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Marking activity of the Kamchatka brown bear (*Ursus arctos piscator*)

Ivan V. Seryodkin

Pacific Geographical Institute FEB RAS, Vladivostok, Russia

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ABSTRACT

The marking activity of brown bears was studied in the Kronotsky Reserve (eastern shore of the Kamchatka Peninsula) between 2002 and 2005. The goal of this investigation was to document communication mechanisms within the species. We recorded descriptions of bears rubbing and marking trees, as well as individual marking behaviour of bears in the Valley of the Geysers. We recorded 203 marked trees in an area of 2.5 km^2. Bears marked mostly stone birches (*Betula ermanii*) with a mean diameter at breast height of 24 cm. Most trees were freshly marked with scratches or teeth marks and also exhibited scarring from previous years. Well-worn tracks were often recorded approaching marked trees. Regarding tree markings, 10.3% of trees were marked intensively, and 32% of trees were clustered. In addition, 88.9% of marked trees were located on ridges, and 79.3% were located on bear trails. The most intensive marking period was between May and June, which corresponded to bear mating season. The most commonly observed behaviour prior to marking was a rigid walking approach, rubbing on the trunk, and biting and removing tree bark. The high density and diversity of rubbed trees in the reserve should be considered a model for monitoring. The conservation of the Valley of the Geysers is intricately related to the wellbeing of the region's bears. Monitoring human impact on bears in the Valley of the Geysers, specifically tourism traffic, should include monitoring of the intensity and frequency of bear marking activity.

Introduction

Brown bear marking activity is a widespread behaviour that has intrapopulation communication meaning (Korytin, 1979; Pazhetnov, 1979; Colmenares and Rivero, 1983; Loskutov et al., 1993; Puchkovsky, 2005 and others). Trees are the main marking objects of bears. According to different varieties of bear marking activities, we can distinguish between the following marks: rubbing, bark biting and scuffing, and branch and trunk breaking. Bears also mark bushes, rocks, boulders, various buildings, and traces of human activity (Kaletskaya, 1973; Harger, 1974; Grachev and Smirnova, 1982; Burst and Pelton, 1983; Zhiryakov, 1991; Nikolaenko, 2003). Track marks (holes in the ground near trees and other marking objects made by forcing and spinning movements of extremities) and rolling places (ground hollows in which bears roll to leave their hair) are also elements of marking activity.

Brown bear marking activities are a means of intrapopulation communication. Marking trees decreases the possibility of undesirable meetings with other individuals, notifies others about the marking animal's social status, and promotes meetings of sexual partners during the rut season (Flerov, 1929; Seton, 1937; Pazhetnov, 1979, 1990; Rukovsky, 1987; Puchkovsky, 1991). Bears' marking

E-mail address: seryodkinivan@inbox.ru.
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activities have complex biological meaning. Nikolaenko (2003) supposed that marking trees could provide a bear contact with its own smell and play a role in psychological tension removal. Some tree-marking behaviours (rubbing, scratches) can be comforting or playful in nature rather than social (Puchkovsky, 2005).

Studying brown bear communication systems is important for monitoring improvements in the species' populations, which inhabit specially protected and industrializing areas (Puchkovsky, 2005). Knowledge about bears' ecology and social behaviour allows for efficient management of their populations. Researchers should take into account the impact human activity has on the structure and functioning of animal populations. Studying the brown bear's marking behaviour contributes to an understanding of the listed issues.

Materials and Methods

Data on brown bear marking activities were collected in the territory of the Kronotsky Reserve as part of the WCS project on Kamchatka brown bear conservation.

Marking tree descriptions were taken in the Valley of Geysers (Geysernaya River Basin) in May 2004 and June 2005. We observed the segment of the Geysernaya River from the inflow of Vodopadnyi Brook and upstream and the lower course of Vodopadnyi. The extent (along the river) of the observed area is 3 km, and the width is 2.5 km. The Valley of Geysers main geothermal complex with hot springs and geysers is located here. Excursions for tourists are also held in this territory. We described 203 trees with bear markings in the area of study.

All discovered trees with bear markings (rubbing, hair, damaged bark, bitten off and broken branches, etc.) were described according to a clear protocol. We determined the coordinates of each tree with a GPS navigation device and described its location (ridge, river or brook terrace, or floodplain) as well as its correspondence with a trail. We also noted tree species, condition (dead or alive), and trunk diameter at breast height. Diameter measurement accuracy is 1 cm. We measured the incline angle of tilted trees and described the incline of the trail and marking type with respect to the trail and tree incline. While working, we separated fresh (this year) marks from old ones (previous years). We recorded traces of a bear's rubbing (hair left on the trunk, polished, dirty, or greasy bark), bark biting (teeth traces and pieces of bark removed with teeth), bark scuffing (scratches and pieces of bark removed with claws), and broken and bitten off branches and trunks. We recorded the height of bark biting and scuffing; when it was impossible to determine the exact mark, we specified the general height for these 2 types of damage. The size (length and width) of bark biting (pieces of bark removed with teeth) was measured. We noted track marks, rolling places, urine marks, and feces near marking trees. Trees with abundant and various fresh and old marks were determined as intensively used marked trees. We combined marked trees in groups if the distance between the next tree was less than 5 meters.

In the Valley of Geysers, track marks and marked trees were described simultaneously. We noted the correspondence of track marks with trails, ridges, and marking objects (for example, trees). We measured the general continuous length of each track mark, the number of separate traces in it, the size of the track holes (length, width, depth), the distance between track holes, the distance between marking objects, and the most remote end of the track mark.

Sizes' average values ($\overline{X}$) of damage left by bears on trees, marking activity elements and trees' diameters, are given in the text with a standard deviation ($\pm\ldots$); the amount of sampling (n) and minimum (min) and maximum (max) values are also given.

We also conducted visual observations of bears' marking behaviour in the valleys of the Kronotskaya, Bogachevka, Tikhaya, and Shumnaya rivers in 2002–2005. While working in each river valley, we estimated the animals' selectivity for marking objects and noted marked trees to determine marking linear frequency, which is expressed in the number of marking objects per 1 km of a bear's trail.

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Characteristics of Studied Region

Kronotsky Reserve is situated on the east coast of the Kamchatka Peninsula. Its territory includes river basins, which flow into the Pacific Ocean; the largest among these are the Shumnaya, Tikhaya, Kronotskaya, Bogachevka, Tiushevka, and Bolshaya Chazhma river basins.

The Valley of Geysers is famous for its hydrothermal features, such as geysers, pulsating sources, mud pots, warm lakes, and steam-gas jets. This valley is a canyon of the lower course of the Geysernaya River (Shumnaya river basin). Its sources are found on the west slopes of the Zheltaya Mountain, which is part of the large volcanic system Kichpinich. The valley's bottom is 300 m above sea level, and its edges are 400 m high. Steep slopes (20–40°) of the valley and its tributaries sometimes change to terraces at different levels. Landforms, especially microreliefs, are diverse and dynamic. There are many water streams (cold, hot, mineralized), screes, gullies, landslips, and rocky outcrops (Lobkov, 2002).

Despite its remote position from the ocean (18 km away), the climate in the Valley of Geysers can be considered relative to the climate on the ocean shore. The amount of precipitation reaches up to 2000 mm per year, which forms non-melting, long-term multimeter snowfields. The seasons' durations differ: winter lasts 180 days, spring 56–77 days, summer 60–90 days, and autumn 60 days. Snow cover sets in no later than the beginning of November and finally melts by the end of June. Snow cover begins melting early in the spring in thermal areas and is melted by the beginning of May. Early snow melting on the thermal areas' periphery and the

earlier start of herb vegetation in the thermal area surroundings create favourable conditions in the central part of the Valley of Geysers for many mammalian species (including the brown bear) to obtain nutrition in early spring.

Flora of the Valley of Geysers includes nearly 300 species of higher vascular plants. Widespread occurrence of a low number of species, which play the main role in landscape formation, is typical for this flora. Among these species are stone birch (*Betula ermanii*), *Pinus pumila*, *Alnus fruticosa*, *Calamagrostis langsdorffii*, *Filipendula camtschatica,* and others. Specialized thermal flora grow in the thermal habitats (Rassokhina, 2002).

The brown bear is usually found in the Valley of Geysers from April until September and is more numerous in May–July. The animal's density in May–June is one of the highest within the reserve and in Kamchatka as a whole. A considerable proportion of adult individuals rut in the middle of June (Mosolov and Nikanorov, 2002).

The Valley of Geysers is a popular destination among tourists. Areas open to tourists, visiting seasons, and recreational load are normalized and strictly controlled.

Results

Marking Object Descriptions

Marking objects for brown bears are mostly trees and, to a lesser degree, bushes, trails to bear baths, buildings, and other traces of human activity.

An overwhelming majority of the marked trees (91.6%) in the Valley of Geysers were stone birches—186 samples, $n = 203$ (Fig. 1).

In addition, there were 13 marked willows (*Salix* sp.) and 4 marked *Alnus hirsute*. All marked trees were alive. The average marked tree's diameter was 24 ± 15 cm (min = 3 cm, max = 85 cm); for birches in particular: $\overline{X} = 25 \pm 15$ cm (min = 3 cm, max = 85 cm);

Fig. 1. Stone birch (*Betula ermanii*) with scratching, biting, and scarring from brown bears.

Table 1
Distribution of brown bear marking trees by trunk diameter categories in the Valley of Geysers.

Dimensional category of the tree trunk, cm	Number of trees	% trees in this category
Below 10	36	17.7
11–20	64	31.5
21–30	59	29.1
31–40	17	8.4
41–50	13	6.4
51–60	7	3.4
61–70	5	2.5
71–80	0	0
81–90	2	1

for willows: $\overline{X} = 10 \pm 4.5$ cm (min = 4 cm, max = 19 cm); and for *A. hirsute*: $\overline{X} = 8.5 \pm 6$ cm (min = 3 cm, max = 17 cm). Most of the marked trees (60.6%) had a diameter between 11 and 30 cm (Table 1).

Some of the marked trees (39 trees, 19.2%) were tilted. The incline angle ranged from 7° to 90° ($\overline{X} = 35.8 \pm 18.3°$). If such trees were located near a bear trail, they inclined toward the trail in most cases (89.5%); otherwise, they inclined parallel to the trail. Bear marks on tilted trees were primarily left on the side of the trail (79%) and rarely on the side opposing the trail or simultaneously on both sides of the trail (in 10.5%). Relative to the incline of the tree, marks were located on the side of the acute angle of incline (76%), opposite the incline (15%), simultaneously on both sides of the acute angle (6%) and around the tree (3%).

Bear rubbings were discovered on 187 marked trees (92.1%). Fresh hair or rubbings in combination with the same from the previous years were found on 165 trees; only fresh marks were found on 3 trees, while only old ones were found on 10 trees. In 6 cases, there was fresh hair and uncertainty about the presence of old rubbings; we were unable to establish the remoteness of rubbings in 3 cases. Rubbing heights on trees varied (from the ground to 207 cm height).

Bites and (or) scuffing were found on 167 marked trees (82.3%). Among all cases, fresh damage in combination with old damage occurred on 70 trees, while only fresh damage was found on 22 trees, and only old damage was found on 58 trees. The age of damage was not established on 17 trees. The highest position of damage (bites and scuffing) for particular trees was 197.8 ± 36.7 cm on average (min = 105 cm, max = 270 cm, $n = 125$). In cases when we could differentiate between the 2 types of damage, this value was $\overline{X} = 176.5 \pm 35.5$ cm (min = 105 cm, max = 270 cm, $n = 50$) for bites, while for scuffing the value was a bit higher: $\overline{X} = 199.8 \pm 38.5$ cm, min = 107 cm, max = 260 cm, $n = 30$. When bites and scuffing were not alone on a tree, they could be located at a lower height than was stated as a minimum value for the highest positions. Bites started at a height of 40 cm. For example, there were 5 bites of different ages on one tree; their heights were 111, 139, 155, 160, and 233 cm.

Bites were visible as rectangular parts of the trunk where bark was removed with the teeth and thus where wood was stripped. The wood retained traces of teeth marks. Usually, such damaged areas were larger in width (across) than in length (vertically). According to 22 measured cases, the square of bite damage on average was 109.6 ± 116.5 cm^2 (min = 8 cm^2, max = 518 cm^2) with a width of $\overline{X} = 10.9 \pm 4.7$ cm (min = 3 cm, max = 20 cm) and a length of $\overline{X} = 9.1 \pm 7.1$ cm (min = 2 cm, max = 37 cm). In some cases, the wood was not stripped, and we observed transversal traces of teeth marks on the birch bark. Bear scuffing presented as stripped areas of wood with a length exceeding the width. Scuffing left on birches more often looked like transversal and longitudinal scratches on bark without reaching the wood because it is quite difficult to remove the multilayer solid bark of this species. Six marked trees (4 willows and 2 birches) had bitten and broken branches; 2 other willows had broken trunks at a height 147 and 180 cm.

In June 2004, we found fresh uretic bear scent markings left on the trunks of 2 contiguous marked birches in the Vodopadnyi brook terrace. Marks were located at a height of 103 cm, had a round shape with a diameter of 13 cm, and issued a sharp smell. Apparently, they were left by one animal.

In the Valley of Geysers, we found 4 rolling places under marked trees. Bear feces were found under 2 trees, and the animal(s) heaped up dry leaves and dust under another tree.

A total of 10.3% of marked trees were characterised by a heightened rate of marks. Such trees had abundant rubbings, bites, and scuffs left by bears over many years (Fig. 1). Among the intensively marked trees were 20 birches and 1 willow.

There were marking tracks on the way to marked trees in 53.7% of cases. These were left on the ground and on the hard snow. In 99 cases, mark tracks came up to a tree from both sides (and more rarely from 3 or 4 sides), usually along the trail; in 10 instances, tracks came up to a tree from only one direction. Sometimes mark tracks occurred between marked trees growing in a row along the trail; they could also be associated with only one tree. In the first situation, mark tracks stretched uninterruptedly from one tree to another. The largest extent of such tracks was approximately 300 m; this mark was left along the trail on a ridge between 2 narrow valleys and connected 7 mark trees. The longest route to a single tree from one side consisted of 41 track holes. The shortest mark track was 364 cm long and consisted of 5 track holes—footprints of a bear's paws. Mark tracks started either from the trees or from a short distance away (up to 2 m). In addition to occurring between marked trees, tracks were found near bear bathing places—hollows in the ground filled with water (Fig. 2).

The average distance between 2 track holes was 77.6 cm (min = 65 cm, max = 117 cm, $n = 138$). Track width (the distance between middle lines of the left and right paws' footprints) varied from 35 to 54 cm. Particular track holes left on the ground had the following size: length –$\overline{X} = 38.7$ cm, min = 34 cm, max = 47 cm; width –$\overline{X} = 24.6$ cm, min = 21, max = 30; depth depended on ground density and was up to 5 cm. The holes' sizes were larger on the snow cover because footprints there were blurred. On some

Fig. 2. Brown bear footprint marks (forefront) in front of the animal's bathing place in the Valley of Geysers.

trails, track holes remained on the ground from year to year, refreshing every season. The average sizes of overlapped foreleg and hind leg footprints were as follows: length—30 cm, width—19 cm. These footprints belonged to animals that marked trees but were outside mark tracks. Thus, track holes were larger than the footprints of bears' paws; the average difference was 8 cm in length and 5–6 cm in width.

In addition to trees, *A. fruticosa* bushes were noted among marking objects. It was revealed from different parts of the reserve that bears rubbed and left bites and scratches on wooden huts and other buildings, especially in places with rare human appearances. If there were trees close to the buildings, they were marked by bears as well. On the seashore, where no trees grow, bears marked short poles or telephone poles dug by humans. Metal oil barrels and helipads were also marked by bears.

Marked Object Distribution

In the Valley of Geysers, marking objects were associated with linear elements of the landscape: ridges, terraces, floodplains, and trails. All marked trees fell under 34 linear sections, most of which correlated with watershed ridges (26) or, in other cases, with terraces (6), a floodplain (1), and a north-facing slope (1). There were 180 marked trees along ridges (88.7%), 21 trees along terraces, 1 tree on a floodplain, and 1 on a slope. Some ridges, which sloped down to brooks or the river, had slope angles. We recorded 111 trees on such ridges, which were distributed in the following way: north (46.8%), south (26.1%), northwest (18%), west (6.3%), east (1.8%), and northeast (0.9%).

Places with bear-marked trees were correlated with stone birch forests and, to a lesser degree, to a floodplain community with *A. fruticosa* and willow. Marked trees were found at an altitude from 270 to 380 m. We did not find any marked objects at a higher altitude.

Among the trees located along the trails, 79.3% of them were marked; 116 trees were located on bear trails and 45 on animal and human trails. The remaining 42 trees were outside of the trails. In 5 cases, trails near trees were not straight and specifically appeared to come up to the trees (only from one side).

In the Valley of Geysers, the linear rate of tree marking in some cases was up to 40 per 1 km. The maximum density of bear marks during the local route segments was noted on trails along the ridges. There, we observed 7 marked trees along a 20-m stretch and 5 marked trees along an 8-m stretch. In 25 cases, trees were located in groups (mark complex): in 18 instances, a group consisted of 2 trees; in 3 cases, it consisted of 3; in 2 cases, it consisted of 4; and one time each, there were 5 and 7 trees in a complex.

Within the Kronotskaya and Tikhaya river basins, marked trees were generally located along trails in river valleys with stone birch forests. Marked trees were observed from the Kronotsky Gulf seashore to the riverhead. Marked object density was lower within the basins of these rivers than in the Valley of Geysers. For example, we identified only 6 marked birches in a 16-km route along the old overgrown road, which passed through stone birch forest from Lake Kronotskoe down the Kronotskaya river valley (0.4 trees per 1 km). There were 11 marked trees on another route that was 10 km long and passed through birch forest and, partly, tundra near the Tikhaya River along the trail (1.1 trees per 1 km). A high linear density of bear marks was noted on a bear trail in a valley of

the Khriukina River (tributary of Kronotskaya River): 9 birches with various elements of bear marks and 6 thin trees broken by bears. On the whole, 12 stone birches that could potentially be used for marking grew along this trail; animals chose 9 of them (75%).

Bears' Marking Behaviour and Marking Activity in Different Seasons

Bears that marked trees exhibited the following behaviour: tree sniffing, rubbing, trunk biting, scuffing, and specific ritualistic walk leaving track marks and urination. At first, animals examined trees, sniffing the trunk while standing on all 4 legs or only on hind legs with forelegs leaned on trunk. Then they turned over and flattened their back, neck, and thrown-back head against the trunk while standing on hind legs or sitting. They started rubbing against the bark, making vertical or horizontal movements. In some cases, animals standing on hind legs rubbed with flattened breast and side of the neck while encompassing the trunk with their forelegs (Fig. 3). Sometimes bears bit the trunk standing on hind legs, on all 4 legs or sitting. More rarely, animals scratched a tree and stripped the bark. Modes of tree marking varied among different bears and even in one animal.

Bears left track marks while approaching a tree (or another marking object) and moving away from it. While leaving track marks, bears put their paws from one track hole to another; they drew their paws aside but did not bend them. In every hole, they kept their paws long, trying to press them into ground. Some bears showed the same reaction when they met humans.

Different bears used the same trees for marking. Animals visiting the Valley of Geysers for a short period stayed longer only to observe and mark trees along the trails they travelled. Bears that stayed in this area for a long time (some animals recognized to the individual level) visited specific marked trees and refreshed their marks periodically. They successively moved from one marked object to another, sniffing and marking each of these. In the Valley of Geysers, we visually observed tree marking only by adult males.

Bears marked objects more intensively during May and June. We observed the maximum amount of fresh marks during this period. Bears demonstrated some acts of marking (usually it was rubbing against the tree) that were considerably rarer during other months of their active annual period. For example, on the Kronotsky Gulf seashore, bears rubbed and bit a wooden pole, which was a marking object for them, during the entire summer and partly in autumn (September, October).

Marked trees were discovered on the banks of spawning rivers (Kronotskaya, Bogachevka, Tikhaya, Shumnaya). During bears' fattening on salmon, we noted bears rubbing against trees; young animals and females also performed this act of marking. We observed bears' behaviour while feeding on spawning salmon for 216 h and 21 min near the Kronotskaya River from August to September of 2003 and 2004. Bears rubbed against trees for 16 min of this time (0.1% of time).

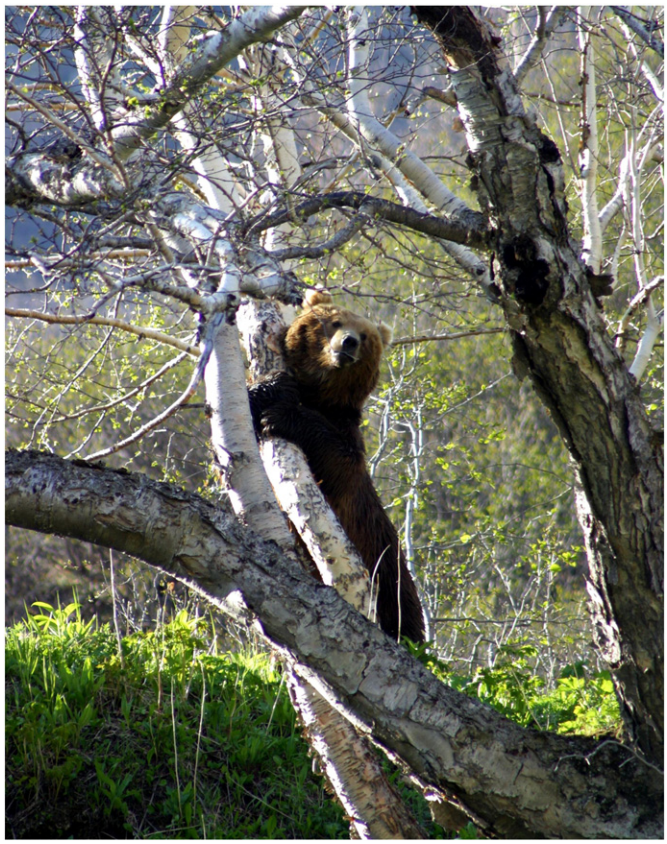

Fig. 3. Brown bear marking birch in the Valley of Geysers.

The products of oil refining were attractive to bears in all seasons. Bears of various sexes and ages visited the kerosene spots left on a helipad. A female bear and her cub came to this location every morning. Both of them rolled upon the spot for hours, rubbing their entire bodies with kerosene. After the female bear died, the cub kept visiting this rolling place on the helipad alone.

Discussion

Brown bear marking behaviour in the Kronotsky Reserve and the type of marks left by these bears is similar to the same parameters in other regions of this carnivore's distribution (Pazhetnov, 1979; Danilov, 1991; Zavatsky, 1991; Aramilev and Solkin, 1993; Puchkovsky, 2005; Seryodkin et al., 2014).

The fact that most of the marked trees in the Valley of Geysers were associated with ridges is explained by the peculiarity of this area, which is located in mountainous terrain with steep slopes and narrow valleys thickly overgrown with elfin wood (*A. fruticosa* and *P. pumila*); there are also many watershed ridges suitable for animal movements. The presence of marked trees along the ridges depends on the existence of suitable trees in the topmost watershed, the underwood density, and the ridge incline.

The best conditions for marking in the Valley of Geysers are determined to be in the lower third of the Geysernaya River's watershed slopes. At an altitude of 400 m, marked trees almost do not occur because ridges become quite steep and overgrown with dense bushes; thus, birches are often located not on the top of the ridges but on its sides. According to Rogers (1977), smell spreads better on ridges because of the sparse woods grown on them. Additionally, the abundance of marked trees on ridges can be correlated with bears using ridges as linear references while moving (Burst and Pelton, 1983).

There are few trees in narrow valleys and brook canyons in the Geysernaya basin, so there are not many marked objects. In river basins, which have wide valleys in the Kronotsky Reserve, most of the marked trees were located within floodplains and terraces. Such geographical distribution of marking objects is typical for other parts of the brown bear habitat, e.g., the northeast of Siberia (Chernyavsky and Krechmar, 2001) and Sikhote-Alin (Seryodkin et al., 2014).

The poor number of tree species used by bears in Kronotsky Reserve can be explained by the dominance of a few dendroflora species (stone birch being foremost) in the forests of this area. In some regions, conifers prevail over others as marking trees (Mills, 1919; Seton, 1937; Dokken, 1954; Meyer-Holzapfel, 1957; Shaffer, 1971; Rogers, 1977; Pazhetnov, 1979; Rukovsky, 1987; Rykov, 1987; Aramilev and Solkin, 1993; Vaisfeld and Chestin, 1993; Puchkovsky, 2000).

In the Valley of Geysers, *P. pumila* is the sole conifer species, but it grows as low brushwood and is not suitable for marking. Different species of birch are also actively used by bears in some regions; for example, in the Middle Sikhote-Alin, 3 species of birch (*Betula platyphylla*, *Betula costata*, *Betula davurica*) make up 21.1% ($n = 674$) of all bear-marked trees (Seryodkin et al., 2014). In the eastern part of Dzungarian Alatau, there are no conifer forests, so bears mark birch actively as well (Grachev, 1981). It appears that choosing birch as a marking object can be explained not only by its predominance in some phytocenoses but also by the morphological and physiological features that are suitable for marking. Among them are the species' rather high value placed on trunk diameter, the absence of branches in the lower part of the trunk, the stratifying bark structure, and profuse sap secretion after damage, which possibly stimulates marking acts. However, bears do not mark birch willingly everywhere. Puchkovsky (1998) noted that in Udmurtia, bears avoid marking this type of tree.

Trunk diameter apparently has an impact on a bear's selection of trees suitable for marking. This theory is supported by the fact that within one of the routes along the Kronotskaya River, the thinnest birch among marked trees had a diameter of 25 cm at breast height, although there were many more thin trees near the bear trail. In the Valley of Geysers, 28.6% of intensively marked trees had diameters exceeding 40 cm; at the same time, such diameters among all mark trees (not counting mark intensity) made up only 15.3% of trunks. Thus, we have reason to suppose that bears prefer to mark thick trees. The numerical decrease of marked trees with a diameter of more than 30 cm compared with trees with diameters from 11 to 30 cm (Table) must be connected with a small part of big-sized trees in a region of study.

Among tilted trees, bears more often chose ones that inclined towards the trail and marked them mostly from the side of the acute angle of incline. Bears in Primorye (south of the Russian Far East) show the same mark selectivity (Seryodkin et al., 2014). The Amur tiger also prefers to mark tilted trees (Yudakov and Nikolaev, 1987; Protas et al., 2010).

The proportion of marked trees with bear rubbing marks was higher than the amount of trees with bite and scuffing marks. Moreover, the percentage of trees with fresh rubbing marks (89.8%) exceeded the percentage of trees with fresh bite and scuffing marks (61.3%). This indicates that rubbing is a more common marking act among bears compared with bark biting and scuffing. This also shows that bark biting and scuffing are not obligate marking acts for bears. This statement is supported by visual observations after animals' marking behaviour.

Some bites on trees in the Valley of Geysers could be more than just marking acts. Low located bites (at a height of 40–100 cm) looked like tapping made by the Asiatic black bear (Seryodkin, 2003) and brown bear (Seryodkin, 2011) in the southern Far East to feed on birch sap. Such bites were made during intensive sap motion.

Another interesting finding included bear uretic marks left on 2 marked birch trunks. This marking act is typical for Amur tigers (Matushkin, 1987; Yudakov and Nikolaev, 1987). Cases of urination are noted for bears as well (Tschanz et al., 1970 in Burst and Pelton, 1983; Shaffer, 1971 in Burst and Pelton, 1983).

Most of the marked trees are permanent for bears and used every year. Ninety percent of the marked trees had fresh marks and marks from previous years ($n = 190$—cases with determined age of mark). Some of the mark trees were not used every year (at one point of making mark descriptions, 7.9% of trees had only old marks). Finally, some new trees were added for marking every year (2.1% of trees had only fresh marks). We did not record any cases in the Valley of Geysers where trees stopped being marked

because of mechanical damages. Under anthropogenic load in Udmurtia, for 8 years and along a 79-km route, 18 mark trees were no longer used, 14 of them through human fault (Puchkovsky, 1998).

Some of the marked trees were used more intensively; these trees have particular meaning in a population's communication system. In the Valley of Geysers, the percentage of intensive marks (10.3%) was on the same order as in Primorsky Krai (15.4%), $n = 674$ (Seryodkin et al., 2014). The subjectivity of this comparison decreases if we take into account the fact that mark intensity was determined in both regions by the same researcher. The location of marked trees in groups (32% were recorded as part of a complex) indicates the duration of a bear's excitement while marking trees. After observing and marking one tree, animals shift their attention to other nearby objects.

Associating marked trees with trails used by humans and animals is typical for all regions (Flerov, 1929; Grinell et al., 1937; Seton, 1937; Pazhetnov, 1979; Grachev and Smirnova, 1982; Burst and Pelton, 1983; Jamnicky, 1987; Rukovsky, 1987; Rykov, 1987; Danilov, 1991; Zavatsky, 1991; Krashevsky, 1991; Bobyr and Onipchenko, 1993; Puchkovsky, 1998; Berzan, 2005). Most of the trails are located in places convenient for movement, and this fact impacts marking object distribution. However, in some cases, bears specifically make paths to a lonely marked tree, deviating from the main trails. According to tracks coming up to a tree and left on the snow, we can speculate that animals know well where mark objects are located and can approach them directly, without using trails, and specifically deviate from their course. The distribution of marked trees along the trails increases the efficiency of trees' involvement in animal communication activities and makes it easier to discover them (Burst and Pelton, 1983).

The number of marked trees in particular habitats rises when the bears' density rises (Puchkovsky, 1998). The density of recorded marked trees in the Valley of Geysers is high (27.1 per 1 km^2). By comparison, the density of noted brown bear-marked trees in Pechoro-Ilychinskyi Reserve (Komi Republic) is 1.4 trees per 1 km^2 on average (Puchkovsky et al., 2003). The high marking density in the Valley of Geysers is explained by the brown bear concentration in this area in spring; the density has values up to 20 individuals per 10 km^2 (Mosolov and Nikanorov, 2002). The distribution of marked trees in groups (mark complexes) outside of Kamchatka is typical for the Kurile Islands (Berzan, 1996, 2001) and Sikhote-Alin (Seryodkin et al., 2014).

The results of bear telemetry showed that animals gather in the Valley of Geysers from wider territories. The Valley of Geysers is attractive for bears as a place for rutting and because of its earlier availability of herbs as a food resource.

Marking trees as an element of bear social activity is common among adult males. Nikolaenko (2003) logged marking acts for females, in addition to specific movement using track marks. Marking has communication meanings during the rut season and also likely during bears' feeding on salmon near spawning grounds with a high bear density. We noted cases of females, adolescents, and cubs rubbing against trees near spawning rivers and on places of oil spills. These cases may belong to other types of behaviour, such as comfortable, based on special reactions (e.g., an animal rubbing itself against some strong-smelling object).

Conclusion

The interaction of brown bears through marking activities is important for individuals' intrapopulation communication in Kamchatka, as in the other parts of its range. Trees are the main marking objects for these animals. The most common marking tree in the Valley of Geysers has the following characteristics: species—stone birch; condition—alive; diameter at breast height—10–30 cm; located beside a trail; has a combination of different marking elements (rubbing, biting, and scuffing); has marks located on the sides facing trails; shows track marks under the marked tree; and is used by bears for many years. The most important features of bear marking behaviour include scratching and rubbing (animal rubbing itself against some strong-smelling object), trunk, and branch biting, bark stripping, and moving within track marks. The marking process is associated with the excited condition of the animal. The highest intensity of marking occurs during the rut season.

The Valley of Geysers is the forefront of bear breeding pair formation in the Kronotsky Reserve. It is possible that the places from which bears arrive to the Valley of Geysers extend beyond the protected area. The frequency, distribution, and characteristics of bear marking can be considered model parameters of Kamchatka brown bear behaviour and ecology. A comparison of these parameters with those in other areas with a different anthropogenic load may be useful to detect violations in the social structure and, consequently, the overall condition of the animal populations.

The conservation of the Valley of Geysers as a unique natural complex is inseparably linked with the welfare of the brown bear population living there. Tourism developed on this local area should not affect the characteristics of natural territories. Marking activity and numbers of brown bears may be the indicators of human impact on biotic connections in the Valley of Geysers.

The period of maximum intensity of marking activity and the number of brown bears in the Valley of Geysers (May–June) is associated with the reproduction period. During this period, the animals must be separated as much as possible from human disturbances.

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