) and wild bees *Apis cerana* in a hollow to feed on them. In the South–West of the Primorsky Krai in March 2013, snow tracking showed that a marten revisited a sika deer kill, previously known to it, during night.

Yellow-throated martens have been anecdotally reported to shifting their activity from diurnal to nocturnal when visiting areas populated by humans. We noted cases of night activity in martens visiting an apiary in Primorsky Krai. A similar shift to nocturnal activity was observed when martens attacked hens and other small live-stock animals in a forest village of West Bengal (India) (Mallick 2013). The same was observed when martens visited areas inhabited by humans in Thailand (Grassman et al. 2005). Such changes in activity can be seen as an adaptation to the presence of humans and the risk of persecution by them. All our research sites are in protected areas where there are no settlements, so we could not verify these assumptions in more detail.

But as we discussed above, the Yellow-throated marten frequently visits food resources their know during the nighttime. These food resources also are used by large predators (brown *Ursus arctos* and Himalayan bears *Ursus thibetanus*) and tigers. This behavior of martens may be related to the avoidance of meetings with the large predators and absence of competitors which have predominantly daytime (bears) and twilight (tiger and leopard) activity patterns (Ji et al. 2022; Seryodkin et al. 2013; Yang et al. 2019).

5 Conclusions

In conclusion, the results clearly show that the Yellow-throated marten in the Far East of Russia and generally in the north of its range in natural habitats with minimal human impact is a highly diurnal species relying on daylight. Only in winter and spring is twilight activity important, although inferior to daytime activity. The most significant changes in the activity of the species occur during the twilight period: morning growth and evening decline. Nighttime activity is always low and does not exceed 3 %. Comparing data obtained in several protected areas allowed us to distinguish two species' activity patterns. One is characterized by unimodal distribution with the expressed peak around noon other has a more smoothed activity with weakly pronounced peaks in the first and second half of the daytime period. At the same time, the first cluster is located in the mainland of Primorsky Krai with a pronounced continental climate with low temperatures in winter, and the second one is located in coastal areas with a temperate climate. Significant differences were found in the activity of the Yellow-throated marten by seasons of the year, which are consistent with seasonal weather changes and physiological requirements of the animals. Severe climatic conditions have the greatest influence on changes in the activity of the Yellow-throated marten in Primorsky Krai. There is a strong negative correlation between the daily activity of the Yellow-throated marten and a decrease in temperatures in winter, as well as an increase in temperatures in summer because the species lives in the pessimum zone near the northern border of its areal. An adaptive shift of activity peaks to twilight and night in anthropogenic areas also observed.

These new data on daily and seasonal activity of the *Martes flavigula* is a small step in learning its ecological niche in the community of terrestrial vertebrates of the south of the Russian Far East. The activity of the Yellow-throated marten in tree crowns remains unexplored, as it is a partially arboreal species. Research methods such as telemetry would be necessary to explore the yellow-throated marten's activity in tree crowns. Also, this study raises new and relevant questions requiring further research. In particular, about the connection of Yellow-throated marten activity with lunar phases, anthropogenic influence and activity of its victims and competitors.

Research ethics: This study was conducted inside National Parks and Reserves in Russia under the current legislation. The methodology employed for the study was non-invasive, using camera traps, therefore, there were no additional permits required.

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