Local Population Size and Dynamics of the Color Polymorphic Bush Cricket, *Isophya rizeensis* Sevgili, 2003 (Orthoptera: Tettigoniidae) within the Fırtına Valley*

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Abstract: *Isophya rizeensis* Sevgili, 2003 (Orthoptera: Tettigoniidae) is a color polymorphic bush cricket endemic to the Fırtına Valley in the northeast of Turkey. This paper describes the local population size and dynamics of the species distributed in 13 different habitat patches within the Fırtına Valley. Local population size varied greatly between sites, and a 1-week delay in nymph emergence and maturation was recorded at the highest habitat patch relative to all habitat patches located at lower altitudes. The results given in this paper suggest that the *I. rizeensis* population in the Fırtına Valley constitutes a metapopulation made up of several local populations under partially different ecological pressures.

Key Words: *Isophya rizeensis*, bush cricket, population size, metapopulation, distribution

Renk Bakımından Polimorfik Olan Çayır Çekirgesi *Isophya rizeensis* Sevgili, 2003 (Orthoptera: Tettigoniidae)'nin Fırtına Vadisi İçerisindeki Yerel Populasyon Büyüklükleri ve Dinamikleri

Özet: *Isophya rizeensis* Sevgili, 2003 (Orthoptera: Tettigoniidae) Türkiye'nin kuzey-güneyinde bulunan Fırtına Vadisine endemik ve renk bakımından polimorfik olan bir çayır çekirgesidir. Bu çalışma *I. rizeensis*'in Fıtına Vadisi içerisindeki 13 istasyondaki yerel populasyon büyüklüklerini ve dinamiklerini ortaya koymaktadır. Yerel populasyon büyüklüğü istasyonlar arasında büyük farklılıklar gösterdiği ve Hopkins'in biyoklimatik kuralı doğrultusunda farklı yüksekliklerde bulunan istasyonlarda nimf çıkışı ve erginleşme bakımından birer haftalık gecikmeler gözlemlenmiştir. Bu çalışmdan elede edilen sonuçlar doğrultusunda Fırtına Vadisi içerisinde bulunan *I. rizeensis* populasyonunun bir birinden farklı ekolojik baskılar altında bulunan bir kaç yerel populasyonundan meydana gelen bir metapopulasyon oluşturduğu söylenebilir.

Anahtar Sözcükler: *Isophya rizeensis*, çayır çekirgesi, populasyon büyüklüğü, metapopulasyon, dağılım

Introduction

The bush cricket *Isophya rizeensis* Sevgili, 2003 (Orthoptera: Tettigoniidae) is a newly described species (Sevgili, 2003) and is similar to most *Isophya* species in Turkey (Çıplak et al., 2002; Sevgili and Heller, 2003). It is endemic to Anatolia and has a very narrow distribution (Sevgili, 2003, 2004). The only population of *I. rizeensis* is situated in the Fırtına Valley in the east Black Sea region of Turkey, ranging from the northern slopes of the Kaçkar Mountains to the lowlands of Çamlıhemşin in Rize Province (Sevgili, 2003, 2004).

I. rizeensis is a large (17.7-25 mm) ground-living bush cricket without flight capability. Males can be classified into 3 distinct groups according to color pattern: black, brown, and green. Females can similarly be classified according to color pattern, but the variation is not as distinct as in males, with green being the dominant color. Nymphs emerge in late May and early June, and adults are found from late June until the end of August. At higher altitudes (over 1500 m), nymph emergence shifts towards the middle of June and the first adults are seen in the second week of July. The species

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feeds mainly on herbs and grasses situated at the bottom of vegetation, and both feeding and mating activity usually occur at night. *I. rizeensis* occurs syntopically with other bush crickets in the lowlands, such as *Poecilimon schmidti*, *P. similis*, *Phonochorion* spp., and *Pholidoptera griseoaptera*, and with *Psorodonotus specularis* and *Phonochorion* spp. in the subalpine and alpine zones of the Kaçkar Mountains (Sevgili, 2004).

Like most species within the genus *Isophya*, *I. rizeensis* is polymorphic for color pattern (Sevgili, 2004). Moreover, this variation in coloration was shown to have a distinct clinal pattern, with dark color morphs appearing in the warmer lowlands (350-1000 m) and pale color morphs appearing in the cooler subalpine zones of the Kaçkar Mountains (1000-2000 m) (Sevgili, 2003; Sağlam, 2004). Since thermal capacity and heating rates of dark individuals are substantially higher than those of pale individuals (Forsman, 1997; Forsman et al., 2002), one would expect darker color morphs to be distributed at higher altitudes; however, color morphs were also shown to inhabit markedly different habitats. Pale color morphs were located in habitat patches with less vegetation coverage where they are susceptible to higher predation rates, while darker color morphs were located at habitat patches with higher vegetation coverage providing better protection from predators (Sağlam, 2004; Sağlam and Çağlar, 2005). Under conditions with elevated risk from predators, selection might favor the more cryptic pale color morph over the black color form in habitat patches located at higher altitudes, offering some explanation for the observed spatial pattern.

Preference for specific vegetation is not rare in bush crickets since many species of Tettigoniidae have highly specialized requirements for courtship and egg laying (Marshall and Haes, 1988 as cited in Cherill and Brown, 1990). Since *I. rizeensis* is a very resident species that usually moves very little and seems to be unwilling to leave its native habitat, this kind of specificity brings about a certain amount of isolation between groups localized on separate vegetation stands. In species with low mobility, even 50-100 m of unsuitable vegetation is enough to delimit one local population from the other (Thomas et. al., 1999). A local population can be interpreted as the demographic unit where most population processes, i.e. reproduction, competition, and predation, take place, and where most interactions among conspecifics occur (den Boer, 1981). Therefore, it

is quite possible that *I. rizeensis* groups in each separate habitat patch might constitute a local population with differing demographic structures.

Persistence of local populations is heavily dependant upon population size (Kindvall and Ahlen, 1992) and small populations are more vulnerable to processes causing extinction than large ones (Shaffer, 1981). *I. rizeensis* occupies an extremely limited range of habitats; therefore, it is severely susceptible to any fluctuations taking place in its environment.

The aim of the present paper was to compare the differences between habitat patches of *I. rizeensis* populations within the Fırtına Valley in relation to local population size and dynamics. This information may be vital for future studies, which will concentrate on the population structure of this endemic species. Therefore, determining key habitat patches is of great importance.

Materials and Methods

Previous to this study, the Fırtına Valley was visited in 2002 for pre-evaluation. A total of 24 suitable habitat patches at varying altitudes were sampled, but the presence of *I. rizeensis* was recorded in only 13 of them. These 13 habitat patches were located at different altitudes and were separated by 1-2 km (Figure 1). All 13 sites were open habitat patches made up of mostly forb/herb shrub and graminoid vegetation. Even within these habitat patches, *I. rizeensis* adults were found as localized groups, since 70% of all adults counts were obtained from shrub vegetation covering, at most, 25% of each habitat patch.

Study Area

The study was conducted in the Fırtına Valley, stretching from the lowlands of Çamlıhemşin (lat 41°02'14.9"N, long 41°00'29.9"E; 353 m) up to the highlands of Elevit Plateau (lat 40°51'17.4"N, long 41°00'45.1"E; 1890 m). The valley has been covered with warm deciduous forests since the Tertiary and harbors many distinct habitats, such as alluvial stream forests, beech forests, boxwood forests, and meadows in the lowlands, and pine forests, subalpine meadows, and grasslands in the highlands near the slopes of the Kaçkar Mountains (Güner et al., 1987). The valley receives abundant rainfall throughout the year with mean precipitation reaching 1296.5 mm. Temperatures are
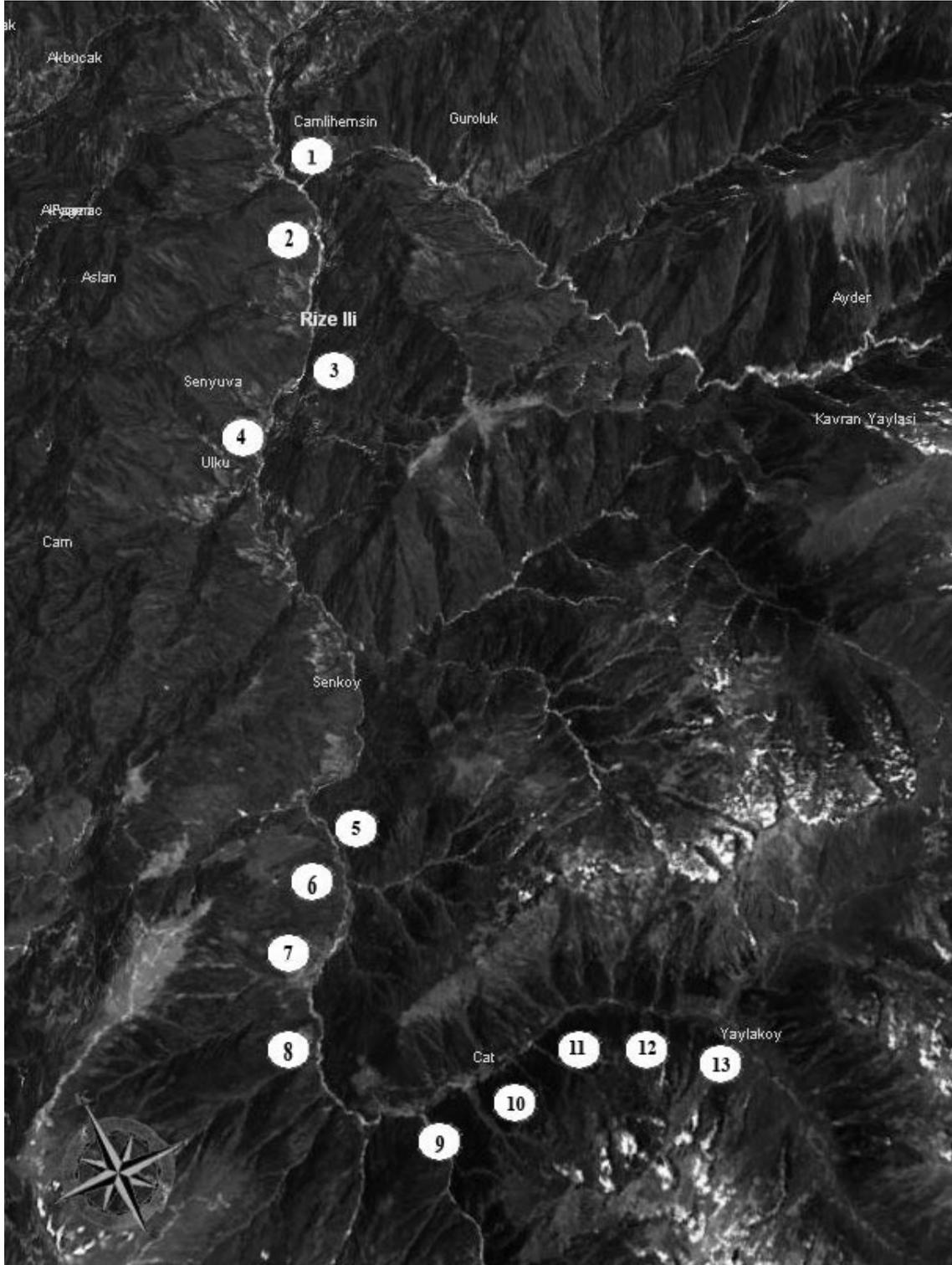
Figure 1. Distribution of the 13 habitat patches within the Fırtına Valley in which *I. rizeensis* was found.

usually low with a yearly mean of 13.5 °C. The highest temperatures are recorded in July and August with a mean of about 21.7 °C, but temperatures within the day vary greatly depending on sunlight and rainfall. Relative humidity is high and constant throughout the year, with a mean of approximately 73%-82%. Fog formation is common in the area, especially at higher altitudes where fog tides come and go on a daily basis.

Field Work and Sampling Procedure

Six field surveys were conducted systematically between June and September 2003. All suitable habitat patches were visited in order to determine the presence or absence of *I. rizeensis*. Presence of *I. rizeensis* was determined through its characteristic stridulation (Sevgili, 2004) and observation of adults and nymphs. In cases where no specimens were observed and no stridulation was heard, the localities where consistently rechecked.

Local population size and dynamics were evaluated by studying 13 habitat patches at varying altitudes where the presence of *I. rizeensis* was confirmed (Table 1). Relative size of habitat patches varied between 20 and 50 m^2, as these were usually forest clearings exposed to the sun. All field work was conducted between 11:00 am and 6:00 pm when the majority of males call consistently. Estimates of local population size were achieved by systematically counting all nymphs, males, and females by walking in straight lines 2 m apart.

Table 1. Altitude and coordinates of the 13 habitat patches in which *I. rizeensis* was found.

Sites	Altitude	Coordinates
Habitat Patch 1	352.7 m	N 41°02'14.9" E 41°00'29.9"
Habitat Patch 2	420.6 m	N 41°00'19.6" E 40°59'20.4"
Habitat Patch 3	442.9 m	N 40°59'46.8" E 40°58'29.4"
Habitat Patch 4	475.2 m	N 40°59'08.2" E 40°57'52.5"
Habitat Patch 5	665.1 m	N 40°56'24.2" E 40°58'04.6"
Habitat Patch 6	883.1 m	N 40°54'59.8" E 40°56'44.2"
Habitat Patch 7	979.9 m	N 40°54'27.1" E 40°56'52.5"
Habitat Patch 8	1028.0 m	N 40°53'16.6" E 40°55'47.0"
Habitat Patch 9	1246.3 m	N 40°51'46.7" E 40°56'05.1"
Habitat Patch 10	1335.6 m	N 40°51'49.2" E 40°57'08.9"
Habitat Patch 11	1485.6 m	N 40°51'46.7" E 40°58'11.3"
Habitat Patch 12	1621.4 m	N 40°51'58.3" E 40°59'05.2"
Habitat Patch 13	1893.9 m	N 40°51'17.4" E 41°00'45.1"

Results

The total number of nymphs and adults obtained from all habitat patches during the 6 sampling periods are given in Figure 2. By the third week of June, nymphs were recorded from all habitat patches within the study site, along with a few adults. All adults sampled during the third week of June were collected from habitat patches at lower altitudes (habitat patches 1-8). The number of nymphs increased throughout June and reached a peak in early July.

After the first week of July, nymph numbers decreased slightly, but always remained above a certain level. The lowest number of nymphs was recorded during the first week of August, but this was mostly due to sampling error caused by heavy and abundant rainfall.
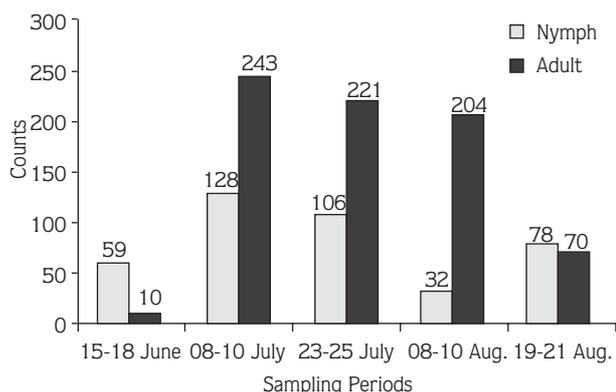

Figure 2. Total number of nymphs and adults of *I. rizeensis* observed in the 13 habitat patches within the Fırtına Valley during the summer of 2003.

Total number and mean population size of nymphs from each of the 13 habitat patches are given in Table 2. Mean population size of nymphs varied greatly between different habitat patches, ranging from 4.33 to 15.50 individuals per patch. The highest number of nymphs were recorded from habitat patches 4 ($\overline{x} = 23.0$) and 10 ($\overline{x} = 17.6$) (Table 2). In all habitat patches, except habitat patch 13, nymphs were recorded until the last week of August, although mean numbers dropped from 11.07 to 5.7 individuals per patch after the second week of July. In habitat patch 13, nymphs were recorded until the second week of July, and no later records of nymphs were noted.

Adult numbers started to increase significantly after the middle of June and reached a peak during the first week of July, and stayed relatively constant throughout July and the first half of August (Figure 2). Adult numbers dropped after the third week of August and had disappeared by the first week of September. Although total numbers of adults were high, mean sizes of local populations in the 13 habitat patches were relatively small, ranging from 1.3 (Patch 10) to 56.25 (Patch 7) (Table 3). Total number of adult counts from habitat patches 1 to 4 was extremely low (4♀♀; 7♂♂); therefore, these were pooled. All records of adults in habitat patches 1 through 4 were during June and July; no samples were obtained from these habitat patches during August. Habitat patch 5 showed a similar trend, with adults being observed only during June and July, although mean population size (19.5) was significantly larger (Table 3). Similarly, habitat patches 10 (1♀; 3♂♂) and 12 (2♀♀; 11♂♂) also yielded low numbers of adults. This was somewhat surprising as nymph numbers in these habitat patches were quite high (Table 2), but they never matured into adults. A relatively high number of adults was recorded from habitat patches 6, 7, 8, 9-11, and 13 (Table 3), with mean size of local populations ranging from 17.00 (Patch 11) to 56.25 (Patch 7). Local population size in habitat patches 6-9 and 11 remained constant until the second week of August and afterwards dropped rapidly, almost disappearing by the last week of August. The only habitat patch with a high number of adults in the last week of August was habitat patch 13, but the population here also disappeared by the first week of September.

Table 2. Total number and mean population size of *I. rizeensis* nymphs in different habitat patches in the Fırtına Valley. (n) = number of samplings.

Habitat Patch	Total	n	Mean Pop. Size	Range
1	13	3	4.33	3-6
2	23	4	5.75	4-7
3	19	4	4.75	2-7
4	46	3	15.33	4-21
5	41	4	10.25	4-23
6	39	4	9.75	9-11
7	37	4	9.25	6-17
8	10	1	10	-
9	36	3	12	10-16
10	53	3	17.6	7-37
11	42	4	10.5	3-18
12	13	1	13	-
13	31	2	15.5	10-21

Table 3. Total number and mean population size of *I. rizeensis* adults (male + female) in different habitat patches in the Fırtına Valley. (n) = number of samplings.

Habitat Patch	Total Counts		n	Mean Pop. Size	Range
	♂	♀			
1 - 4	7	4	2	5.5	5-6
5	29	10	2	19.5	11-27
6	77	21	3	32.6	12-53
7	205	20	4	56.3	12-115
8	63	17	4	20.0	23-31
9	102	18	4	30.0	6-49
10	3	1	3	1.3	1-2
11	40	28	4	17.0	5-24
12	11	2	2	6.5	2-11
13	73	17	4	22.5	19-40

Discussion and Conclusion

Results show that almost all individuals had matured into adults by the first week of July, and total population size remained relatively constant until September (Figure 2). The fact that no fluctuation in adult population size was determined during July-September indicates that like most crickets living in temperate zones (Kindvall, 1995a; Gywnne, 2001), *I. rizeensis* produces a single generation per year with a 1-year life cycle.

As expected, local populations situated at differing altitudes showed a weak seasonality. The presence of adults at habitat patches below 800 m during the second week of June indicates that nymph emergence in these patches had started at the end of May. Only first and second stage nymphs were present in habitat patches located over 800 m in June. Maturation was complete in all habitat patches by the first week of July, except for habitat patch 13. Crickets were still at the nymph stage in the first week of July in this habitat patch and maturation was complete by the last week of July. As a result, a 1-week delay in nymph emergence and maturation was recorded in habitat patch 13 relative to all other habitat patches located at lower altitudes. No difference in development time from nymph to adult stage was recorded between habitat patches as maturation was completed in a relatively short time, 2-3 weeks in all habitat patches. This is in accordance with other data showing that crickets situated in cooler environments mature at a relatively fast rate (Mousseau, 1997).

Population size showed great variation between habitat patches. Local population size was extremely low in habitat patches 1-4, 10, and 12. The lack of adults in habitat patches 1 through 3 was not surprising since mean nymph numbers in these patches were also low. These patches might have reflect the distributional edge of the species since, unlike patches 4, 10, and 12, both nymph and adult numbers were low. Low numbers of nymphs in these patches could reflect a deficiency in embryonic development and reduction in egg hatching ratios; hence, these patches would be most unsuitable for colonization.

Nymph numbers in habitat patches 4, 10, and 12 were high all season long, but they never matured into adults. Nymph development is heavily dependant upon temperature and number of sunshine hours (Begon, 1983; Haes et al., 1990), and development of bush crickets is negatively affected during wet and cloudy seasons (Kindvall, 1995b). In extremely cloudy summers, the time of last molt can be delayed considerably (Grant et al., 1993). The 2003 season in the Fırtına Valley was characterized by extremely wet and cloudy conditions, with the number of sunny days reduced to 3-4 per month (Sağlam, 2004). This was uncharacteristic, even for the Fırtına Valley, where rainfall and cloudy weather are quite common. This extreme weather could have reduced

nymph development, explaining the occurrence of nymphs from all habitat patches all season long. Habitat patches 4 and 12 had much higher levels of cover when compared to other habitat patches (Sağlam, 2004), and so sunshine in these patches was extremely limited. This situation could explain the almost total lack of adults in these habitat patches, but is not a valid explanation for the situation in habitat patch 10, which received adequate amounts of sunshine (Sağlam, 2004). Other factors, such as predation, mainly by spiders and reptiles, and extreme cold, which reduces foraging activities (Harrison and Fewell, 1995; Danner and Joern, 2004), could also be responsible.

Mean population size of *I. rizeensis* was relatively large in habitat patches 6-9, 11, and 13, but varied significantly between patches. The factors that regulate local populations of *I. rizeensis* are not yet known; however, both weather conditions and predation are known to have significant effects on bush cricket population densities (Joern, 1992; Kindvall and Ahlen, 1992; Kindvall, 1995b). Cooler microclimatic conditions reduce fitness by negatively affecting foraging activity, food intake, and digestion (Chappell and Whitman, 1990; Harrison and Fewell, 1995; Pitt, 1999). Microclimatic conditions were significantly warmer in habitat patches 6 and 7 than in patches 8, 9, 11, and 13 (Sağlam, 2004). This could have been the reason for the higher mean population sizes seen in these patches, but previous studies show that the effect of predation is also significant. Potential predators of grasshoppers include birds, mammals, reptiles, and spiders, as well as other arthropods (Churchfield et al., 1991; Bock et al., 1992; Belovsky and Slade, 1993). All of these predators can regulate bush cricket population size by directly affecting survival, but also by negatively affecting thermoregulatory behavior. Bush crickets, including *I. rizeensis*, are classical heliotherms, using behavioral mechanisms to maintain high diurnal body temperatures (Chappell and Whitmann, 1990). In cool environments, crickets move up in the vegetation, exposing themselves to direct solar radiation. Where predation rates are high, crickets are forced to move lower in the vegetation for better protection (Pitt, 1999). This subjects the organism to less favorable and cooler microclimatic conditions, resulting in a decrease in activity and hence fitness.

Habitat patches 8, 11, and 13 were characterized with low levels of vegetation coverage, leaving the crickets susceptible to higher predation rates (Sağlam, 2004; Sağlam and Çağlar, 2005). Consequently, mean population sizes in these habitats were lower (Table 3). Alternatively, the highest mean population sizes were recorded in habitat patches 6 and 7 (Table 3), which were characterized by denser vegetation, providing better protection from predators. In addition, mean population size of habitat patch 9, which was also characterized by high vegetation coverage, was closer to patches 6 and 7, despite the negative effects brought on by a cooler microclimate. These data collectively suggest that the direct and indirect effects of predation might be more effective in controlling local population size of *I. rizeensis* in the Fırtına valley than the direct effects of microclimatic conditions.

The results given here strengthen the assumption that *I. rizeensis* individuals in each habitat patch constitute a local population under partially different ecological pressures. When the population is taken as a whole, it can be said that the *I. rizeensis* species in the Fırtına Valley constitutes a metapopulation. A metapopulation can be defined as any set of local populations with turnover (Hanski and Gilpin, 1991). The term turnover here refers to the 2 processes of colonization and extinction, and a metapopulation refers to the state of local populations where these 2 processes are determined by independent stochastic events taking place in each habitat patch. To have a better understanding of the metapopulation dynamics thought to be acting on *I. rizeensis*, future work must concentrate on the probabilities of local extinction and colonization taking place in different habitat patches. In addition, more information is needed on the intra- and interspecific interactions and stochastic events regulating population densities of the species, as well as a detailed study of its dispersal capacity.

References

Begon, M. 1983. Grasshopper populations and weather: the effect of insolation on *Chorthippus brunneus*. Ecological Entomology 8: 361-370.

Belovsky, G.E., Slade, B.J. and Stockhoff, B.A. 1990. Susceptibility to predation for different grasshoppers: an experimental study. Ecology 71: 624-634.

Boer, P.J. den 1981. On the survival of populations in heterogeneous and variable environments. Oecologia 50: 39-53.

Bock, C.E., Bock, J.H. and Grant, M.C. 1992. Effects of bird predation on grasshopper densities in an Arizona grassland. Ecology 73: 1706-1717.

Chappell, M.A. and Whitman, D.W. 1990. Grasshopper thermoregulation. In: Biology of Grasshopper*s* (eds. R.F. Chapman and A. Joern). John Wiley & Sons, New York, pp. 143-172.

Cherill, A.J. and Brown, V.K. 1990. The habitat requirements of adults of the water-biter *Decricus verrucivorus* (L.) (Orthoptera: Tettigoniidae) in Southern England. Biological Conservation 53: 145-157.

Churchfield, S., Hollier, J. and Brown, V.K. 1991. The effects of small mammal predators on grassland invertebrates, investigated by field exclosure experiment. Oikos 60, 283-290.

Çıplak, B., Demirsoy, A., Yalım, B. and Sevgili, H. 2002. Türkiye'nin Orthoptera (Çekirgeler = Düzkanatlılar) faunası pp. 681-707. In: Genel Zoocoğrafya ve Türkiye Zoocoğrafyası "Hayvan Coğrafyası". (ed. A. Demirsoy). Meteksan A. Ş., Ankara, Türkiye. 1007 pp.

Danner, B.J. and Joern, A. 2004. Development, growth, and egg production of *Ageneotettix deorum* (Orthoptera: Acrididae) in response to spider predation risk and elevated resource quality. Ecological Entomology 29: 1-11.

Forsman, A. 1997. Thermal capacity of different color morphs in the pygmy grasshopper *Tetrix subulata*. Annales Zoologici Fennici 34: 145-149.

Forsman, A., Ringblom, K., Civantos, E. and Ahhensjö, J., 2002. Coevolution of colour pattern and thermoregulatory behaviour in polymorphic pygmy grasshoppers, *Tetrix undulate*. Evolution 56: 349-360.

Grant, A., Hassall, M. and Willott, S.J. 1993. An alternative theory of grasshopper life cycles. Oikos 66: 263-268.

Güner, A., Vural, M. and Sorkun, K. 1987. Rize florası, vejetasyonu ve yöre ballarının polen analizi. Türkiye Bilimsel ve Teknik Araştırmalar Kurumu Matamatik, Fiziki ve Biyolojik Bilimler Araştırma Grubu. Proje No: TBAG-650.

Gwynne, D.T. 2001. Katydids and Bush-Crickets: Reproductive behaviour and evolution of the Tettigoniidae. Comstock Publishing Associates. Cornell University Press, Ithaca and London. pp. 317.

Haes, E.C.M., Cherill, A.J. and Brown, V.K. 1990. Meteorological correlates of Water-biter (Orthoptera: Tettigoniidae) abundance. The Entomologist 109: 93-99.

Hanski, I. and Gilpin, M.E. 1991. Metapopulation dynamics: brief history and conceptual domain. In: Metapopulation Dynamics: Empirical and Theoretical Investigations. (eds. M.E. Gilpin and I. Hanski. Pp. 3-16. Linnean Society of London, Academic Press. London.

Harrison, J.F. and Fewell, J.H. 1995. The thermal effects on feeding behavior and net energy intake in a grasshopper experiencing large diurnal fluctuations in body temperature. Physiological Zoology 68: 453-473.

Hopkins, A.D. 1920. The bioclimatic law. Journal Wash. Acad. Sci. 10: 34-40.

Joern, A. 1992. Variable impact of avian predation on grasshopper assemblies in sandhills in grasslands. Oikos 64: 458-463.

Kindvall, O. 1995a. Ecology of the bush cricket *Metrioptera bicolor* with implications for metapopulation theory and conservation. Swedish University of Agricultural Sciences, PhD Thesis. SLU/Repro, Uppsala.

Kindvall, O. 1995b. the impact of extreme weather on habitat preference and survival in a metapopulation of the bush cricket *Metrioptera bicolor* in Sweden. Biological Conservation 73: 51-58.

Kindvall, O. and Ahlen, I. 1992. Geometric factors and metapopulation dynamics of the bush cricket, *Metrioptera bicolor*, Philippi (Orthoptera: Tettigoniidae). Conservation Biology 6: 520-529.

Mousseau, T.A. 1997. Ectoterms follow the converse to Bergmannn's rule. Evolution 51: 630-632.

Pitt, C.W. 1999. Effects of multiple vertebrate predators on grasshopper habitat selection: trade-offs due to predation risk, foraging, and thermoregulation. Evolutionary Ecology 13: 499-515.

Sağlam, İ.K. 2004. Research on the altitude dependent, ecological distribution and colour polymorphism of the bush-cricket *Isophya rizeensis* Sevgili, 2004 (Orthoptera: Tettigonoiidae), M.Sc. thesis, Hacettepe University Institute of Pure and Applied Science Ankara, 123 pp.

Sağlam, İ.K. and Çağlar, S.S. 2005. Distribution and habitat characteristics of the color polymorphic bush-cricket *Isophya rizeensis* Sevgili (Orthoptera: Tettigoniidae: Phaneropterinae) in Turkey. Entomological News 116: 309-324.

Sevgili, H. 2003. A new species of bushcricket (Orthoptera: Tettigoniidae) of the palearctic genus *Isophya* (Phaneropterinae) from Turkey. Entomological News 114: 129-137.

Sevgili, H. 2004. A revision of the Turkish species of *Isophya* Brunner von Wattenwyl (Orthoptera: Tettigoniidae: Phaneropterinae), PhD thesis, Hacettepe University Institute of Pure and Applied Science Ankara, 387 pp.

Sevgili, H. and Heller, K.G. 2003. A new species of the genus *Isophya* Brunner von Wattenwyl from Turkey (Orthoptera, Tettigoniidae, Phaneropterinae). Tijdschrift voor Entomologie 146: 39-44.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. Biosciences 31: 131-134.

Şişli, M.N. 1996. Çevre Bilim: Ekoloji. Yeni Fersa Matbaacılık, Ankara.

Thomas, J.A., Rose, R.J., Clarke, R.T., Thomas, C.D. and Webb, N.R. 1999. Intraspesific variation in habitat availability among ectothermic animals near their climatic limits and their centers of range. Funct. Ecol. 13: 55S-64S.