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Ecological Distribution and Population Dynamics of the Mediterranean Tortoise, *Testudo graeca nikolskii*, in Xerophytic Forests of the Western Caucasus, Southern Russia

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Testudo graeca nikolskii is an increasingly scare subspecies of the Mediterranean tortoise found in dry subtropical forests of the Caucasus of southern Russia (Fig. 1). All populations in the Caucasus and Transcaucasus appear to be declining (Bannikov et al., 1977; Red Book of the USSR, 1984; Inozemtsev and Pereshkolnik, 1987; Inozemtsev, 1993; Inozemtsev and Pereshkolnik, 1994). Destruction of juvenile tortoises by predators (Red Book of the RSFSR, 1983), uncontrolled human collection of both adult and young animals (Red Book of the RSFSR, 1983; Red Book of the USSR, 1984), and habitat degradation (Red Book of the RSFSR, 1983; Darevsky and Orlov, 1988) are considered to be the main factors of such reduction. There are presumably other factors also (Inozemtsev, 1991; Inozemtsev and Pereshkolnik, 1985), and it is the overall combination of stresses that is proving fatal for these reptiles. This combination of influences sooner or later leads to a progressive population decline of the tortoises.

In this paper I present information on the overall distribution and abundance of the Mediterranean tortoise in xerophytic forests of the western Caucasus of southern Russia, obtained in a study along the Black Sea coast between the Durso – Lake Abrau area and Novorossiysk (Fig. 2).

Study Area. — The landscape of this mostly mountainous area, where the highest hills range from 100 to 300–400 m above sea level, is very rugged. Slopes are cut by numerous gullies and ravines; the average slope of the terrain does not exceed 25° for the most part, but that of the gullies and ravines varies from 25 to 35° and in some cases is even more. The climate is of Mediterranean type: the summer is hot and dry, the winter is temperate to cold with maximum precipitation in November – January and minimum in May and August (Fig. 3).

A peculiarity of the area is the strong, hurricane-like cold northern wind (the *bora*) that blows towards the seacoast through the low-mountain crossing near Novorossiysk for days at a time, mostly in autumn and winter.

Pecularities of the physico-geographical conditions, the geological past of the western Caucasus, and the sequence of establishment of the species of plants found in the region and their subsequent evolution determine the uniqueness of this dry to subtropical floristic complex. Typical trees and arborescent forms include *Juniperus excelsa*, *J. foetidissima*, *Pistacia mutica*, *Celtis glabrata*, *Pinus pithyusa*, *P. pallasiana*, *Arbutua andrachne*, and *Taxus baccata*; understory species include *Ruscus ponticus*, *Lonicera tatarica*, and *Cistus tauricus*. Where trees have been cut, there are usually isolated bushes and small groups of *Paliurus spinachristi* and *Jasminim fruticans*, which often form dense brushwood.

The zone of forest topsoil of the dry subtropics of the western Caucasus is represented by two main associations. The more ancient of these is pistachio-juniper forest, located at altitudes of a few meters to about 200 m above sea level on slopes facing the sea to the south and southwest. The main trees of this association are the above-mentioned junipers and pistachio and also *Quercus petraea*, *Sorbus torminalis*, and *Cotoneaster integerrima*.

The second association is oak-hornbeam forest at about 150 m and higher, covering slopes of mainly northern and eastern exposures. In the canopy the main trees are *Quercus pubescens* and *Q. petraea*, *Carpinus orientalis*, *Tilia caucasica*, *Fraxinus excelsior*, and *Acer compestre*; in the second tier there is *Carpinus orientalis*; in the understory there are *Sorbus graeca*, *Cornusmas*, *Viburnum tinus*, *Euonymus verruccosa*, and *Hedera helix*.

Both the forests and the more sparse tree growth areas located on the intermediate and lower slopes, especially those facing the sea, have been exposed to strong anthropogenic influences during recent decades. They are subject to different influences by many forms of human activity, often leading to the direct extirpation of both natural plant communities and their resident wildlife (Inozemtsev, 1991). Similar effects are felt on most of the xerophytic forests in the region, including the area of our researches.

Methods. — The main parts of the long-term tortoise census and determination of the distribution and ecology of tortoises were carried out in the areas of responsibility of the Dept. of Forestry of Novorossiysk situated between Ujnay Ozereevka and Mishacko settlement on the slopes of Mount Koldun and Mount Amzay, and on 4 km of seashore extending from the valley of "Wide Ravine" to Mishacko.

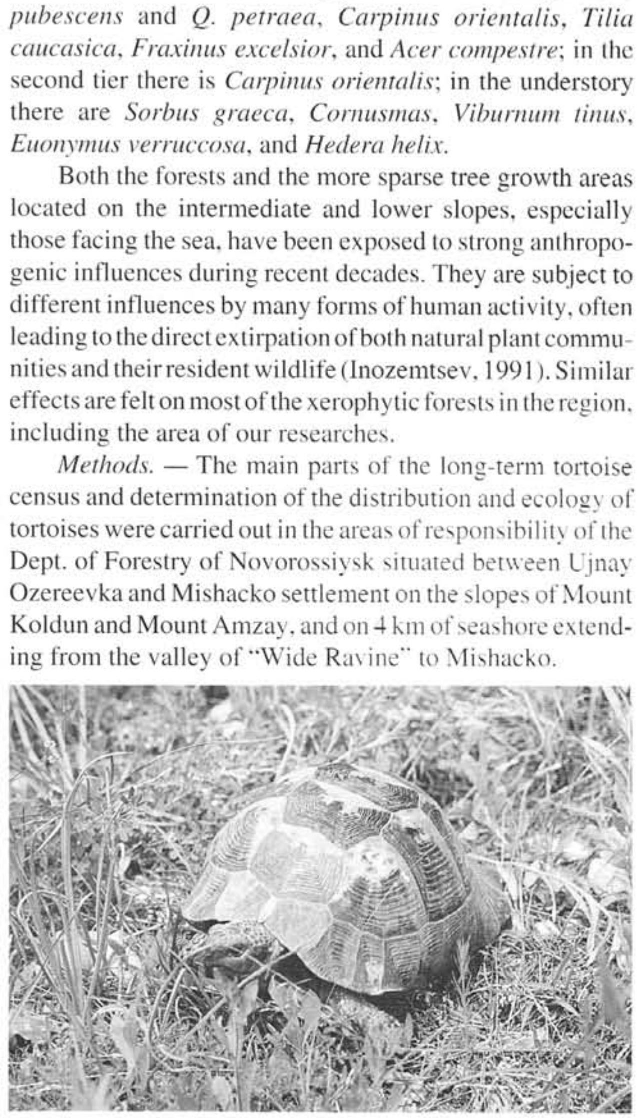

Figure 1. Adult *Testudo graeca nikolskii* in the western Caucasus of southern Russia. Photo by A.A. Inozemtsev.

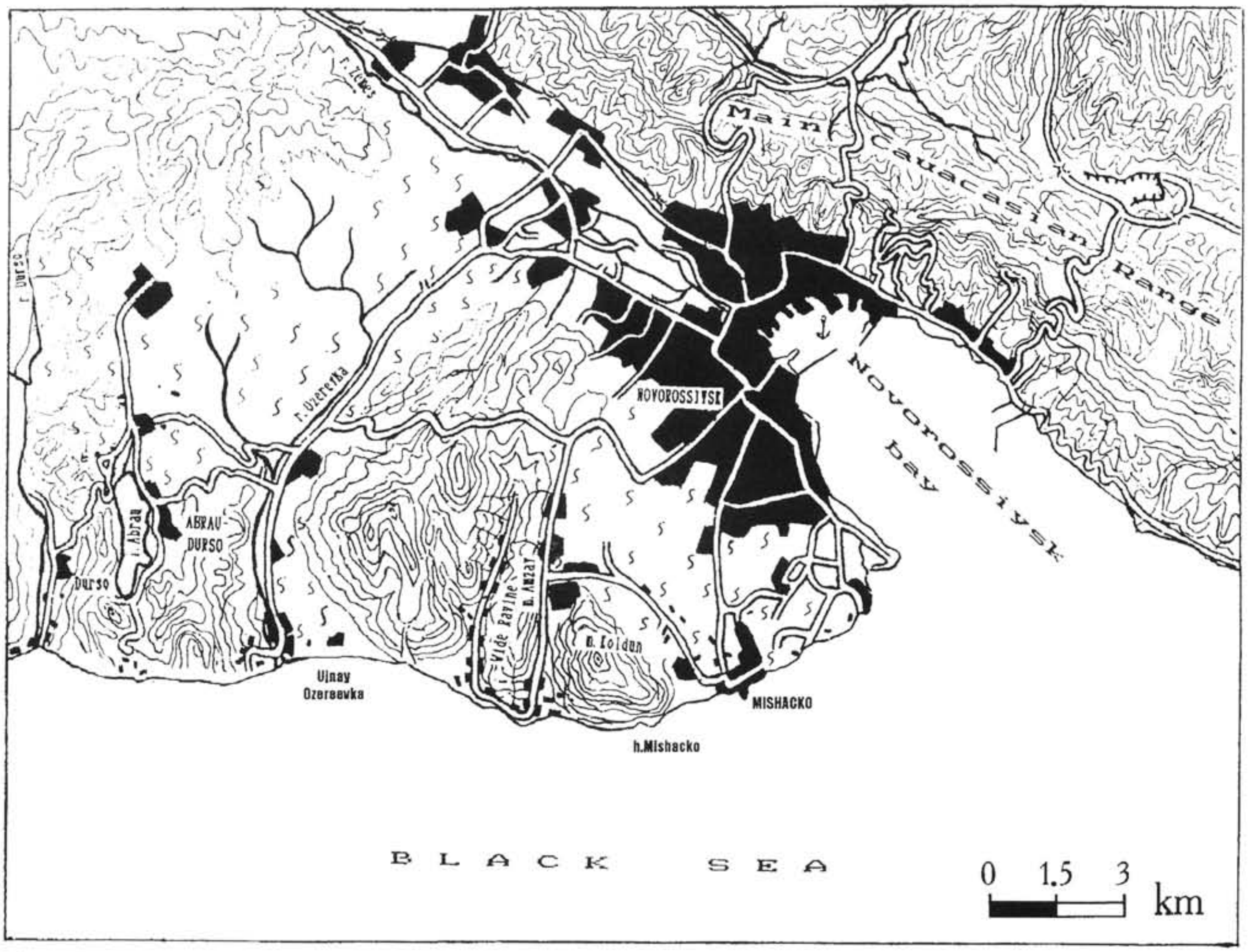

Figure 2. Map of study region of the Black Sea coast, western Caucasus, southern Russia. Study area is west of Novorossiysk between Ozereevka and Mishacko on Mount Amzay and Mount Koldun. Black areas represent urban development, white areas with S's are vineyards, topographic contours represent mountainous areas. Roads and rivers are also marked.

Eight permanent research areas (from 1 to 3 ha each) were established in different habitats: 1) in *Carpinus* forest on the southwest slopes of Mount Koldun, 2) in stone screes of the southeast slope of Mount Amzay, 3) in sparse juniper forest (about to be cleared for pasture) on the west slope of Mount Koldun, 4) in sparse pistachio-juniper forest on southern facing slopes, 5) in a broad area of pine forest, 6) in an open glade amid hornbeam-oak forest with separate stands of pure juniper on the southern slope of Mount Koldun, 7) in oak-carpin-juniper forest on the northwest slope of Mount Amzay, and 8) in glades covered with jasmine and separate stands of *Paliurus* on the southwest slopes of Mount Koldun. Each observation period lasted 3–5 hours, depending upon the size and ruggedness of the area, and was usually carried out by 3–4 people and a dog.

Each month we examined 30–50 ha. Walking transects were conducted in oak-hornbeam-juniper forest at an altitude of 20–50 m on the south-facing slopes extending for a distance of 1.5 km; through mixed ecosystems (e.g., different kinds of trees, glades, old burnt areas, stone screes) at 100–150 m above sea level on the western slopes (distance 3 km); in an oak-hornbeam forest with abundant juniper trees and extensive glades at 150–200 m above sea level on east and northeast facing stopes (distance 2 km); and along a stream-bed in the oak-hornbeam forest with sporadic juniper in some places in the canyons of Mount Koldun and Mount Amzay (distance 2 km). Total monthly transect length was about 80 km.

The recording of the density of tortoises in various habitats was conducted over several years: in 1981 (April – October); 1982 (May, July – September); 1983 (April – May, July – September); 1984 (May – September); 1985 (May – July); 1986 (end of May – July); 1987 (middle of May – June); 1989 (end of April – June); 1990 (end of May); 1991 (June – July, September); 1992 (end of April – May, September); and 1995 (end of April – September), with more or less the same intensity of effort every month.

During the study approximately 1500 tortoises were examined and measured (excluding recaptures), of which about 700 were marked. Body temperature measurements were taken with an electric thermometer inserted into the cloaca. Air temperature was also recorded. Sex was determined for specimens with carapace lengths of more than 150 mm based on the characters described by Lambert (1982).

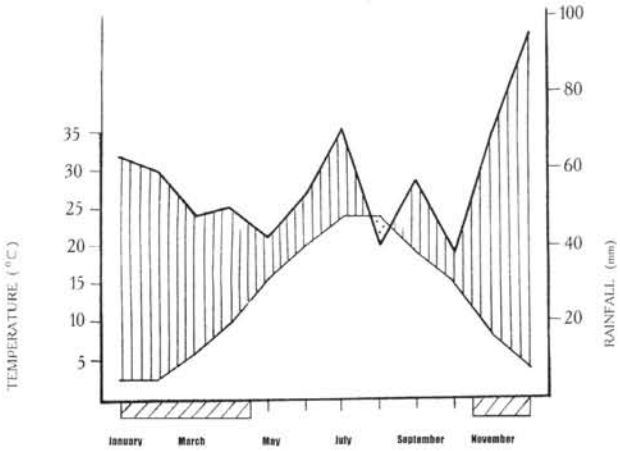

Figure 3. Climatic data for average monthly temperature (left axis and bottom curve) and total monthly rainfall (right axis and top curve) at Novorossiysk (altitude 9 m) near the study area. Average annual temperature is 12.7°C (range of temperature extremes, –24 to 37°C) and total annual rainfall is 688 mm. Vertically striped zones are times of adequate rainfall, stippled zone represents the dry period. Months with frost, but with average temperatures above 0°C, are represented by horizontal bars.

Results and Discussion. — Tortoises followed seasonal preferences in choosing their habitat. In spring the highest densities were found in open habitats such as glades, meadows, and sparse woodlands (Fig. 4). In April 1981 the average density of the tortoise population in a glade was 5.6 individuals/ha. In closed-canopy forest it was difficult to find any tortoises in the spring; they were concentrated in glades, meadows, and sparse forests. The overall population density was 0.2–0.3 individuals/ha in 1981–82, 0.2 in 1983–85, and 0.1 in 1986–87. Since the surveys were usually conducted in spring (the breeding season, when adults were sexually active and easily observed), the figures given mostly reflect the density of mature individuals.

Later in the year, as available food changed (including a decline in the nutritive value of dandelions, *Taraxacum* sp., growing in open areas, as well as clover, *Trifolium* sp., and other fodder plants), the density of tortoises in glades and

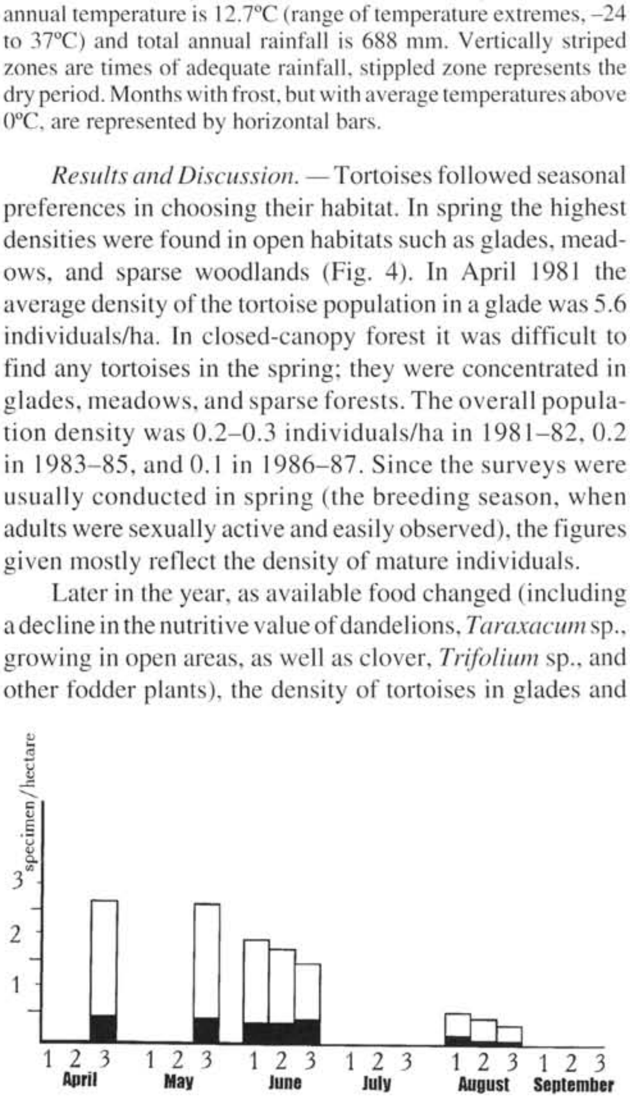

Figure 4. Seasonal changes of population densities of tortoises on sea-facing mountainsides at Mount Koldun in 1995. Open bars = tortoises in meadows and open glades; black bars = tortoises in forests. Months divided into three 10-day intervals; each interval constituted 4 surveys in 2 meadows (2 and 3 ha each) and 8–10 km surveys in hornbeam-oak-juniper forest.

open juniper forests declined as considerable numbers of tortoises migrated to adjacent forest habitats. Probably one of the main factors that caused such a migration is temperature, which became excessive during daytime hours in open, sunlit places.

Tortoises were active within a rather wide range of air temperatures, varying from 15 to 31°C. Above or below this range activity was sharply reduced. Tortoises became inactive at a deep body temperature of 10°C or if it ranged upwards to 31–32°C, (particularly when air temperature exceeded 30°C) and tortoises were then no longer seen in open sunlit places such as glades and vast boulder screes. In summer the deep body temperature of active tortoises varied from 26 to 33°C. When the air temperature was between 18 and 33°C, 20% of tortoises with cloacal temperature of 25°C were active, 30% at 26°C , about 40% at 27°C, 50% at 28°C, 60% at 32°C, and 35% at 33°C (n = 98, all adults; Fig. 5).

Other factors that affected or curtailed activity included the long cold northern winds (the *bora*), heavy rains, and sharp cold snaps. For example, when the *bora* started to blow and the temperature dropped sharply (in summer by about 8–10°C), tortoises did not leave their shelters. But when the *bora* episode was over and normal weather resumed, tortoises left their shelters and grazed on the first warm and windless day. During such times they concentrated in the glades. In the cold early hours of 12 September 1982, during a *bora* episode, a thorough inspection of a glade (2 ha) by six people, only one tortoise, well dug in under bushes, was found. But on 18 September 1982, after the wind dropped and the temperature was 21°C by 1000 hrs, 6 active tortoises were found in the same glade.

To a certain degree the type of diurnal activity depended on the habitat. In open places such as glades maximal activity of tortoises occurred in the morning and evening hours and ceased in the afternoon; but in forests where there were lesser changes of temperature of the ground surface air and no direct sunlight, activity patterns were more constant (Fig. 6). Nevertheless, due to the fact that tortoises of the western Caucasus xerophytic forests have diurnal activity periods (Inozemtsev and Pereshkolnik, 1994), and an individual adult's daily activity period does not exceed 10 hrs, morning records (from 0600 to 1100 hrs) exceeded afternoon records (from 1400 to 1800 hrs) by about 20%. In order to keep their body temperature at an optimal level, tortoises move back and forth between open and shaded areas (Lambert, 1982, 1984; Inozemtsev, 1983; Inozemtsev and Pereshkolnik, 1994), and they spend a great deal of their waking time in behavioral thermoregulation (Lambert, 1981; Meek and Jayes, 1982). A large percentage of the tortoises inhabiting the western Caucasus have migrated from the hot open glades and meadows into the cooler forests by June.

This relative increase of the tortoise population in forests needs to be interpreted carefully: dispersal in a forest territory vastly larger than the open glade and meadow areas of their early-spring concentration increased the population density of the forest areas only insignificantly (Fig. 4).

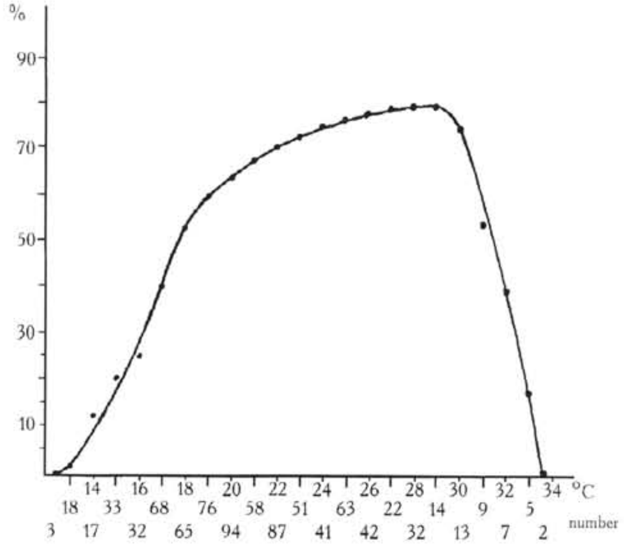

Figure 5. Activity of adult tortoises relative to air temperature (between 0700 and 1200 hrs). Horizontal axis = air temperature (°C); vertical axis = percentage of observed tortoises found to be active. Numbers under the horizontal axis = number of tortoises observed at each temperature.

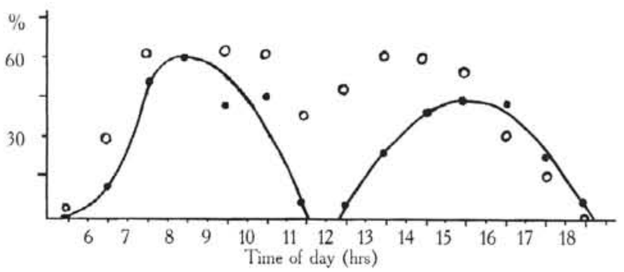

Figure 6. Time-related daily activity of mature tortoises in different biotopes in June. Horizontal axis = time of day (hrs); vertical axis = percentage of observed tortoises found to be active. Solid dots = active specimens in meadows (with fitted curve); open circles = active specimens in woods.

On the hottest summer days (usually in mid-July to mid-August) tortoises sometimes concentrated near forest streams and the scarce permanent lakes and ponds in the woods. Tortoises have been observed drinking at such places (Levinson, 1977; Inozemtsev and Pereshkolnik, 1994).

By autumn, tortoises dispersed throughout the woods in search of wintering sites. Starting in September, the number of adult tortoises in glades decreased quickly (late in September they were seldom found, except for neonates of the year). In the fall tortoise concentrations in the various habitats became almost even.

Seasonal population density redistribution patterns differed for different age groups of tortoises. Mature tortoises during the early-spring mating period congregated in open areas (e.g., glades, meadows, stone slopes) which presented favorable conditions for mating and soil types that facilitated nest excavation and egg-laying. Both properly buried eggs and also single, unburied eggs were found in the glades. At the same time a significant number of adult tortoises could be found in the adjacent forest. Mature tortoises probably moved extensively between open habitats and glades into nearby forests which probably provided better conditions for cover during low-activity periods. The migration of male and female adult tortoises followed different patterns. During mating times the more active males were often seen in the glades, although some of them later left these areas. The females, seeking sites for nest excavation and oviposition, spent more time in the glades. Correspondingly, the observed sex ratio (females:males) in the glades was 1:1.1 in April; 1:1.3 in May; 1:0.8 in June; 1:0.9 in July, and approximately 1:1 later in the year.

In summer, when the grass burns, immature tortoises were found in the open areas. They increased in abundance by the end of summer, while the number of adult tortoises diminished. During their first year juvenile tortoises remained close to their place of birth, making short move-

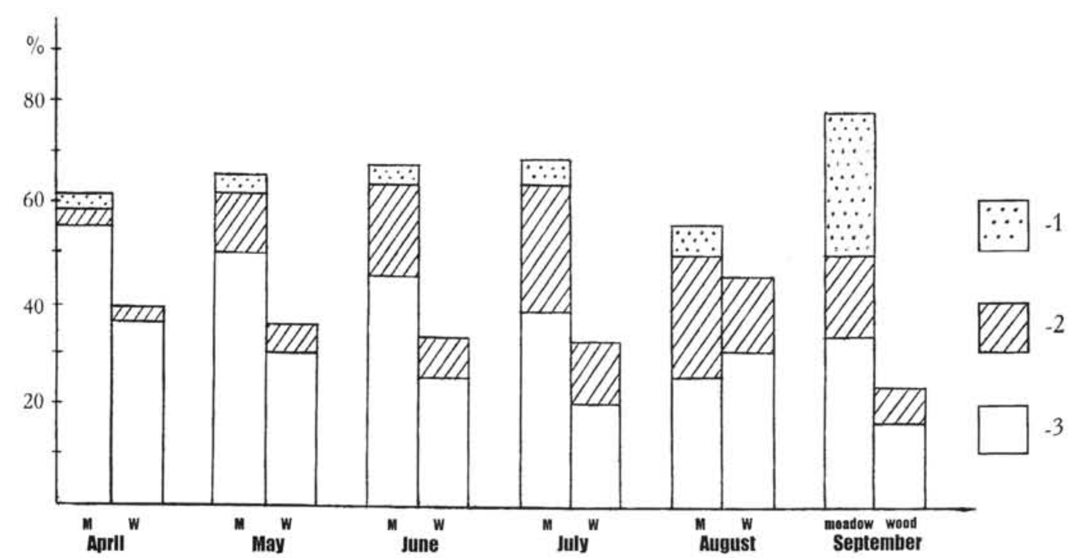

Figure 7. Percentage of tortoises found in different biotopes during different months. M = meadows (1-3 ha areas); W = woods adjoining meadows. 1 (dotted bars) = juveniles (CL to 60 mm, age up to 0.5 yrs); 2 (striped bars) = subadults (CL from 60 to 150 mm, age from 1 to 13.5 yrs); 3 (open bars) = adults (CL more than 150 mm, age above 14 yrs).

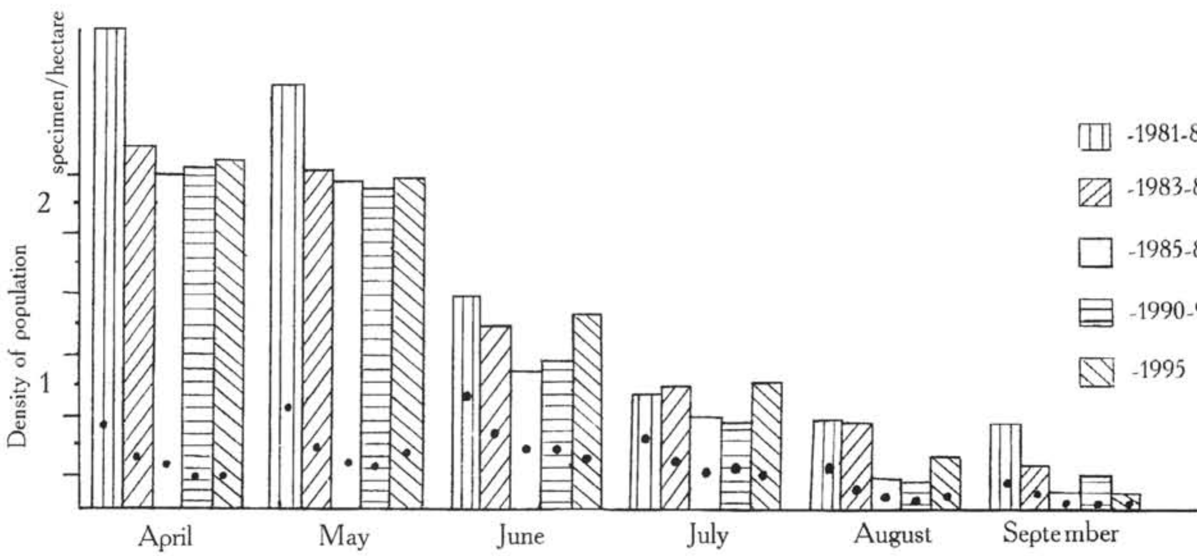

Figure 8. Population dynamics of tortoises on mountainsides (50-200 m above sea level) in 1981–95. Vertical axis = population density (specimens/ha); horizontal axis = months. Bars = population density of tortoises in meadows and sparse juniper woodlands. Dots = population density of tortoises in woods.

ments only under cover of thick grass and dense stunted jasmine (Fig. 7).

The above-mentioned seasonal environmental preferences for tortoises should be adjusted by considerations of differential daily activity patterns of various age groups which affected their probability of discovery. In fact, the duration of daily activity of adult tortoises diminished progressively as hot weather approached (July – August, when grass in the open areas is normally burnt), but it did not change significantly among subadult animals. Among juveniles, observed activity duration increased with age to a certain degree. The considerable increase in juvenile abundance in the glades, usually in mid- to late September, was a result of near-synchronous hatchling emergence.

Overall tortoise abundance in the study area has dimished progressively during the entire observation period, i.e., since 1973 (Inozemtsev, 1993; Inozemtsev and Pereshkolnik, 1994). However, the decline probably began even earlier, most likely around the middle of the century. The ecosystem was previously able to compensate for stress and the xerophytic forests remained almost unchanged until the 1940s, protected by their rugged terrain with sleep slopes, dense subtropical forests, and scarcity of access roads. There was thus good natural protection of habitats on the sea-facing mountain slopes (particularly the south-facing slopes of Mount Koldun and Mount Amzay, where our observations were made) until recently.

Forest slopes and the seashore to the west of Novorossiysk were subject to serious deterioration and change in the early 1970s when a highway was constructed to provide access to various recreational sites. Both dense and open xerophytic forests on the slopes were affected and reduced by the ensuing rapid development. Land was exploited for tourist and recreation centers, sports grounds, and roads. At the same time exotic trees and other vegetation were planted there, including larch (*Larix decidua*), poplar (*Populus bolleana*), walnut (*Juglans regia*), and *Aesculus hippocastanum*. Pistachio trees, junipers, and other indigenous trees are vanishing. The number of people visiting the area, or living in holiday camps, has increased along with proliferation of overall development. The impact of anthropogenic factors on the ecosystem of the area has increased correspondingly.

This process has had a discrete, episodic nature and quantitative changes in the environment have accumulated gradually. When construction of roads and recreation centers was completed, and traffic, tourist visits, and further construction followed, there was a resultant sharp growth in anthropogenic transformation of the entire ecosystem. The following anthropogenic stages of this developmental process may be identified as follows:

1. Exploration of virgin wilderness for brief open-air holidays (ca. 1950–70);

2. Construction of small summer camps and development of rustic resort areas (ca. 1970–74);

3. Construction of major buildings and further exploration of undeveloped territory (ca. 1975–79);

4. Replacement of older, smaller wooden buildings by larger, multilevel stone buildings, and creation of a health resort area (ca. 1980–85);

5. Relative stabilization of the levels of recreation and industrial and construction activity (ca. 1986–90);

6. Decrease of developmental activity; reduction of recreational impact on the accessible parts of the landscape (ca. 1991–95).

Such step-wise construction (and exploration), with old buildings replaced by new and more permanent ones within 3–6 years, and the latter, in their turn, also soon replaced — all these factors have caused a continuous increase in human impact on the ecosystem, hampering natural regulation of ecological forces that stabilize nature. The xerophytic forest ecosystem has steadily and rapidly deteriorated as a result. The forests have vanished first on mountain slopes (up to the very tops) and vineyards are planted on the formerly forested sites.

Because of these negative effects on the ecosystem, the numbers of tortoises in the study area began to decline rapidly. In 1973–75 the average density of the tortoise population in xerophytic forests was 0.3 individuals/ha, in 1981–82 it was about 0.2, and in 1986–87 it was less than 0.1.

However, along with the destruction or abandonment of vineyards in 1987–89 during Gorbachev's anti-alcohol campaign, the decrease of the tortoise population may have become less acute. In conjunction with the five- to ten-fold reduction of the number of tourists (caused by substantial price increases for accomodation and transportation) and concomitant decrease in overall local economic activities in the summer months, the tortoise population density may have stabilized in 1991–92 (Fig. 8).

Tortoises have practically vanished in forests adjacent to resort areas (built by 1985), adjoining the new highway (where they have been intensively exploited since the 1980s), and near the coastline (where in summer there are still large numbers of tourists). Tortoises have also abandoned forest meadows where cattle habitually graze, as well as places with habitat deterioration due to recreational development. Tortoises are rare in forests between Gelendzhik and Divnomorsk where there has been recent resort construction; there are practically none in forests bordering Lake Abrau in the southeast.

Thus, despite tortoise population density stabilization in xerophytic forests and positive trends in mean tortoise size at the Caucasus seashore (pers. obs.), the available habitat is shrinking and the number of tortoises is also decreasing.

An additional concern results from plans for construction of a major interstate oil pipeline, extending from the Trans-Caspia region in the northeast to a sea terminal 12 km west of Novorossiysk. The completion of this project would bisect the area populated by the Mediterranean tortoise west of the Caucasus, destroy part of its available habitat and make it difficult to maintain a stable population of tortoises in this rapidly developing region.

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