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Phenology and factors influencing the abundance of *Lyciasalamandra fazilae* (Amphibia: Salamandridae) in Turkey

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Abstract. Biotic and abiotic factors determine the distribution, population size, abundance and site occurrence of amphibians. To study these variables in relation to the abundance of *Lyciasalamandra fazilae*, the Göcek Lycian salamander, from Turkey, we conducted field studies in southwestern Anatolia. The active season of this species was between November and April. Environmental data were correlated with the species' abundance. Our analyses demonstrated the significant roles of factors such as distance to road, slope, vegetation cover, leaf litter depth, soil moisture, distance to stony area, soil temperature, and altitude. Terrain, slope, leaf litter depth, and vegetation cover were important explanatory factors for the salamanders' abundance. We interpret these findings in terms of amphibian conservation and habitat management programs.

Key words. Abundance, Caudata, conservation, environment, habitat characteristics.

Introduction

An increasing number of studies have examined the proximate environmental influences on the distribution of amphibians (e.g., Hecnar & M'Closkey 1996, 1998, Başkale & Kaya 2009, Sayim et al. 2009). Understanding how species distribution is affected by habitat variables and geographic isolation is one of the main goals of ecologists and conservation biologists (Krebs 1972, Scott et al. 2002). Recently, the ecological value of amphibians has become a research focus because of global amphibian declines and/or extinctions (Schmidt & Pellet 2005, Skei et al. 2006).

Lycian salamanders were first described by Steindachner (1891) from Dodurga (Muğla, Turkey) based upon a species currently known as *Lyciasalamandra luschani*. Further investigations revealed the existence of six species within an East–West gradient of less than 400 km between the cities of Alanya and Marmaris, including some Greek and Turkish islands (Veith et al. 2001, 2008, 2016, Öz et al. 2004, Veith & Steinfartz 2004, Weisrock et al. 2006). The Göcek Lycian salamander, *Lyciasalamandra fazilae* (Basoglu & Atatür, 1974), one of these species, is a local endemic of Turkey and distributed from northwest of Fethiye to the eastern shore of Lake Köyceğiz, and on the islands of Tersane and Domuz (Veith et al. 2001). It is listed as 'Endangered' by the IUCN Red List of Threatened Species (www.iucnredlist.org, last accessed on 4 January 2017) in view of its naturally restricted range and the continued decline of its habitats. In many instances, effective conservation of amphibian populations is limited by the lack of species-specific ecological knowledge. The present study therefore focuses on quantifying the duration of the active season and ecological variables determining the abundance of this salamander.

Material and methods

Our field studies were conducted from 1 November 2013 through 30 May 2014 during day time between 10:00 h and 19:00 h throughout the known range including Tersane and Domuz Islands (Fig. 1). The study sites included two protected areas, Fethiye-Göcek and Köyceğiz Dalyan, near Muğla, which cover an area of 1,266 km². The altitude of the sites ranges from 0 to 1,100 m above sea level.

To identify the duration of the active season of this species, field studies were conducted on the Dalyan population two or three times a week by two researchers. Environmental data were collected using 69 randomly selected 10 × 10-m squares. Air and soil temperatures were recorded to estimate the abundance of salamanders in each square, the surface area was searched throughout the squares at least during three sampling periods (mean: 4.2, range: 3–6) in different weather conditions for 10 min by two researchers, who also overturned all objects that potentially served as cover for the amphibians. We recorded the number of individuals present in each square, and the highest number of individuals recorded during one survey was used for an abundance index. We assessed abundance using the following index: (0) = no individuals; (1) = only one individual present; (2) = two or three individuals present including males, females or juveniles; (3) = more than four individuals present. We identified the sex of the individuals found based on secondary sexual characteristics: in males, the cloacal region is swollen and they possess a hedonic protuberance above the tail base.

To understand the species' habitat selection mechanism, environmental features were recorded: leaf litter depth (cm), vegetation cover (0–25% = 1, 26–50% = 2, 51–75% = 3, 76–100% = 4), terrain slope (0–25% = 1, 26–50% = 2, 51–75% = 3, 76–100% = 4), altitude (m), distance to rocky area (cm), distance to road (m), distance to urban features (m), and soil moisture (%). The distance to rocky areas was measured from the centre of each square to the nearest stone using a Leica laser distance meter with an accuracy of 1 mm and a range of 0–80 m. Leaf litter depth was measured with a flat ruler with an accuracy of 1 mm. This parameter was recorded randomly at least five times in different positions within each square, and the averages of the measurements were calculated for statistical analyses. Vegetation cover was measured using a spherical crown densitometer (Convex Model A) at the midpoint of each square. Altitudes and coordinates of each square were recorded with a Garmin 62S GPS receiver. The coordinate data were transferred to a computer and the distance to the nearest road and to the nearest urban feature of each square were calculated using ArcGIS 10.0 (ESRI). The slope of each square was measured using a clinometer (Haglöf CI Clinometer). For soil moisture, soil samples (ca. 100 g) were weighed on a precision scale in the field, dehumidified in a drying oven at 60°C for 72 h in the lab, and then reweighed. The soil moisture was calculated from the differences between the weights of the respective samples.

In order to assess differences between the sites regarding salamander abundance, data were ranked to satisfy the assumption of a normal distribution and then subjected to ANOVAs. We then applied Pearson's correlation coefficients to examine correlations between all the variables. Multicollinearity issues were addressed by multiple regression analyses. For the correlation analysis, we defined variables with correlation coefficients of > 0.5 as highly correlated pairs. To predict the abundance of the Göcek Ly-

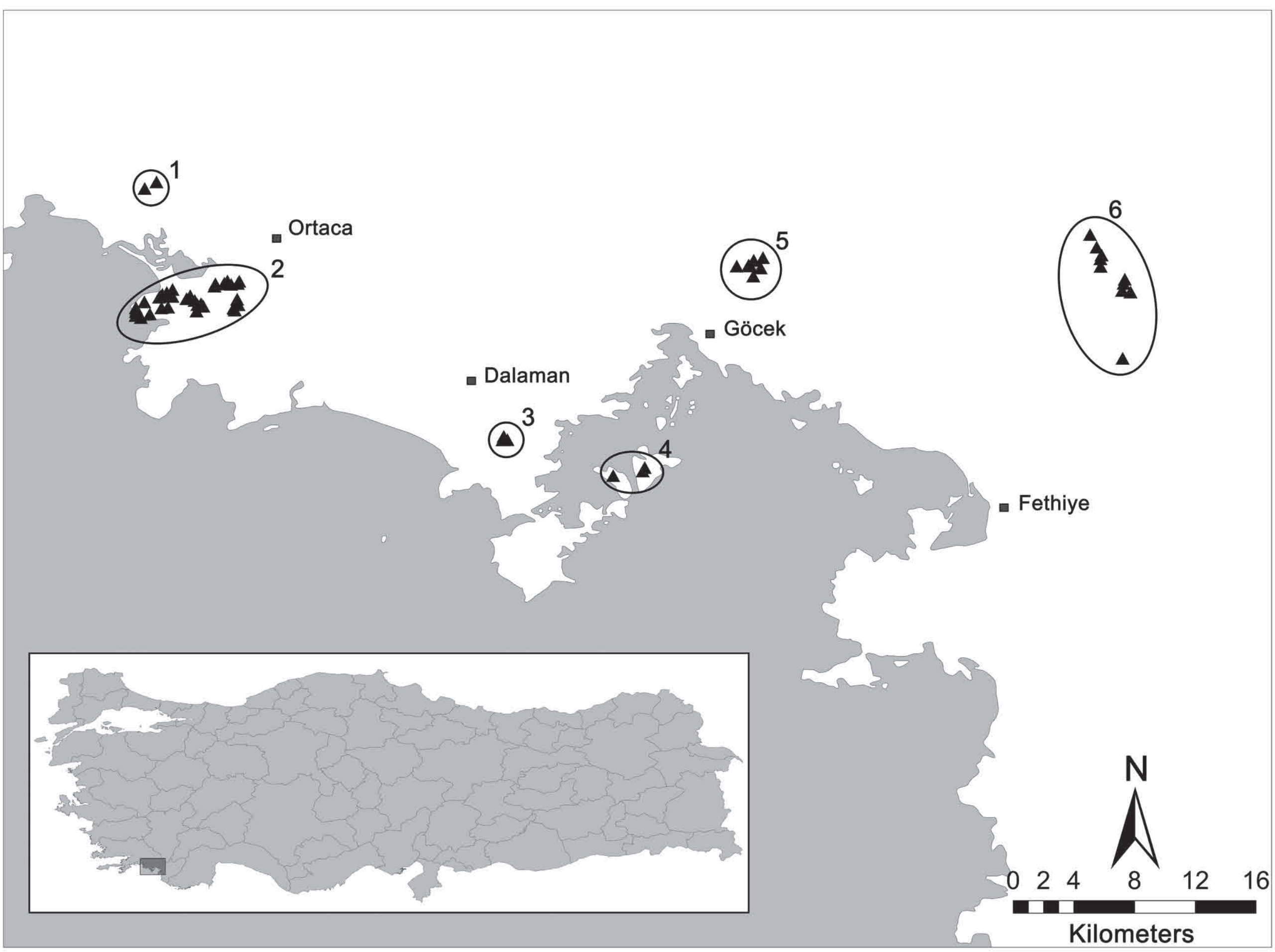

Figure 1. Known distribution of the Göcek Lycian salamander on the Turkish coast, *Lyciasalamandra fazilae* (1 = Ülemez Mountain-Köyceğiz, 2 = Dalyan, 3 = Kapıkargın-Dalaman, 4 = Islands populations, 5 = Gökçeovacık-Göcek, 6 = Üzümlü-Fethiye). The position of the area of the map within Turkey is shown in the inset.

cian salamander based on habitat variables, we used stepwise regression analyses in SPSS for Windows There was a strong correlation between air and soil temperatures (r^2 = 0.842; P < 0.001; N = 110), which is why only soil temperatures were considered in the statistical analyses.

Results

Coordinates, altitudes and the number of observed individuals are given in the Appendix. Individuals of *Lyciasalamandra fazilae* were detected in 54 out of 69 squares (see Appendix), yielding a site occupation of 0.78. A total of 181 individuals (92 females, 73 males, 16 juveniles) were detected during the sampling period. The mean density was 2.62 ± 0.266 individuals (maximum 8 individuals) per square.

The active season of salamanders started on 12 November 2013 and ended on 21 April 2014. Its beginning coincided with the first autumn rains and a sharp decrease in air temperature (< 20°C), and its end with higher air temperatures (22°C and above) (Fig. 2). The highest number of individuals was observed at temperatures from 2 to 18°C (mean 12.99 ± 0.403°C). As can be seen in Figure 2, these temperatures were recorded from early December through mid-February. The frequency of individuals shows no relationship with humidity or the amount of rainfall (P > 0.05).

We mostly recorded the Göcek Lycian salamander in pine forest and open areas covered by grass, karstic limestones, and olive trees. The species was also found in areas close to agricultural fields and near fruit orchards (olive, lemon and pomegranate) and limestone walls. The one-way ANONA revealed significant differences between the species abundance index and certain environmental features such as distance to road, slope, vegetation cover, leaf litter depth, soil moisture, distance to rocky area, soil temperature, and altitude (Table 1).

Our multiple regression analysis built three fitting multiple linear regression models to describe the relationship between abundance and environmental variables. The R-squared statistics indicated that fitting models explained 51.1, 0.58.6 and 62.2% of the variability of environmental variables, respectively. (F = 69.99, 46.66 and 35.66; P < 0.001) (Table 2). According to Model 1, vegetation cover positively affected the abundance of the Göcek Lycian salamander. In addition to vegetation cover, leaf litter depth also affected its abundance (Model 2). Furthermore, Model 3 suggested that leaf litter depth and vegetation cover were positively related to abundance, and there is a negative relationship with slope (Table 2).

Discussion

The active season of *Lyciasalamandra fazilae* extends from mid-November to late April. This observation coincides with the finding by Özeti & Yılmaz (1994), i.e., that the species can be detected in autumn and spring. We observed that temperature is the major factor affecting the initiation and duration of the active season, i.e., we observed the highest number of individuals from early December to

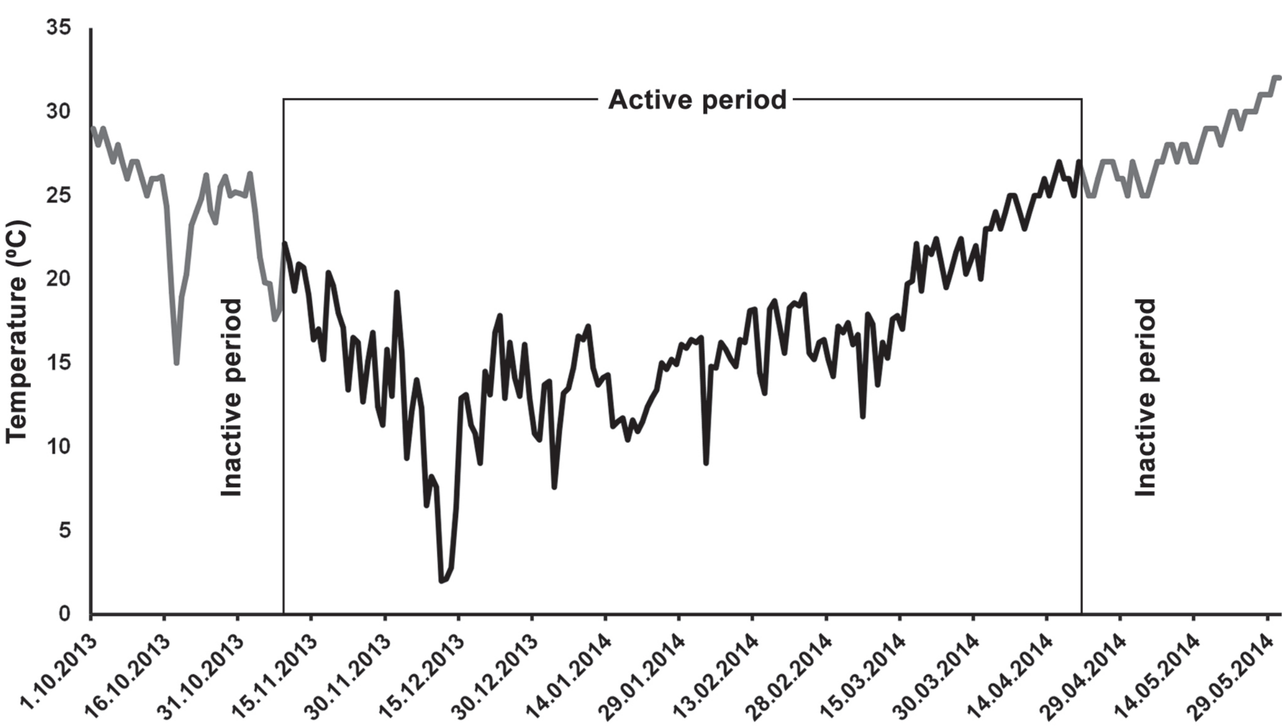

Figure 2. Temporal distribution of the detection of the species relative to air temperature for the Dalyan population.

Table 1. Results of the descriptive statistics and one-way ANOVA of habitat variables related to the abundance of Göcek Lycian salamanders. * $p < 0.05$; ** $p < 0.001$.

Parameters	Abundance index	N	Min.	Max.	Mean	S.E.	df	F	Sig. (2-tailed)
Distance to road (m)	0	15	1	1612	328.40	132.236	3	4.612	0.005*
	1	13	5	9852	2195.69	1101.193			
	2	16	1	1800	188.25	109.212			
	3	25	10	1200	150.68	47.516			
Distance to urban features (m)	0	15	2	3500	1091.27	261.344	3	2.062	0.114
	1	13	10	9980	2533.46	1111.696			
	2	16	10	3516	863.69	280.274			
	3	25	16	2850	1263.88	169.631			
Slope of terrain (°)	0	15	20	70	44.33	3.042	3	26.638	0.000**
	1	13	10	30	22.69	2.308			
	2	16	10	30	17.50	1.936			
	3	25	3	40	18.72	2.030			
Vegetation cover (%)	0	15	10	80	33.33	5.382	3	39.979	0.000**
	1	13	40	90	69.23	4.416			
	2	16	45	90	79.06	2.895			
	3	25	60	100	80.00	1.658			
Leaf litter depth (cm)	0	15	3	20	7.40	1.234	3	12.230	0.000**
	1	13	10	25	15.92	1.546			
	2	16	10	30	19.06	1.894			
	3	25	10	35	21.20	1.739			
Soil moisture (%)	0	15	10	50	17.07	2.510	3	5.373	0.002*
	1	13	19	35	24.85	1.454			
	2	16	15	34	23.44	1.435			
	3	25	20	40	25.68	1.220			
Distance to rocky area (cm)	0	15	8.6	591.2	163.39	54.446	3	9.309	0.000**
	1	13	7.7	55.2	18.43	3.438			
	2	16	5.0	44.2	12.23	2.581			
	3	25	1.4	28.5	8.80	1.249			
Soil Temperature (°C)	0	15	7.9	17.9	13.77	0.837	3	3.995	0.011*
	1	13	8.4	15.2	12.32	0.566			
	2	16	8.4	14.4	11.56	0.414			
	3	25	8.2	14.4	11.31	0.414			
Altitude (m)	0	15	11	1059	417.93	86.904	3	2.755	0.049*
	1	13	3	397	129.08	33.268			
	2	16	5	1036	226.38	75.057			
	3	25	12	1053	324.32	60.503			

mid-February at 2 to 18°C. In temperate zones, amphibian breeding activity depends on rainfall and number of daylight hours, as well as temperature, whereby the response to these factors varies between species (Blankenhorn 1972, Collins & Wilbur 1979, Cree 1989, Fukuyama & Kusano 1992, Stebbins & Cohen 1995). Our results suggest that the amount of rainfall and humidity might not affect activity in the Göcek Lycian salamander. This corresponds to earlier findings that temperature plays a major role in the regulation of amphibian reproductive cycles, while rainfall has an additional trigger effect, e.g., to reproductive behaviour (Duellman & Trueb 1994, Stebbins & Cohen 1995, Camargo et al. 2005).

The importance of environmental factors in amphibian ecology is well known (e.g., Hecnar & M'Closkey 1998, Schmidt & Pellet 2005). Amphibians are highly susceptible to any change in their habitat because they possess a highly permeable skin and spend their lives both in terrestrial and freshwater ecosystems (Barinaga 1990, Blaustein & Wake 1990, 1995, Phillips, 1990, Blaustein 1994, Alford & Richards 1999). Although, environmental conditions considerably affect amphibian richness,

Table 2. Factors affecting the relative abundance of Göcek Lycian salamanders: Model summary (A) and coefficients (B) of the stepwise regression analysis. * $p < 0.05$; ** $p < 0.001$.

(A)		Estimates			ANOVA	
Model No.	R^2	Adjusted R^2	S. E. of the estimate	df	F	Sign.
1	0.511	0.504	0.825	1	69.999	0.000**
2	0.586	0.573	0.765	2	46.663	0.000**
3	0.622	0.605	0.737	3	35.663	0.000**

(B) Model No.	Parameters	Non-standardized coefficients B	S. E.	Standardized coefficients Beta	t	Sign.
1	Constant	-0.71	0.309		-2.293	0.025
	Vegetation cover	0.04	0.004	0.715	8.367	0.000**
2	Constant	-0.91	0.292		-3.101	0.003**
	Vegetation cover	0.03	0.005	0.572	6.403	0.000**
	Leaf litter depth	0.04	0.012	0.308	3.452	0.001*
3	Constant	0.15	0.507		0.295	0.769
	Vegetation cover	0.02	0.005	0.436	4.289	0.000**
	Leaf litter depth	0.04	0.012	0.27	3.089	0.003*
	Slope	-0.02	0.008	-0.247	-2.499	0.015*

distribution, population structure, abundance, site occurrence, and habitat preferences (Duellman & Trueb 1994, Stebbins & Cohen 1995), these factors have often been somewhat neglected and/or the described characteristics have not been systematically recorded. The current information on the habitat characteristics of Lycian salamanders broadly covers all species in this genus and is therefore considered more generally applicable to Lycian salamanders (cf. Özeti & Yilmaz 1994). Accordingly, *Lyciasalamandra* species are terrestrial, inhabit rocky limestone areas usually in pine forests and maquis, sometimes around single-standing pines and olive trees, sometimes in deciduous forest dominated by oaks and juniper, and occasionally occur in accumulations of rocks or on hillsides without vegetation (e.g., Başoğlu & Özeti 1973, Baran & Atatür 1998, Veith et al. 2001). The vertical distribution of the species is known to range from 25 to 1,400 m above sea level where the mean annual rainfall may be as little as less than 1,000 mm (Veith et al. 2001, Yildiz & Akman 2012). In our study on the abundance of *L. fazilae*, we found a significant effect of factors such as distance to road, terrain slope, vegetation cover, leaf litter depth, soil moisture, distance to rocky area, soil temperature, and altitude. Knutson et al. (1999) addressed the question of which land use – agriculturally used or urbanized – has the greater impact on amphibian species richness. These authors noted a positive effect of agriculture on amphibian species richness. Many researchers, however, have found that agricultural and urban land cover have negative effects on amphibian species richness (e.g., Richter & Azous 1995, Bonin et al. 1997, Lehtinen et al. 1999, Atauri & De Lucio 2001). Our study shows that the distance to urban features did not affect the presence of the Göcek Lycian salamander. Accordingly, we detected individuals close to both agricultural and urban areas. We did, however, find a negative relationship between abundance and distance to urban features: salamander abundance decreased close to villages (up to 100 m).

Descriptive statistics revealed that *L. fazilae* prefers lower altitudes, greater vegetation cover, a greater leaf litter depth, shallow slopes, and greater soil moisture. This habitat type provides ample shelter during times of inactivity and when hiding from predators; it also helps to maintain the moisture levels necessary for salamander movement. Furthermore, a multiple regression analysis implies that vegetation cover and leaf litter depth are explanatory variables, and have positive effects on abundance. These two factors provide consistently moist microhabitats. The skin of amphibians is a major organ for respiratory gas exchange and must be kept moist (Pough et al. 2012). Evaporation from the skin will limit the activity of most amphibians. In this case, moist microenvironments are important for reducing the rate of evaporative water loss from the skin in terrestrial amphibians.

In addition, multiple regression analysis also showed that the other most explanatory environmental factor is slope, with this amphibian species preferring flatter over steeper slopes (range = 3–40°; mean = 19.3 ± 9.13°). Ramotnik & Scott (1988) noted that steep slope and high altitude were the most useful variables for predicting the occurrence of Jemez Mountains salamanders and Sacramento Mountain salamanders. Also, adult yellow-blotched salamanders preferred slopes of 30.4°, whereas juveniles preferred slopes of 22.4° (Germano 2006).

Understanding the role of land use in determining species presence and abundance patterns is fundamental to designing efficient conservation strategies (Bulger et al. 2003). Consequently, many studies have focused on identifying the cause or causes of amphibian declines in natural and semi-natural environments; some studies have been conducted in the laboratory to explain the effects of causative factors (e.g., Barinaga 1990, Blaustein & Wake 1990, Wyman 1990, Drost & Fellers 1996, Fisher & Shaffer 1996, Hecnar & M'Closkey 1996, Webb & Joss 1997, Alford & Richards 1999, Gillespie & Hero 1999, Gardner 2001). Nevertheless, conservation strategies for amphibians restricted to aquatic habitats are of limited use if the adjacent terrestrial habitats are destroyed or become inaccessible following human activities (Semlitsch 1998). Although the restricted range of the Göcek Lycian salamander incorporates two protected areas, the major threat to this species is habitat loss caused by forest fires and unchecked urbanisation. These two factors will gradually destroy salamander habitats. Moreover, over-collection for scientific and hobby purposes, and road traffic on rainy days will lead to decreasing natural populations. Within this context, we have urged authorities (The Ministry of Environment and Urban Planning and Water Affairs and Ministry of Forestry and Water Affairs, General Directorate of Nature Conservation and Natural Parks) to take additional legal steps to protect this species. Our data are also an important step forward in better defining and specifically protecting the critical habitat of the species, both inside and outside the currently protected areas. Finally, to help prevent future amphibian declines, we have initiated an education programme for land managers, land owners, and local residents that emphasizes the importance of amphibians and how to protect them using brochures and talks with local people and tourists.

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Appendix

Details of square-wise field surveys: Coordinates, altitudes and numbers of observed individuals.

Locality	Square No.	Latitude	Longitude	Altitude (m above sea level)	Number of observed individuals
Dalyan population	1	36.774190°	28.630847°	11	0
Dalyan population	2	36.775049°	28.631267°	3	1
Dalyan population	3	36.774136°	28.631779°	38	3
Dalyan population	4	36.774321°	28.631596°	33	1
Dalyan population	5	36.773994°	28.630440°	16	3
Dalyan population	6	36.773995°	28.630172°	12	1
Dalyan population	7	36.773357°	28.629320°	5	2
Dalyan population	8	36.773782°	28.629957°	12	4
Dalyan population	9	36.775038°	28.636436°	32	8
Dalyan population	10	36.762500°	28.615400°	21	5
Dalyan population	11	36.765806°	28.615880°	73	8
Dalyan population	12	36.763433°	28.623800°	133	1
Dalyan population	13	36.767050°	28.630700°	397	0
Dalyan population	14	36.761300°	28.618483°	84	4
Dalyan population	15	36.764733°	28.615633°	47	3
Dalyan population	16	36.767067°	28.615517°	67	0
Dalyan population	17	36.767467°	28.634617°	502	0
Dalyan population	18	36.770550°	28.620533°	107	0
Dalyan population	19	36.773833°	28.637200°	142	4
Dalyan population	20	36.776200°	28.633833°	10	2
Dalyan population	21	36.777967°	28.637250°	9	3
Dalyan population	22	36.773850°	28.637133°	139	2
Dalyan population	23	36.774217°	28.647700°	182	4
Dalyan population	24	36.772467°	28.645533°	240	5
Dalyan population	25	36.771450°	28.650367°	237	4
Dalyan population	26	36.769367°	28.653983°	334	5
Dalyan population	27	36.768000°	28.653767°	326	3
Dalyan population	28	36.769067°	28.654517°	346	1
Dalyan population	29	36.768033°	28.655517°	351	4
Dalyan population	30	36.768967°	28.652000°	318	0
Dalyan population	31	36.765117°	28.651500°	263	0
Dalyan population	32	36.779917°	28.662183°	151	3
Dalyan population	33	36.781300°	28.662633°	101	0
Dalyan population	34	36.782983°	28.669750°	51	0
Dalyan population	35	36.781167°	28.669767°	95	1
Dalyan population	36	36.781700°	28.667917°	97	2
Dalyan population	37	36.780967°	28.671983°	101	1
Dalyan population	38	36.781567°	28.675933°	153	3
Dalyan population	39	36.782833°	28.676817°	156	1
Dalyan population	40	36.772183°	28.675550°	170	2
Dalyan population	41	36.767100°	28.673483°	302	4
Dalyan population	42	36.766567°	28.673783°	290	8
Dalyan population	43	36.765733°	28.674117°	277	5
Dalyan population	44	36.768909°	28.676365°	217	8
Üzümlü-Fethiye population	45	36.791617°	29.187228°	1033	5
Üzümlü-Fethiye population	46	36.796117°	29.187133°	1059	0
Üzümlü-Fethiye population	47	36.781600°	29.200900°	810	6

Locality	Square No.	Latitude	Longitude	Altitude (m above sea level)	Number of observed individuals
Üzümlü-Fethiye population	48	36.803017°	29.184867°	1036	3
Üzümlü-Fethiye population	49	36.776400°	29.204950°	653	0
Üzümlü-Fethiye population	50	36.777400°	29.199983°	804	0
Üzümlü-Fethiye population	51	36.810500°	29.180983°	964	0
Üzümlü-Fethiye population	52	36.737150°	29.200283°	493	4
Üzümlü-Fethiye population	53	36.784017°	29.201550°	751	3
Üzümlü-Fethiye population	54	36.798367°	29.187783°	1053	4
Tersane Island population	55	36.672400°	28.917067°	62	1
Tersane Island population	56	36.670333°	28.915883°	125	1
Domuz Island population	57	36.667617°	28.898383°	49	1
Kapıkargın-Dalaman population	58	36.690900°	28.833517°	55	4
Kapıkargın-Dalaman population	59	36.688833°	28.832867°	49	5
Kapıkargın-Dalaman population	60	36.688900°	28.835733°	121	3
Gökçeovacık-Göcek population	61	36.791800°	28.971583°	397	1
Gökçeovacık-Göcek population	62	36.791900°	28.979667°	525	4
Gökçeovacık-Göcek population	63	36.792417°	28.978667°	511	0
Gökçeovacık-Göcek population	64	36.785883°	28.981433°	461	0
Gökçeovacık-Göcek population	65	36.790700°	28.985783°	553	3
Gökçeovacık-Göcek population	66	36.795250°	28.981667°	582	5
Gökçeovacık-Göcek population	67	36.796800°	28.987133°	641	4
Ülemez Mountain-Köyceğiz population	68	36.841667°	28.627733°	73	4
Ülemez Mountain-Köyceğiz population	69	36.837833°	28.620750°	166	1