Full Text:

Questionnaire and field data on the distribution of snow leopard (*Uncia uncia*) and Asiatic ibex (*Capra sibirica*) in southern Siberia were gathered from 1984 to 1991. The number of registered encounters with snow leopard was 55 (13 sightings, 42 tracks), the majority being recorded between the 1950's and the 1980's. In June of 1988 an expedition was undertaken to the Southern Altai, the Bukhtarmy River basin and Lake Markakol'. From June to August 1991 an expedition was undertaken to conduct investigations in the watershed of the Greater Sayan Mountains, from Munku-Sardyk Peak (3492 m) to the western edges of Peak Topograf (3044 m). This included regions within the Eastern Sayan, Eastern Tuva, Western Tuva, Western Sayan, in the Altai along the junction of the Shapshal'skiy and Tsagan-Shibetu Mountains, and also along the upper reaches of the Greater Ona, Chulyshman, Bashkaus, and Chui rivers. Surveys were conducted on foot over a total of 700 km and through 17 mountain passes. V.N. Mishenin, S.N. Garmashov, and R.E. Koshkarev took part in the expeditions and the author sincerely acknowledges their work. This article presents all the material gathered, as well as evidence received from correspondence after our initial publication of several articles in the journal *Tourist* in 1984 and 1986.

A paradoxical situation has been observed over the past ten years in the southern Siberian region, for against the background of a general decrease in number and reduction of range of primary snow leopard prey such as ibex (Sobanskiy and Yeshyelkin 1975, Sokolov 1979, 1988, Shvetsov et al. 1984, Smirnov 1988a,b), an increase is observed in the number of encounters with snow leopard. Snow leopard today is observed in regions where it was not noted before, for example in parts of Kuznetskiy Alatau and Kanskiy Mountains (Zavatskiy 1988, Shurygin 1988, Smirnov et al. 1991, Figure 1, Tables 1,2). The increase in encounters with snow leopard would be in doubt except for the fact that observations of tracks are supported by actual sightings (Table 2).

Following analysis of snow leopard population group stability in Central Asia, Eastern Kazakhstan, and Southern Siberia core areas, Koshkarev (1990) concluded that, at the present time, the most critical situation for this species is in eastern Kazakhstan and southern Siberia. Such impressions were reinforced mainly by the **TABLE 1. Location of snow leopard sign in southern Siberia, 1951-1991.**

Region	Tracks	Sightings	Total	%
Altai	34	17	51	35.7
Western Sayan*	28	17	45	31.4
Tuva Mts**	8	13	21	14.7
Eastern Sayan	9	8	17	11.9
Kuznetskiy Alatau	4	-	4	2.8
Transbaikal	-	3	3	2.1
Abakanskiy Mts	-	2	2	1.4
Total***	83	60	143	100.0

* a significant portion of encounters here occurred in the Sayano-Shushenskiy Reserve (Zavatskiy 1988), giving an unrealistic impression of the whole territory

** number of encounters in Tuva is low because a realistic geographic analysis demanded we exclude parts connected to Western and Eastern Sayan.

*** 88 (47 visual) from sources in literature; 55 (13) from data we collected

Sources: Zavatskiy 1988, Matyushkin 1981, 1990, Smirnov et al. 1991, Sokolov 1988, Shvetsov et al. 1984, Shurygin 1988, *Redkiye zhivotnye Kazakhstana* (Rare Animals of Kazakhstan) 1986.

TABLE 2. Time-period breakdown of snow leopard sign encountered in southern Siberia, 1951-1991.

Period	Tracks	Sightings	Total	%
1951-1960	6	5	11	7.7
1961-1970	11	6	17	11.9
1971-1980	23	22	45	31.5
1981-1990	38	26	64	44.8
1991	5	1	6	4.1
Total	83	60	143	100.0

Sources: see Table 1.

small number and rareness of extant groups and their isolated or semi-isolated position within regions of non-preferred landscape, e.g., desert, deep snow, taiga, or what have been termed "death regions" for snow leopard (*sensu* Severtsov 1981). These facts demonstrate the great scale of contemporary retreat of range boundaries for snow leopard in southern Siberia (Grum-Grzhimaylo 1914, Stronganov 1962, Geptner and Sludskiy 1972, Matyushkin 1984, Smirnov et al. 1991) and further migration (Geptner and Sludskiy 1972, Matyushkin 1981, Shvetsov et al. 1984, Koshkarev 1990) characteristic of animal populations in crisis situations (Panfilov 1960). Southern Siberia encompasses an apparently critical boundary delimiting the northern extent of snow leopard and ibex distribution where both species experience the most extreme natural conditions within their ecological limits (Koshkarev 1988, 1990).

PAST AND PRESENT DISTRIBUTIONS

According to fossil remains of ibex and drawings of ibex and snow leopard (Gromov et al. 1963, Okladnikov and Zaporozhskaya 1969, 1970, Geptner and Sludskiy 1972, Smirnov 1988 a,b, Smirnov et al. 1991), the known limit of both species' ranges may be estimated at 300 km north of the current one, at the latitude of Krasnoyarsk-Tomsk (Figure 1). Paleontological and archeological data indicate that this boundary was reached by the animals repeatedly, in the Pleistocene, Neolithic and Bronze ages (2,000 yr B.C.). Beginning in this period there was apparently a clear border to steppe vegetation, supported by paleogeographic data from the Bronze age (Grichuk, 1961). Conducive climate conditions in some periods enabled an extension of the steppe and ranges of major species right up to northern reaches of the mountains of southern Siberia (Figure 1).

At the present time, the most northern group of snow leopard and ibex (Smirnov et al. 1991) is recorded 300 km south of the line of their maximum past extent. The border of the steppe retreated twice as far, and in Sayan it reached close to $51^{\circ}30'$ in the Greater Sayan Mountains and Akademika Obrucheva (Figure 1). To the south of this latitude there is a sharp increase in aridity (Sedel'nikov 1988), thus delimiting the modern zone of steppe vegetation up to 50° in the North Chui Mountains (Figure 1). These delimitations are related to the rising Altai-Sayan mountain is part of the continental divide between the basin of the Arctic Ocean and the drylands of Central Asia (Kushev 1957, Sedel'nikov 1988).

Current wide displacements of the critical landscape delimitations created the main conditions which determine the ability of snow leopard and ibex to penetrate into mountains of Southern Siberia, as well as the scale of their expansion. Their position always has depended on how far the steppe of Central

Asia could invade the depth of Siberia, or conversely how far south the Siberian environment could penetrate into Central Asia.

At present, animals of southern Siberia find themselves in a crisis situation, having populated the territory within this fluctuating northern steppe boundary. Within the 300 km belt conditions of existence for these animals are deteriorating to the point where further settlement to the north is not possible, and the species remain restricted to their current geographic range. As a result, an increase in encounters with snow leopard is now observed, as they shift their northernmost limit (Zavatskiy 1988, Shurygin 1988, Smirnov et al. 1991). We can note this as a critical signal that animals which had been maintained in local core areas need to undertake unusual long-distance movements to seek out areas of the best habitat. On the other hand, it is difficult to explain the appearance of snow leopard in Kuznetsk Alatau and Kansk Mountains (Zavatskiy pers. comm., Zyryanov pers. comm.) in regions of the eastern and central Sayan (Smirnov et al. 1991) and in Transbaykal (Matyushkin 1981), where prey species (ibex) are absent or very isolated and rare.

Surveys in southern Siberia in the summer of 1991 on a route lying along or up to 100 km north of the critical climate delineation, we observed no sign of permanent presence of snow leopard, although sparse groups of ibex were patchily distributed. An analogous situation now characterizes regions where the range of snow leopard has disappeared along the inner and western Tien Shan (Koshkarev, in press). In the Eastern and Greater Sayan Mountains, Okinskiy, Tunkinskiy, and Kitoiskiy (Figure 1), the appearance of snow leopard, regardless of the presence of ibex, is currently noted as extremely rare or absent (Medvedew, 1990, pers. comm.). Evidently, under very low densities of prey, hunting becomes unproductive. If the approximate number of ibex in the Eastern Sayan is 2,000 (Opryshko 1975, Smirnov 1984, 1988a,b, Medvedew 1990), its density is not more than 5-10 per 100 km^2. Transient individuals are only rarely noted with low densities of wild ungulates. The common leopard (*Panthera pardus*) is present in western Turkmenia, and although it prefers other prey such as porcupine and domestic animals, it survives in some areas (Gorbunov and Lukareviskiy 1991).

The best conditions for snow leopard and ibex in southern Siberia probably occurred during the Pleistocene ice periods, characterized by cold, arid conditions (Vereshchagin and Baryshnikov 1980) when the habitat of central Asiatic species of animals reached its farthest northern extent. The most arid climate was observed under maximum cold periods (Grichuk 1961, Markov 1965, Maksimov 1982). In a graphic representation of global change of climate in 40,700 to 1,850-year rhythms (Figure 2), the peak of aridity and maximum cold comes at transitional times of cold-dry (C-D) and warm-dry (W-D) intervals. At these intervals the forest zone takes up the least area; the steppe, on the other hand, dominates, being widely distributed also in the high mountains, thus creating optimal conditions for an increase in range for snow leopard and ibex (Figure 3).

Apparently the arid periods of ice ages, accompanied by dispersal of steppe vegetation in the Paleoarctic (Yurtsev 1967, Sher 1971, Val'ter 1974, Markov 1986, Tolmachev 1986, Vereshchagin 1988), served as the main impetus to the large scale migration of flora and fauna in Asia, the largest manifestation of which was the trans-Bering migration. The Pleistocene expansion of snow leopard and ibex from Central Asia to southern Siberia was probably a small part of this general migration process connected with the ice ages. It is clear that the maximum range of both species occurred during the same late Pleistocene ice period as the biggest wave of migration of mammals across the Bering Strait (Matyushkin 1988: 77).

The last favorable push of snow leopard and ibex area occurred in the so-called "little ice age" (16th-19th centuries), when the last large activity of mountain ice sheets was widely observed (Shnitnikov 1957, 1973, Maksimov 1972, 1982, Imbri 1988), causing the northward movement of steppe habitat. The maximum action of glaciers was recorded in the first half of the 19th century, and they also moved in the transitional C-D and W-D intervals of the 1,850 year rhythm (Figure 2, Maksimov 1982, 1986). Evidence provided by P. Pallas (1811, cf. Geptner and Sludskiy 1972) and Radde (1862) about visits of snow leopards at this time to southwest Baikal and the Krasnoyarsk region is in agreement with this period of range expansion. The farthest northern visits by tiger (*Panthera tigris*), even to Yakutsk, up to the first half of the 19th century were possible only under conditions of an arid regime (Geptner and Sludskiy 1972).

FIGURE 2. Graphic representation of 1850-year and 40,700-year cyclic climatic processes (Maksimov 1986). Climate intervals are as follows: cold-wet (C-W), cold-dry (C-D), warm-dry (W-D) and warm-wet (W-W).

The favorable situation created during C-D and W-D intervals of the 40,700 and 1,850 year rhythms (Figure 2) allowed not so much the northern movement of range borders for snow leopard and ibex, as it did a growth of habitat area and population density of both species inside previous range limits. The movement of the limits of steppe vegetation, and thus of the northern boundary of Central Asian animals in the post-ice age period, was not greater than 300 or a maximum of 500 km. A similar dynamic for the boundary of the steppe, forest, forest-tundra and tundra zones occurred in the Russian plain and northeast European part of the USSR (Serebryannaya 1982, Nikiforova 1982).

The southern Siberian section of snow leopard range appears to be a natural continuation of the Mongolian and should be considered with it as one core area, isolated or semi-isolated from basic parts of the Dzhungaro-Gobi basin population. The isolated position and vulnerability of these groups of snow leopard and ibex in the northern sections demand high priority to their preservation. Southern Siberian populations probably always had a migrational relationship to a Mongolian nucleus, where until not long ago the density of snow leopard and ibex was higher than in southern Siberia, but it was the Gobi Altai that apparently played the role of basic core area. (Bannikov 1954, Opryshko 1975, Sukhbat 1975, Vold and Dorshzundui 1976, Sokolov 1979, 1988, Mallon 1984, Smirnov 1988 a,b).

FIGURE 3. Schematic representation of the relative changes in abundance of mountain landscape vegetation and ibex and snow leopard distribution related to climate change. The scale is arbitrary and illustrates general measures of landscape development. Climate intervals are as designated in Figure 2.

The general situation has not changed even today, and data collected in Mongolia by E.N. Matyushkin (pers. comm.) from 1987 to 1990 fails to confirm the existence of large established groups of snow leopard and ibex north of the Gobi-Altai. The largest reserve of both species in the Siberian-Mongolian region, and also in the whole range, remains the Sayan-Shushenskiy (Zavatskiy 1988) and Greater Gobi (Zhirnov and Il'in 1986). However, these large reserves do not have sufficient intermediate links in the form of protected territory or ecological corridors. The Azas Reserve (northeast Tuva) and the Altai Reserve (northeast Altai) do not appear to guarantee of the survival of the snow leopard and ibex, in that they lie to north of the general steppe boundary. Having noted this generally unfavorable situation, additional measures of protection are necessary to prevent future extinctions of the populations of both species. Tendency toward extinction will certainly follow the continuous division and reduction of range and localization and isolation of various groups of animals.

PROTECTED AREAS

In evaluating the creation of an effective network of protected areas in the Siberian-Mongolian section of snow leopard range, one must remember that the southern Siberian region is located almost wholly north of the steppe boundary. Thus, from the strategy of survival of the snow leopard and ibex the basic role is played by Mongolia, with an auxiliary one by southern Siberia. Eighty-two percent of all encounters with snow leopard and its sign in southern Siberia was registered south of the steppe boundary or in the transitional zone, predominantly in Sayan Shushenskiy Reserve (Zavatskiy 1988). The encounters occur mainly in the southern and southeastern Altai (Sobanskiy, in press), southwest Tuva and western parts of Western Sayan (Figure 1, Table 1). In the northwest Altai and northeast Eastern Sayan, the most humid regions of southern Siberia (Sedel'nikov 1988), frequency of encounters with snow leopards drops sharply (Figure 1, Table 1) and the number of prey apparently does not exceed 15-20% of its regional population (Opryshko 1975, Sobanskiy and Yeshyelkin 1975, Sokolov 1979, 1988, Sobanskiy 1980, Shvetsov et al. 1984, Smirnov 1988 a,b, Medvedew 1990).

Growth in numbers of snow leopard and ibex in conditions of southern Siberia is realistically difficult even in the western regions close to or south of the steppe boundary, although such a tendency is currently noted in the Sayan-Shushenskiy Reserve (Gushchin and Zavatskiy 1980, Zavatskiy 1988). In the Altai, along the right bank of the Chulyshman in the northernmost region, the last group of ibex has diminished, despite being in a reserve (Sokolov 1988), and visits by snow leopard to the Teletskiy Lake have also decreased (Sobanskiy, in press). In the high mountain part of the Azas Reserve we did not observe sign of snow leopard and ibex in the summer of 1991, although recent evidence of snow leopard tracks in this reserve is known (Vasil'chenko 1990).

To create an optimum network of habitat for snow leopard and ibex in southern Siberia, it is also important to consider requirements related to the orientation of rugged mountain regions. All current cores of habitation for both species are found in mountains of east-west orientation (Figure 1, Table 1). Such mountains, with contrasting natural conditions on opposing slopes, allow animals to escape destructive deep snows, characteristic for southern Siberia, and go further to the north than in regions with mountains of north-south extension. Thus, the most northern groups of snow leopard and ibex are recorded in regions of east-west trending mountains, for example in Yergak-Targak-Taiga and Udinskiy (Smirnov et al. 1991, Figure 1). East-west mountain orientation is also distinguishable from known cores of these animals' habitation in the southern Alta, Tuva, and Western and Eastern Sayan (Figure 1).

Our work represents an attempt to synthesize and explain the northern limits of snow leopard and ibex distribution. More detailed field research because much distributional data for both species is out of date or demands verification. Questions left open concern the connections of southern Siberian populations with those of Mongolia and China, the role of preserving core areas in supporting populations in their entirety, and overall strategies and tactics for species preservation.

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FIGURE 1. Orographic map of southern Siberian mountains showing past and present extreme distributions of snow leopard and ibex (scale 1:5,000,000). Symbols used: 1 mountain ranges; 2 border of southern Siberian mountains; distribution limits of snow leopard in past; contemporary distribution limits of snow leopard; northernmost contemporary presence of snow leopard and ibex; critical landscape transition zone today; research sites; 1991 expedition routes.

FIGURE 2. Graphic representation of 1850-year and 40,700-year cyclic climatic processes (Maksimov 1986). Climate intervals are as follows: cold-wet (C-W), cold-dry (C-D), warm-dry (W-D) and warm-wet (W-W).

FIGURE 3. Schematic representation of the relative changes in abundance of mountain landscape vegetation and ibex and snow leopard distribution related to climate change. The scale is arbitrary and illustrates general measures of landscape development. Climate intervals are as designated in Figure 2.