EVALUATION OF POTENTIAL HABITATS OF SNOW LEOPARD *(UNCIA UNCIA, SCHREB.)* IN ALTAY-KHANGAY-SAYAN REGION AND IN THE TERRITORY OF RUSSIAN FEDERATION: GIS APPROACH.

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Evaluation of the status of any species requires a comprehensive information on its habitats. Development of a detailed map of potential habitats as a unique spatial model is a complex theoretical and applied task. This is especially true for poorly investigated and hard-to-observe species, such as Snow Leopard (*Uncia uncia*).

To develop a map of potential habitats, all territories within natural range of the investigated species shall be ranked by their suitability for this species.

Development of a landscape map of Altay-Khangay-Sayan ridge as a model of typical (ideal, intact) habitats contributed to practical execution of this task. The map served as basis to depict and analyze the basic arrangement, spatial pattern, and other parameters of the natural–territorial complexes and ecoton (transient) systems closely correlated with the orographic–climatic, lithogenic, and other key features of the investigated territory (Samoylova *et. al*, 2000).

Brief Description of the Landscape Map and Principles of its Development.

The map plotted to a scale of 1:1,000,000 utilizes the structure–genesis principle, and displays specific features and regularities of the regional mountain zonality. The latter is characterized by (i) the barrier effects and aspect differences of the mountain ridges, and (ii) shifted and diffusive (diffusive) boundaries of zonal and sub zonal landscapes in terms of the plane positions of super depressions, etc. The map distinguishes 191 kinds of landscape (the basic cartographic units), 17 landscape types, and 13 landscape sub-classes and genera.

Analysis of the landscape map makes it possible to:

1. Delineate more accurately the areas of maximum diversity of the environmental conditions and ecological parameters and their spatial conjugation,
2. Compare the obtained field data with historical information, and
3. Reveal the regions needed urgent environmental intervention, such conservation measures in typical and unique habitats (Samoylova et. al, 2000).

The following criteria were used for evaluation of the landscapes in terms of their potential suitability as Snow Leopard habitats:

1. Snow Leopard is attributed primarily the medium and high mountain zones, whereas low mountains serve as Snow Leopard habitats in more arid and unpopulated regions.
2. Snow Leopard prefers strictly dissected landscapes abundant of rocks, screes, and deep canyons. These factors are of particular importance when evaluating potential

habitats with use of landscape map, since the latter is a generalized model and combines dissected landscape elements with more gradual ones.

3. Snow Leopard is attributed primarily to woodless, open landscape elements, such as mountain tundra, steppe, alpine, and sub alpine environments. In the Altay–Sayan–Khangay region these environments are, however, often combined with forest areas depending on slope aspect.
4. Glacial–nival and some of mountain tundra landscapes are assigned to the semi-optimal type of habitats (see legend) because of a deep snow cover in wintertime making these areas inaccessible for mountain ungulates and ounce.

All potential habitats were pooled into three basic types: optimal, semi-optimal, and hardly suitable.

The group of optimal habitats includes the following landscape types: (see legend below):

- High mountain
- Exaration and erosion-denudation
- Steppe and cryopetrophytic
- Deeply dissected, planated, stony-screes high mountains

  II-14 with bunchgrass steppes, juniper groves associated with steppe-like sedge and cobresia communities on mountain-steppe raw-humus and mountain-chestnut soils

- Medium mountain
- Erosion-denudation
- Tundra

  III-2 Sharply and deeply dissected medium mountains, with stony talus, cryogenic meso- and microforms of relief with shallow unconsolidated deposits; moss –lichen, shrub tundra on mountain-tundra soils

- Tundra-cryophyte– meadow-steppe
- Deeply dissected medium mountains with steep slopes and stony talus

  III-3 with cryophitic cushion vegetation and open cryopetrophytic communities on mountain-steppe skeletal soils (on planated summits of ridges)

  III-4 with grass–Cobresia tundra on mountain-tundra soils associated with grass steppes on mountain chestnut shallow soils and mountain-steppe soils

  III-4 with steppe-like Cobresia communities and forb – grass meadows on mountain-meadow raw-humus soils associated with bunchgrass steppes on mountain-steppe raw-humus soils

  III-4a with low-Betula (yernik) tundra on mountain-tundra peat-mucky cryogenic soils associated with grass steppes and steppe-like Cobresia communities on mountain-steppe soils

- Alpine and subalpine meadow

  III-5 Deeply dissected medium mountains with steep slopes, locally with rock outcrops and talus, with a shallow mantle of defluction deposits, loamy-boulder till; alpine tall- and low grass meadows, parcels of subalpine meadows and sparse forests on mountain-meadow soils

- Sub-golets (subalpine) sparse-forest

  III-6 Sharply dissected medium mountains with steep slopes and thin mantle of defluction-solifluction loams, fragmentary tills; sparse and open forests (larch, cedar – larch, cedar), subalpine meadows, and shrubs on mountain-meadow, mountain peat-mucky cryogenic soils

- Forest-steppe

  III-12 Deeply dissected medium mountains with steep slopes, locally with rock outcrops and stony talus, with a thin loamy-stony mantle; larch, birch – larch forests on slopes of northern aspects on mountain soddy long-seasonally-frozen and mountain-forest chernozem soils, associated with dry (bunchgrass, shrubs) steppes on mountain-steppe chernozem soils on slopes of southern aspects ("peristeppes", or slope-differentiated forest-steppes)

  III-12a Deeply dissected medium mountains with a mantle of defluction and deluvial loams with larch, birch – larch, aspen – birch herbaceous forests (frequently garden-like) on mountain dark gray forest soils associated with forb – grass meadow steppes on mountain leached and podzolized chernozems

- Steppe
- Deeply dissected medium mountains with steep slopes, locally with rock outcrops and stony talus, with a thin mantle of unconsolidated deposits

  III-15 with semidesert wormwood – bunchgrass steppes on mountain light chestnut soils

- Desert

  III-16 Deeply dissected, locally rocky, medium mountains with stony talus, features of arid processes; semideserts and steppe- deserts, and their petrophytic variants *(Stipa spp., Artemisia frigida, Salsola arbuscula)* on mountain pale-brown and brown solonetzic soils

  IV-15 with semidesert forb-wormwood-bunchgrass *(Cleistogenes, Agropyron)* steppes with *Caragana* on mountain light chestnut soils

- Gorges and V-shaped valleys, rocky, with low, fragmentary terraces constituted by pebble-boulder deposits

  P.1 with sparse, primarily larch forests with admixture of dark coniferous and small-leaved species on the slopes, frequently with poplar, spruce and willow

floodplain thickets on mucky-gley soils; on the slopes – shallow brown forest soils

P.8 with shrub steppes, petrophytic variants of moderately dry and dry steppes on mountain chestnut, mountain-steppe soils and chernozems

The group of semi-optimal habitats includes the following landscape types:

- High mountains
- Exaration and erosion-denudation
- Glacial-nival

I-1 Alpine deeply dissected high mountains with steep slopes, rock talus and glacial tills in valleys; cryopetrophytic plant communities, moss – lichen and low-shrub tundra on skeletal mountain-tundra soils alternating with nival – glacial complexes

- Tundra

II-1 Alpine deeply dissected high mountains with steep slopes, rock talus and glacial tills in valleys; cryopetrophytic plant communities, moss – lichen and low-shrub tundra on skeletal mountain-tundra soils alternating with nival – glacial complexesII-1

II-2 Planated deeply dissected high mountains with a shallow stony-loamy mantle, nival–cryogenic features; lichen–moss, shrubby tundra, locally associated with cryophyte forb–grass– sedge and Cobresia communities on mountain-tundra peat-mucky cryogenic and mountain peat-raw-humus soils

II-2a Planated hilly – strongly undulating high mountains with a mantle of loamy-boulder till and sandy-loamy glaciolacustine deposits; sedge – moss – low Betula (yernik), meadow, sedge-Cobresia, locally bogged, tundra on mountain-tundra soddy, mountain peat-raw-humus cryogenic and peat-gley soils

- Tundra – cryophyte-steppe
- Planated, deeply dissected high mountains with steep slopes, fragments of till mantle, locally of alpine, with stony placers, with a shallow stone-loamy mantle

II-3 with cryophyte cushion vegetation on mountain-steppe stony soils, sometimes associated with Cobresia and sedge communities on mountain raw-humus cryogenic stony soils

II-4 with combinations of tundra, grass – Cobresia, sedge – Cobresia meadows, cryophyte grass steppes on mountain-tundra, and mountain-steppe raw-humus cryogenic soils

II-4b with steppe-like Cobresia, cryophyte grass – forb – sedge communities, frequently associated with cryophyte steppes on mountain-steppe raw-humus cryogenic soils

- Planated hilly– inselberg – strongly undulating high mountains with a thick mantle of loamy-boulder till, locally with lacustrine and glaciofluvial deposits

  II-4a with shrubby (yernik), sedge – grass – Cobresia tundra on mountain-tundra soils associated with small-bunchgrass steppes (on slopes of southern aspect) on mountain-steppe soils

  II-5 Planated, with rounded summits, deeply and sharply dissected high mountains with rock outcrops and talus, locally of alpine type with a shallow loamy-stony mantle, with fragments of boulder-loamy till, stony placers; alpine and subalpine meadows and low shrubs, parcels of tundra and sparse forests on mountain-meadow soils

  II-5a Hilly – strongly undulating planated high mountains with a mantle of loamy-boulder till, parcels of sandy-loamy lacustrine deposits; alpine and subalpine shrubs and meadows on mountain-meadow soils, frequently with fragments of tundra

- Steppe and cryopetrophytic
- Deeply dissected planated high mountains with rock outcrops and stony talus

  II-13 with moderately dry forb – small-bunchgrass steppes, fragments of meadow steppe on mountain-steppe soils

- Sub-golets (subalpine) sparse-forest

  II-6 Planated, with rounded summits, deeply dissected high mountains with a mantle of solifluction – defluction loams, fragments of till; sparse forests of cedar, larch, locally fir, and subalpine tall-grass meadows and shrubs on mountain-meadow soils, with parcels of tundra on mountain peat-mucky cryogenic soils

- Tundra-cryophyte – meadow-steppe
- Deeply dissected medium mountains with steep slopes and stony talus

  V-4a Planated inselberg – hilly – strongly undulating medium mountains with a shallow mantle of loamy-stony deposits, fragments of glacial sediments; associations of moss-shrubby, grass – Cobresia tundra on mountain-tundra soils with cryophitic steppes on mountain-steppe soils (on southern slopes)

- Sub-golets (subalpine) sparse-forest

  IV-6 Moderately dissected, locally weakly sloping medium mountains with a mantle of loamy-stony deposits, with rock outcrops, talus, with fragments of glacial sediments; cedar – larch, cedar, larch sparse forests associated with subalpine meadows, or tundra (shrubby, moss – lichen) on mountain-meadow, and mountain peat-mucky cryogenic soils

- Forest-steppe

  IV-12 Weakly and moderately dissected, locally planated, medium mountains with a mantle of defluction deposits varying in composition; with slope-differentiated forest-steppes ("peristeppes") – association of larch, small-leaved forests on mountain-forest gray, soddy long-seasonally-frozen soils with steppes, and their petrophytic variants on mountain-steppe chernozemic soils (slopes of southern aspect)

- Desert

  IV-16 Moderately and weakly dissected, locally planated, medium mountains with features of arid processes, locally rock outcrops and stony talus; semideserts and steppizated deserts *(Stipa, Salsola arbuscula, Nanophyton),* their petrophytic variants on mountain pale-brown soils

- Low mountains
- Steppe
- Sharply dissected (sometimes fragmented) low mountains with steep slopes, a thin mantle of unconsolidated deposits, locally with rock outcrops and stony talus

  V-14 with dry small-bunchgrass, sometimes shrubby, steppes on mountain southern chernozems, mountain dark chestnut soils, locally with parcels of forb – grass moderately dry steppes on mountain typical chernozems

  V-15 with semidesert wormwood – bunchgrass steppes and their petrophytic variants on mountain light chestnut soils

- Desert
- Sharply and deeply dissected low mountains, locally with sharp ridges and arid features

  V-16 with semideserts and steppe-like deserts (Ceratoides, Salsola arbuscula) on mountain pale-brown and mountain desert-steppe soils

The group of hardly suitable potential habitats includes the following landscape types:

- Medium mountain
- Erosion-denudation
- Tundra

  IV-2 Planated strongly undulating medium mountains, frequently overlain by boulder-loamy till, with cryogenic mesoforms of relief, with tundra (moss – shrubby, meadow) on mountain-tundra soddy or peat-gley soils, locally bogged

- Forest
- Deeply dissected medium mountains with steep slopes and thin mantle of defluction deposits, locally with rock outcrops and talus

  III-9 with larch (sometimes garden-like), birch – larch forests on mountain-forest chernozemic and mountain-forest soddy soils alternating with forest meadows ("yelan") on mountain humus-accumulative soils

- Steppe
- Deeply dissected medium mountains with steep slopes, locally with rock outcrops and stony talus, with a thin mantle of unconsolidated deposits

  III-13 with moderately moist, rich-forb – grass and moderately dry forb – feather grass steppes on leached, podzolized and typical mountain chernozems and mountain- steppe chernozemic soils

  III-14 with dry bunchgrass steppes on mountain chestnut soils, locally with parcels of moderately dry steppes on mountain-steppe chernozemic soils

- Alpine and subalpine meadow

  IV-5 Weakly and moderately dissected medium mountains with a mantle of stony-loamy deposits, cryogenic features, locally planated with a mantle of boulder-loamy till; alpine and subalpine low- and tall-grass meadows and shrubs, locally with subalpine sparse forests on mountain-meadow soils

  IV-12a Hilly – strongly undulating planated medium mountains with a prominent mantle of defluction loams, locally displaying loessic properties; forb – grass meadows and meadow steppes on mountain leached and podzolized chernozems in association with birch, larch – birch, pine – birch forests with broad-leaved forbs on mountain dark gray forest soils

- Moderately dissected, locally planated medium mountains with a thin stony-loamy mantle, with stony talus

  IV-14 with dry small-bunchgrass steppes with Caragana, their petrophytic variants on mountain chestnut soils, with parcels of moderately dry steppes on mountain chernozems

- Low mountains
- Steppe
- Sharply dissected (sometimes fragmented) low mountains with steep slopes, a thin mantle of unconsolidated deposits, locally with rock outcrops and stony talus

  V-13 with meadow forb – grass steppes, locally shrubby, grass – forb meadows on mountain leached and podzolized chernozems with parcels of moderately dry forb – feather grass steppes on mountain typical chernozems

- Desert
- Sharply and deeply dissected low mountains, locally with sharp ridges and arid features

  V-17 with southern deserts and their petrophytic variants *(Anabasis brevifolia,* almond, perennial saltworts, *Sympegma)* on mountain shallow and weakly developed gray-brown soils

Results and data analysis

The total area of the Altay-Khangay-Sayan region is estimated as 1553943 km^2. Northern part of this region (647867 km^2, 41.7%) lies to the territory of Russia. The estimated areas of basic Snow Leopard habitats in the Russian part of the region are shown in Table 1.

Habitat type	Total area of the habitat km^2	Proportion of the total area of the region. %
Optimal	28578.35	4.41
Semi-optimal	127408.49	19.66
Hardly suitable	21767.48	3.36
Total	177749.32	27.43

The relative area of the optimal habitats versus the area of semi-optimal and hardly suitable habitats is about 19%.

The corresponding figures for the entire Altay-Khangay-Sayan region are shown in Table 2.

The relative area of the optimal habitats versus the area of semi-optimal and hardly suitable habitats is about 27 %.

Habitat type	Total area of the habitat km^2	Proportion of the total area of the region. %
Optimal	108155.57	6.96
Semi-optimal	312826.22	20.11
Hardly suitable	91369.27	5.88
Total	512411.06	32.95

Lower relative area of the optimal habitat in the Russian territory of the region compared to the region as a whole is quite understandable taking into account the most northern part of the Snow Leopard range lays in Russia. This results in lower area of both total potential habitats and optimal habitats in the Russian part of the region. The total proportion of potential Snow Leopard habitats in Russia is lower compared to that the region as a whole, which is primarily due to favorable conditions in the Mongolian part of the Snow Leopard range. This estimation is in agreement with the expert estimation of the Snow Leopard populations in Mongolia that is 4–6 times higher compared to Russia (Jackson, Hunter 1996; Poyarkov et al. 2001).

Our estimations of the ratio between the optimal and potentially suitable habitat area in Russian part of the region are close to the results obtained by Jackson and Hunter (1996): 19% and 16 %, respectively.

At the same time, our estimation of the absolute area of potential habitats differs significantly from the estimation made by Jackson and Hunter (1996). According to our data, the total area of potential habitats is about 177749 km^2 versus to 302546 km^2 stated by Jackson and Hunter, i.e. the variation factor is about 1.7.

To our opinion, the total area of potential Snow Leopard habitat presented in the paper by Jackson and Hunter (1996) is overestimated, since it covers 47% of the Russian part of the region (647867 km^2). Beside of that we cannot agree with the ratio between the optimal and potential Snow Leopard habitats suggested by the same authors (Jackson, Hunter, 1996): it is suggested to be significantly less in Mongolia compared to Russia. This is, however in contradiction with factual materials: Snow Leopard population in Russia is known to be much lower than in Mongolia, on which territory lies the most central part of the Snow Leopard range. Our original data also confirm the latter viewpoint.

The area of the Snow Leopard potential habitats estimated form the landscape map was 3 times less than that estimated from a large-scale topographic map (1: 100 000) (Poyarkov et

al., 2001). This is due the landscape map in itself is based on a comprehensive and deep evaluation of the territory (see above), whereas a topographic map is no more than an altitudinal model of the territory.

The Structure of Potential Habitats

The structure of potential Snow Leopard habitats reflects a spotty, insular character of its range. The latter is subdivided into two basic subregions: Western and Eastern. Western subregion includes the habitats of Mountain Altay, western Tyva, and southern Khakasia. The largest habitats lie in the Argut river basin and in the Shapshalskii ridge. These two areas are interconnected through a range of smaller potential habitats (stations). Eastern subregion includes the habitats of East Sayan, Kitoiskii and Tunkinskii golets and somewhat desolated habitat in the Sangilen ridge. Potential Snow Leopard habitats of West Sayan and West Tannu-Ola lie in the middle and serve as potential "corridors" providing Snow Leopard migration and gene exchange between Western and Eastern parts of the Snow Leopard range in the territory of Russia. In this connection, Snow Leopard populations and habitats of West Sayan are of particular importance.

Additional Factors Influencing Snow Leopard Pattern in the Region

Most of researchers believe than the snow cover depth is of high importance and serves as a factor limiting Snow Leopard distribution over western Altay, and in particular in western part of Katunskiy ridge (Ognev, 1935; Geptner, Sulks, 1972 et al.).

Low winter temperatures and monotonous landscape may limit actual Snow Leopard distribution in the eastern part of this species range in Russia .

The all above discussed is just a first approach to the problem and does not take into account many important features influencing the Snow Leopard habitats. The actual Snow Leopard-inhabited area inhabited in the investigated region and Russia, as a whole is much smaller compared to the above-presented estimation. This preliminary analysis shall serve as a basis for further studies aiming at the Snow Leopard conservation strategy improvement.

References:

V.G. Geptner and A.A. Sludskiy. 1972. *Snow Leopard*. // Mammals of USSR. Moscow. 206-243.

Ognev S.I. 1935. *Snow Leopard (snow leopard)* // Animals of USSR and adjacent countries. Moscow-Leningrad. 260-270.

Poyarkov A.D., Lukarevskii V.S., Baidavletov R.Zh., and Subbotin A.E. 2001. *Evaluation of potential Snow Leopard habitats, structure, and population in the mountain Altay and western Sayan*// Results and perspectives of theriology development in Siberia. Irkutsk. 274-277.

Samoylova Г.С., Vesselovskii A.B., and Subbotin A.E. , 2000. *Landscape map of the Altay-Khangay-Sayan ecological region as a basis for a projected SPNA network in the North of Central Asia* // Strictly Protected Natural Areas. Proceedings of the II-d International Conference, A-Petersburg, 2000. 132-133.

Jackson R., Hunter D. O.1996. *Snow leopard survey and conservation handbook*. // International Snow Leopard Trust. 154 p.