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Key Factors Determining the Ecological Niche of the Himalayan Marmot, *Marmota himalayana* Hodgson (1841)

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Abstract—Four key factors determining the ecological niche of the Himalayan marmot, *Marmota himalayana* Hodgson (1841), in the Central Himalayas (Nepal) have been identified. These are elevation above sea level, temperature, the presence of accumulative formations, and feeding conditions. The Himalayan marmot ecologically differs from all other marmots of the world fauna, and the main difference is that the lower boundary of its range lies very high—3000 m above sea level.

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Key words: Himalayan marmot, the Himalayas, ecological factors.

The range of the Himalayan marmot, *Marmota himalayana* Hodgson (1841), extends over a vast area in the mountains of South Asia, including the Kuenlun, Arkatag, Altyn Tagh, and Nan Shan mountain ranges, the Tibetan Plateau, Sikkim, and Bhutan (Sclater, 1891; Bobrinskii, 1937; Gromov *et al.*, 1965; Wang Sibo and Yang Ganyun, 1983; Ma Yung *et al.*, 1987; Bibikov, 1989). From an ecological standpoint, however, *M. himalayana* is the least studied species of the world marmot fauna (Gromov *et al.*, 1965; Zimina, 1978; Bibikov, 1989). This is especially true of the Nepal part of the species range (in the Central Himalayas), which lies at the southern limit of the distribution of the genus *Marmota* (Nikol'skii and Ulak, 2005). For this reason, the purpose of this study was to describe the main features of the *M. himalayana* species niche in the Central Himalayas (Nepal).

Modern methods of describing the ecological niche of an animal are based on the concept of *n*-dimensional space (Hutchinson, 1957, 1978). In essence, this refers to "the whole range of conditions in which an individual lives and *reproduces*" (Pianka, 1981). As "the whole range of conditions" is impossible to delimit, the procedure of describing a concrete ecological niche is reduced to the identification of a few key factors, or "axes of resource space" (Shenbrot, 1986).

In describing the ecological niche of *M. himalayana*, we distinguished four basic ecological factors: elevation above sea level, temperature, the presence of accumulative formations, and feeding conditions. Taken together, they cover a broad range of conditions necessary for the life of marmots and are sufficient for characterizing the *realized* ecological niche of the Himalayan geographic population of *M. himalayana*. Following the concept of ecological niche as a hypervolume (Hutchinson, 1978), we assume that the *fundamental* niche available to the species throughout its range is broader than the *realized* niche of any population inhabiting only part of the range. Thus, *M. himalayana* marmots inhabiting two neighboring parts of the species range, the Himalayas and the Tibetan Plateau, live at approximately the same elevations, although these parts markedly differ in climatic conditions: a tropical moist climate prevails south of the Himalayas, and the climate of cold high-mountain deserts prevails north of the Himalayas (Dolgushin and Osipova, 1989).

The data for this study were obtained in the course of field observations on two *M. himalayana* colonies in the Manaslu mountain range (the Central Himalayas, Nepal) in 2003 and 2004 (Nikol'skii and Ulak, 2004). The colonies were in the Larke River valley, near the villages of Sama and Samdo, at elevations of 3530 and 3780 m a.s.l., respectively (approximate coordinates 28°40′ N, 84°40′ E). The landscape of the river valley is typical of the Central Himalayas. Figures 2–5 illustrate ecological conditions in the study region.

Elevation above sea level is the key ecological factor for *M. himalayana* as well as for other mountain species, because most of the other factors directly depend on it. In the Central Himalayas, *M. himalayana* occurs in the area between the timberline and the snow line, at elevations of 3000 to 5500 m (Dobremez and Jest, 1976; Shrestha, 1997; Majupuria and Majupuria, 1998; Klatzel, 2001; Nikol'skii and Ulak, 2005), in the subalpine and alpine mountain belts (Schweinfurth, 1957; Walter and Breckle, 1991).

Schweinfurth (1957) in his geobotanical review considers several profiles of the Himalayas, which provide a good idea of elevations at which the distribution

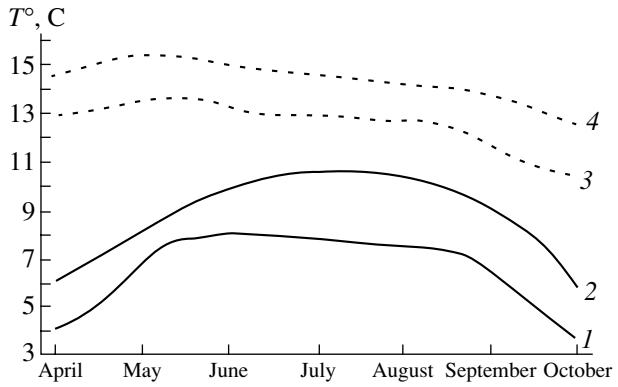

Fig. 1. Dynamics of (*1, 2*) monthly average and (*3, 4*) monthly average maximum air temperatures from April to October in *M. himalayana* colonies near the villages of Sama and Samdo in the Manaslu mountain range, at elevations of 3530 m (*2, 4*) and 3780 m (*1, 3*), respectively.

of *M. himalayana* is most probable in view of the altitudinal zonality of the region. One of these profiles, Mount Annapurna (the massif closest to the study area), was described in our previous publication (Nikol'skii and Ulak, 2005). The lower limit of *M. himalayana* distribution strictly coincides with the timberline, while the upper limit is less distinct, but colonies with high animal density occur at elevations of up to 4500 m.

Marmota himalayana is a high-mountain species that differs from all other marmots of the world fauna in that the lower limit of its distribution never descends below 3000 m. For example, the long-tailed marmot *M. caudata*, its neighbor in the range, ascends to equally high elevations (in Tajikistan, to 5000 m), but the lower limit of its distribution is 1500 m (Davydov *et al.*, 1978).

Temperature. As noted previously (Nikol'skii and Ulak, 2005), the location and climate of the Himalayas facilitate *M. himalayana* expansion far south (almost to 27° N): in high-mountain belts inhabited by this species, air temperature never reaches the critical value (22–25°C) at which marmots suffer from heat stress and their activity on the surface sharply decreases (Türk and Arnold, 1988; Melcher *et al.*, 1990; Semenov *et al.*, 2001; Soroka, 2001).

Considering that temperature in the mountains of South Asia decreases by 0.65°C per 100 m elevation and using data from the Katmandu Weather Station located at an elevation of 1324 m (*Klimaty…*, 1975), we calculated air temperatures for *M. himalayana* colonies near the villages of Sama and Samdo, where our observations were performed (3530 and 3780 m a.s.l., respectively).

Figure 1 shows the dynamics of monthly average temperature and monthly average maximum temperature from April to October, i.e., in the period between arousal from hibernation and the onset of the next hibernation season. Assuming that the ambient temperature for active marmots is usually between the monthly average and the monthly average maximum temperatures but closer to the latter (the daytime temperature), we may conclude that marmots in both colonies remain on the surface at 8–12°C.

Fig. 2. The side of a river valley in the Manaslu range near the village of Sama (3530 m a.s.l.). Alluvium with a deep layer of light soil underlies the second terrace occupied by a large *M. himalayana* colony.

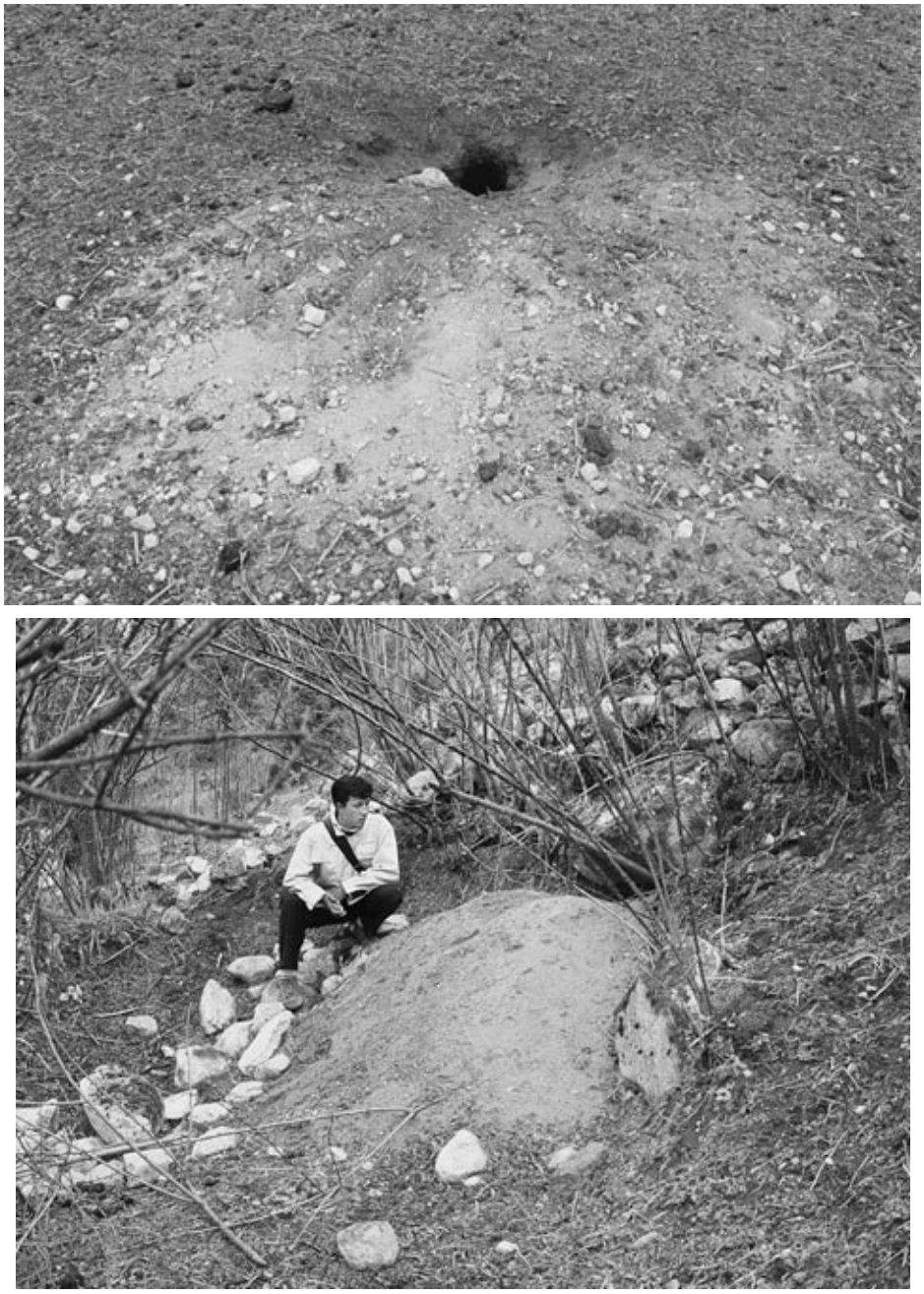

Fig. 3. Earth mounds near *M. himalayana* burrows.

On the whole, the temperature niche realized by the geographic population of marmots in the Central Himalayas (3000–5500 m a.s.l.) is in the range of 5 to 15°C.

Marmots in the Himalayas live under conditions of temperature optimum. A relatively *uniform climate* is the main parameter characterizing the ecological niche of *M. himalayana.* The highest temperature in the period of marmot activity is far from the critical value (20–25°C) that leads to stress and cessation of activity. On the other hand, the minimum temperature (approximately 5°C) is sufficient for the growth of plants on which these rodents feed. Moreover, our sporadic observations of *M. himalayana* burrows have shown that temperatures within and beyond the burrow differ by only a few degrees (Ulak, 2004). This also contributes to the maintenance of uniform thermal conditions for *M. himalayana* within its range.

Accumulative formations. Burrows are vitally important for any marmot species. They are large and deep: the depth of nest burrows in most marmots is usually 2–3.5 m (Bibikov, 1989), but it may reach 6–7 m in some species (Romanovskii, 1961; Chekalin, 1967;

Fig. 4. Typical *M. himalayana* habitats on alluvial terraces in the Larke River valley, the Manaslu mountain range. In the lower right corner is a plowed field to be planted with potatoes, with a herd of yak–cattle hybrids grazing on the left of it. Elevation about 3600 m a.s.l.

Fig. 5. A Himalayan marmot near its burrow on a pasture with obvious signs of overgrazing and abundant livestock manure.

Kizilov and Berendyaev, 1978). Himalayan marmots inhabiting Tibet were reported to hibernate in burrows deeper than 10 m (Yusov, 1958; Bannikov *et al.*, 1964). This may be an overestimation, but we have no other data on the depth of *M. himalayana* burrows. However, the potential of *M. himalayana* as a great burrower is indirectly confirmed by its large body size: the average animal weighs more than 7 kg (Bibikov, 1996).

Marmots can dig their large burrows only in areas where the ground is *light* and sufficiently *deep*. Koblov (1941) was the first to note this fact: "Animal distribution in mountain areas clearly shows that soil conditions and, in particular, the depth of the light soil layer influence the distribution of burrowing animals not only through the vegetation, but also directly."

In this respect, habitats of *M. himalayana* are favorable: they abound in accumulative formations such as alluvial, deluvial, and fluvioglacial deposits, which are of light texture, no less than 10 m deep, and ideal for burrowing (Fig. 2). All *M. himalayana* burrows we examined were made in the light ground formed in the course of accumulative (mainly alluvial) processes (Fig. 3).

Recall that alluvium is sediment deposited by a river in the floodplain, and its accumulation in river valleys is often accompanied by the formation of terraces, i.e., flat strips of land differing in width that more or less abruptly descend onto one another (Leont'ev and Rychagov, 1979). These alluvial terraces with a deep layer of light ground are the areas where *M. himalayana* marmots form large colonies and their population density is especially high. In the Manaslu mountain range, it reaches 10 families per square kilometer, and each colony comprises up to 30 families.

The colonies would have occupied an even greater area were it not for anthropogenic barriers (buildings, fences, etc.) and competition with man. In the Himalayas, people settle on alluvial terraces above the timberline and use them as farmland, because the relatively large size, flat topography, and well-developed fragmentary soils make these areas especially suitable for agriculture in high mountains (Dobrovol'skii, 1989).

Deluvial and fluvioglacial deposits are also populated by marmots, but to a lesser degree. The main factor is that they are markedly smaller in area than alluvial terraces. Marmot settlements on these deposits look like outposts established at a distance from the main colony.

Feeding conditions. All marmot colonies that we examined were in areas used as grazing grounds for livestock (yaks or, less often, horses, goats, and sheep). Throughout these areas, even at the base of forested slopes, the signs of overgrazing were apparent (Fig. 5). Marmots peacefully cohabited with livestock and fed exclusively on pastures, as other food sources were almost entirely absent.

It has been repeatedly noted that various marmot species have a preference for livestock grazing grounds (Abelentsev *et al.*, 1961; Bibikov, 1967; Davydov, 1974; Seredneva and Nesgovorov, 1977; Bibikov and Berendyaev, 1978; Tokarskii, 1997; Ronkin and Savchenko, 2000), and *M. himalayana* is no exception. This ecological feature is attributed to the fact that their favorite food is readily accessible in pastures: in all food plants, marmots eat primarily the soft, juicy parts that are at the initial stages of growth and development (Stogov, 1956; Bibikov, 1967; Sludskii *et al.*, 1969; Davydov, 1974; Ronkin and Savchenko, 2000). According to many authors (Abelentsev *et al.*, 1961; Bibikov, 1967; Davydov, 1974; Seredneva and Nesgovorov, 1977; Bibikov and Berendyaev, 1978; Ronkin and Savchenko, 2000), conditions in pastures are most favorable for the maintenance of continuous plant growth. Grazing prevents the accumulation of dead plants that cover young shoots and make them inaccessible to marmots. Moreover, livestock bite off apical shoots, which promotes an increase in the phytomass of young plants favored by marmots.

The preference for yak grazing grounds in *M. himalaya-na* apparently has a long history, and its feeding habits and adaptations are apparently associated with these ungulates. In the past, *M. himalayana* shared grazing grounds with wild yaks (*Poephagus mutus*). In Tibet, the main sector of the *M. himalayana* range, they gathered in large herds of up to 1000 animals each (Przhevalsky, 1946). Wild yaks have survived in this area, but their herds are much smaller (Geptner *et al.*, 1961).

Domesticated yaks and yak–cattle hybrids have displaced wild yaks from many areas of their former range, but the type and degree of impact on the vegetation has remained the same. As in the case of reindeer, domesticated yaks hardly differ in the mode of life from their wild ancestors and continue to use the same grazing grounds.

Although we did not analyze the species composition of plants consumed by *M. himalayana* marmots, an idea of plant associations characteristic of their habitats could be inferred from a small herbarium collected in the vicinity of Sama in late April 2004. It included the following plants (in some cases, the species was impossible to determine): *Iris potanini*, *Carex* sp., *Agrostis* sp., *Deschampsia* sp., *Koeleria* sp., *Taraxacum* spp. (two species), *Saussurea* sp., *Ranunculus* sp., *R. hirtellus, Berberis angulosa, Primula* spp. (three species), *Potentilla* spp. (two species), *P. peduncularis, Gentiana* sp., *Halenia elliptica, Euphrasia himalayca*, and *Polygonum amplexicaulis*. G.A. Savchenko (personal communication) characterized the aggregate of these species and genera as a "cold meadow" association. According to Schweinfurth (1957), "moist alpine scrub and meadows" are typical of the corresponding altitudinal belt in the Central Himalayas.

Based on the data presented above, we conclude that the subalpine and alpine belts of the Central Himalayas, where *M. himalayana* lives, are characterized by the

optimum of key factors determining the ecological niche of this species: (1) favorable air temperatures; (2) a deep layer of light ground on alluvial terraces, which is convenient for digging deep burrows; and (3) grazing grounds for livestock (mainly yaks), in which optimal feeding conditions for marmots are maintained.

The role of precipitation as an ecological factor remains unclear. Monsoon rains falling in the Himalayas from June to September must have an effect on the distribution and activity of marmots. A contrast between the patterns of moisture supply in the main part of the *M. himalayana* species range (in Tibet) and at its southern boundary (in the Himalayas) deserves special attention: the annual amounts of precipitation in these neighboring regions differ by an order of magnitude (Yusov, 1958). Unfortunately, the responses of marmots to changes in the pattern of moistening and, in particular, precipitation are almost entirely unknown. Hopefully, this major factor of the ecological niche of marmots, including *M. himalayana*, will be investigated in our future studies.

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