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Richness and Distribution of Amphibian Species in Relation to Ecological Variables in Western Aegean Region of Turkey

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Abstract

Ecological factors, such as water chemistry variables, regional landscape variables, occurrence of predators, have considerable effects on amphibian distribution and richness. These variables in relation to amphibian species-richness and distribution were investigated by field work studies between February 2006 and August 2008 in freshwater ponds and lakes of Aegean Region, Turkey. Seven amphibian species were observed at the study sites, with mean species richness 4.29±0.34 species per habitat (range= 2 to 6). We used Pearson's correlation coefficients to examine correlations between the variables and to reduce the number of explanatory factors. The data were submitted to a multiple regression analysis at water chemistry and microhabitat scales in order to investigate the most important explanatory factors influencing amphibian species richness and their distribution. According to the results of statistical analysis six regional landscape and nine water chemistry variables were found to be important explanatory factors for amphibian species richness in this region. These results were evaluated and interpreted in term of amphibian conservation and habitat management programs.

Key words: Amphibian species richness, naïve proportion of site occupied, water chemistry, explanatory factors.

Ege Bölgesi'nin (Türkiye) Batısındaki Amfibi Tür Zenginliği ve Dağılışlarının Ekolojik Değişkenlerle İlişkileri

Özet

Suyun kimyasal değişkenleri, bölgesel habitat değişkenleri ve predator canlı varlığı gibi ekolojik faktörlerin amfibi tür zenginliği ve dağılışları üzerinde dikkate değer bir etkisi vardır. Amfibi tür zenginliği ve dağılışları ile ilişkili bu değişkenler Ege Bölgesi'nde yer alan tatlı su göl ve göletlerinde Şubat 2006-Ağustos 2008 tarihleri arasında gerçekleşen arazi çalışmaları ile araştırılmıştır. Çalışma alanları içerisinde yedi amfibi türü tespit edilmiş ve ortalama tür zenginliği her bir habitat için 4,29±0.34 (min=2; maks=6) olarak hesaplanmıştır. Değişkenler arasındaki korelasyonları test etmek ve tanımlayıcı faktör sayısını azaltmak için biz Pearson korelasyon katsayılarını kullandık. Amfibi tür zenginliğine ve dağılışlarına etki eden en önemli tanımlayıcı faktörleri bulmak için elde edilen su kimyası ve mikrohabitat verileri çok yönlü regresyon analizine tabi tutulmuştur. İstatistiksel analiz sonuçlarına göre, bölgesel habitat değişkenlerinden altısının ve suyun kimyasal değişkenlerinden dokuzunun bu bölgedeki amfibi tür zenginliği için önemli tanımlayıcı faktör oldukları tespit edilmiştir. Bu sonuçlar, amfibilerin korunması ve habitat yönetim programları açısından değerlendirilmiş ve yorumlanmıştır.

Anahtar Kelimeler: Amfibi tür zenginliği, işgal edilen alanların ham oranı, su kimyası, tanımlayıcı faktör.

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INTRODUCTION

Understanding of species distribution which is affected by habitat variables and geographic isolation is one of the main goals to an ecologist and conservation biologist (Kreps 1972, Scott et al. 2002). The awareness of amphibian ecology has much increased since the knowledge on the global amphibian decline crisis (Schmidt and Pellet 2005, Skei et al. 2006). Amphibian distribution, population size, abundance, site occurrence, diversity, and their growth rate have considerably affected by environmental conditions. Because

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amphibians have intimate contact with many components of the environment due to their highly permeable skins, they are considered to be valuable gauges of environmental health or stress (Barinaga 1990, Blaustein 1994, Blaustein and Wake 1990, 1995, Phillips 1990). Amphibians are also functionally important for nutrient cycling and ecosystem energy-flow in most freshwater and terrestrial habitats (Beebee 1996, Gehlbach and Kennedy 1978, Werner and McCune 1979). Since they are primary consumers as larvae (Alford 1999, Seale 1980), and primary predators as adults (Blaustein and Wake 1990, Blaustein et al. 1994), as well as being preys for other invertebrates and vertebrates (Blaustein and Wake 1990, Duellman and Trueb 1994). On account of the fundamental importance of amphibians to many ecosystems, global decline of amphibians could be detrimental to the maintenance and sustainability of ecosystems at a local and global scale.

Many ecologists have emphasized the importance of amphibian ecology (Hecnar and M'Closkey 1998, Schmidt and Pellet 2005), but we have little ecological information about many amphibian species in many parts of the world. Moreover, many studies have focused on determining the cause of amphibian declines in natural environments as well as in laboratory conditions (Alford and Richards 1999, Barinaga 1990, Blaustein and Wake 1990, Fisher and Shaffer 1996, Gardner 2001, Gillespie and Hero 1999, Wyman 1990). Nevertheless, there are very few ecological data pertaining to the amphibian species in western Aegean Region which are cited in faunistical studies (Kumlutaş et al. 2000, 2004).

The present study is focused on amphibian species richness and distribution in western Aegean Region of Turkey. We also explored which explanatory variables -regional landscape and water chemistry- were associated with amphibian species richness and site occurrences.

MATERIAL AND METHODS

Study area

Western Aegean Region is located in the west part of the country, extended towards the Aegean Sea. A few natural lakes and ponds are located in this region. Agricultural activities are the main income for the local inhabitants thus artificial dams have been constructed recently. Coast of the western Aegean Region has typical Mediterranean climate which extends towards the eastern parts due to the vertical location of the mountain ranges to the coast.

We studied 41 sites from 14 natural amphibian localities including seven lakes, two temporary rivers and five ponds. Distribution of these localities in western Aegean region was given Fig. 1. Four of them (only ponds) are man-made habitats but they have been constructed approximately over 150 years ago so we assumed that they are natural.

Field and laboratory works

Surveys were conducted after 2100 h for ~ 90 min, and each site was visited at least 9 times with 2-5 people during the breeding seasons of 2006-2008. For detecting presence of species, we used call surveys and visual encounter survey, and all species were recorded as present (1) or absent (0).

Ecological variables were selected according to regional landscape features and previously published works (Bain 1999, Hecnar and M'Closkey 1996, 1998, Krep 1989, McDiarmid 1994, Skei et al 2006). For each locality the following ecological variables were recorded. Fish presence, introduced fish presence, habitat type (with four scores: lake=1; pond=2; stream=3; puddle=4) emergent vegetation presence, submerged vegetation presence, vegetation cover rate (with five scores: no vegetation=0; 0-25 percent=1; 26-50 percent=2; 51-75 percent=3; and 76-100 percent=4); substrate type (with three scores: mire=1; mud= 2; sandy soil=3), water permanency (with two scores: permanent=1; semi-permanent= 2), maximum depth of water (with three scores: 0-1m=1; 1-2m= 2; 2m<=3), forest edge presence within 30m, grass presence surrounding the water body, cane presence surrounding the water body and canopy presence surrounding the water body were recorded as a landscape regional variables. The presence or absence of fish species was either determined visually by scanning the surface of the ponds and lakes or via captures of fishing activities in the day time. Water samples were collected from approximately 50 cm distance to shore, 10 cm below the surface. Electrical conductivity, pH, dissolved oxygen (DO) and salinity were measured in the field using Hach Portable pH/Conductivity/Dissolved Oxygen Meter, and air temperature were measured with a digital thermometer. Turbidity, water colour and organic matter were analyzed in Tahtalı İZSU Laboratory. Total hardness, iron, ammonium, magnesium, calcium, manganese, nitrite, nitrate and

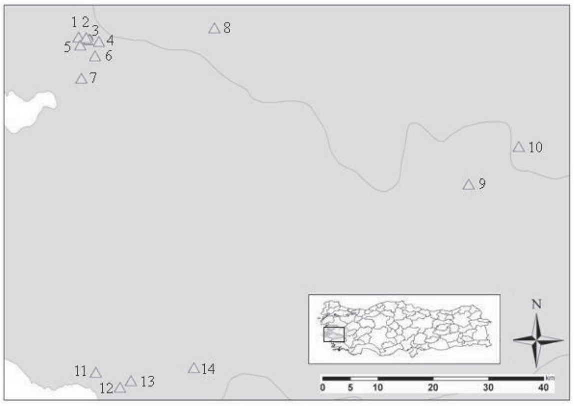

Fig 1. Distribution of studied localities in western Aegean Region; 1) Karagöl, 2) Sarnıç, 3) Göztepesi, 4) Soğanharımı, 5) İkizgöller, 6) Göldağ, 7) Kocaçay, 8) Sülüklü, 9) Gölcük, 10) Bozdağ, 11) Klaros, 12) Gebekirse, 13) Barutçu, 14) Belevi

chlorine were measured within 48 h in the laboratory using DR 2800 Portable Spectrophotometer, following the manufacturer's procedures.

Statistical analysis

Naive proportion of site occupied (naive ψ) belonging to each species were calculated as number of sites where the target species detected / total number of sites. Correlations between all the variables were tested by Pearson's correlation coefficients, and the problem of multicolinearity in multiple regression analysis. For the correlation analysis, we defined as highly correlated pairs of variables with correlation coefficients of <0.5. Thus, to avoid multicolinearity among the explanatory variables in the multiple regression analyses, as well as to reduce the number of explanatory factors. Then, to identify the most important explanatory factors related to amphibian species richness, we used Multiple Regression Analysis with backward selection using Statgraphics V. 5.0 Software.

RESULTS

Seven amphibian species were detected in study sites with mean species richness 4.3±0.34 species per site (range= 2 to 6). Naive Proportion of site occupied (naive ψ) and species distributions on localities are shown in Table 1. The difference between naive ψ varied considerably among species after accounting for species occurrence. According to our results, *Pelophylax bedriagae* was detected on 37 of 41 sites, *Hyla arborea* was detected on 17 of 41 sites, *Bufo bufo* and *Pseudepidalea viridis* were detected 21 of 41 sites, *Rana macrocnemis* was detected 3 of 41 sites and *Lissotriton vulgaris* and *Triturus karelinii* were detected on 13 of 41 sites.

The water bodies in the area are slightly alkaline and have a low ionic content. Descriptive statistics of water chemistry variables were given in Table 2. Most of the water bodies are surrounded by forests of *Pinus brutia* and *Quercus* sp. Average air temperature was 17°C (range 0-28) during field studies.

The Multiple Regression Analysis showed the results of fitting a multiple linear regression model to describe the relationship between amphibian species richness and 30 independent variables. The R-Squared statistics indicated that the model as fitted explains 75.32% of the variability for regional landscape variables (14 independent variables, F=16,78; P<0,01) and 76.94% of variability for water chemistry variables (16 independent variables, F=8.90; P<0.01) in amphibian species richness. According to Multiple Regression Analysis, while introduced fish, habitat type and altitude, DO, iron, nitrite, chlorine and salinity were negatively related to the amphibian species richness, there are positive relationships with grass, canopy and emergent vegetation, water colour, manganese, nitrate and total hardness (Table 3).

DISCUSSION

Although, 8 amphibian species were indicated in the literatures (Baran and Atatür 1998, Çaydam 1974, Özeti and Yılmaz 1994), we detected 7 amphibian species (5 anuran species and 2 urodelan species) in the study sites. Only Syrian spadefoot (*Pelobates syriacus*) from reference species was not observed during sampling seasons in the study sites by reason of its fossorial habit or being a rare species in this region. According to naive ψ values, while, *P. bedriagae* is a common species in this region, *H. arborea*, *P. viridis* and *B. bufo* can be observed in this region at approximately 50% of sites. In addition to this, *L. vulgaris*, *T. karelinii* and *R. macrocnemis* are rare species in this region. Site occupancy estimates were calculated only for *H. arborea* of these species from 27 sites in western Switzerland by Pellet and Schmidt (2005), and in their study the naive ψ values were higher than our estimates (0.667).

Characteristics such as water colour, turbidity, pH, density and surrounding vegetation cover, permanency and presence of tadpole predators can influence anuran breeding site choice (Evans et al.

Table 1. Distribution of amphibian species and naive ψ on study sites.

Locality	*P. bedriagae*	*H. arborea*	*P. viridis*	*B. bufo*	*R. macrocnemis*	*L. vulgaris*	*T. karelinii*
Karagöl	+	+	+	+		+	+
Sülüklü	+		+	+		+	+
İkizgöller	+	+	+	+		+	+
Gölcük	+	+	+	+		+	+
Belevi	+	+	+	+			
Gebekirse	+	+	+	+			
Barutçu	+	+	+	+			
Soğanharımı	+					+	+
Göldağ	+					+	+
Göztepesi	+		+	+		+	+
Sarnıç	+					+	+
Bozdağ				+	+		
Kocaçay	+	+	+				
Klaros	+	+	+			+	+
naive ψ	0.9024	0.4146	0.5122	0.5122	0.0732	0.31707	0.31707

Table 2. Descriptive statistics of water chemistry variables.

	N	Min.	Max.	Mean	Std. Error	Std. Deviation
DO (%)	41	4.6	10.9	6.543	0.211	1.351
Turbidity	39	1.5	22.8	5.982	0.740	4.624
Colour (mg l^{-1} Pt)	41	19	288	76.15	8.420	53.920
Ph	41	7.0	9.6	7.848	0.099	0.632
Iron (mg l^{-1})	41	0.01	4.40	0.4756	0.137	0.878
Manganese(mg l^{-1})	41	0.001	0.73	0.23527	0.039	0.250
Nitrite (mg l^{-1})	41	0.001	0.26	0.016	0.007	0.042
Nitrate(mg l^{-1})	41	0	5	0.59	0.170	1.080
Ammonium(mg l^{-1})	41	0	0.55	0.1126	0.021	0.136
Organic M.	37	0.1	9.6	2.941	0.450	2.740
Calcium (mg l^{-1})	41	5.5	66.8	28.36	2.418	15.485
Magnesium(mg l^{-1})	41	4.08	63.66	15.6663	1.858	11.896
Cl(mg l^{-1})	39	9.0	282.0	34.331	9.053	56.536
T. hardness(°dH)	41	4.6	69.3	15.962	1.940	12.424
Cond. (µScm- 1)	38	34	947	356.73	42.900	253.820
Salinity (%)	41	0.1	3.9	0.524	0.149	0.952

Table 3. Results of Multiple Regression Analysis for variables effected to amphibian species richness.

	Parameter	Regression coefficient	Standard Error	T Statistic	P-Value
Regional landscape variables	Constant	3.017	0.419	7.196	0.0000
	Introduced fish	-0.457	0.219	-2.092	0.0442
	Habitat type	-0.264	0.121	-2.184	0.0362
	Grass	0.792	0.288	2.756	0.0095
	Canopy	1.075	0.206	5.225	0.0000
	Emergent vegetation	0.644	0.250	2.582	0.0144
	Altitude	-0.0008	0.0002	-3.563	0.0011
Water chemistry variables	Constant	2.156	0.897	2.405	0.0242
	DO	-0.230	0.107	-2.145	0.0423
	Water colour	0.010	0.003	3.394	0.0024
	Iron	-0.969	0.152	-6.372	0.0000
	Manganese	3.152	0.666	4.735	0.0001
	Nitrite	-49.687	15.813	-3.142	0.0044
	Nitrate	0.620	0.146	4.239	0.0003
	Chlorine	-0.122	0.020	-6.231	0.0000
	T. hardness	0.373	0.055	6.781	0.0000
	Salinity	-1.738	0.290	-5.988	0.0000

1996, Gascon 1991, Spieler and Linsenmair 1997). Amphibian species are sensitive to their aquatic habitat perturbation (Blaustein et al. 1994, Welsh and Ollivier 1998) and pollutants have been shown to be involved in decreasing of some species (Carey and Bryant 1995). This might explain the negative effect of high concentrations of irons, chlorines and nitrogen components on the species richness. Our results also indicate that high concentration of irons, chlorines and nitrites negatively affected to amphibian species richness (Table 3). Recently, the number of studies of interaction between ecological variables and amphibian populations has been increased (Gagne and Fahrig 2007, Lips et al. 2001, Loman and Lardner 2006, Pavignano et al. 1990). Effects of some of these variables have been investigated in detail. Many chemical products used in agriculture and industry pollute aquatic habitats, causing potentially severe damage to ecosystems. For example, the increase in concentration of nitrate in surface water on agricultural land due to numerous sources may be hazardous to many species of fish, wildlife, and even humans. Nitrogen pollution can alter the primary producers and microbial communities of aquatic ecosystems (Carpenter et al., 1998; Fenn et al., 2003). Particularly, nitrates are toxic to amphibians (Marco et al. 1999) and these and other components of nitrogen may reduce of number of amphibian species when reach higher concentrations in a habitat. The concentration of nitrate, or other compounds, necessary to induce negative effects can vary between species (Hecnar 1995), and even between the populations of the same species (Johansson et al. 2000). Also, increased mortality with exposure to nitrate concentrations were found in *R. catesbeiana*, (Smith et al. 2005), *R. clamitans*, (Smith et al. 2005) and *R. pretiosa*, (Marco et al. 1999). The levels of dissolved gases (oxygen, carbon dioxide, nitrogen, and hydrogen sulfide) are important, and aquatic environments should not contain contaminants such as heavy metals, chlorine and chloramines, or other chemicals (Cassidy 2006). Wassersug and Seibert (1975) explained that there is little or no correlation between DO concentration and behavior of most stages of amphibian larvae until the DO concentration drops below a critical level. Our results indicated that decreasing DO showed a negative effect on species richness (Table 3).

Salt concentration of ponds, lakes and wetlands is a global problem that poses a great threat to most freshwater biodiversity, including amphibians. Smith et al. (2007) found that species occurrence was high approximately at 6% seawater and then dropped rapidly for six tadpole species. Also, it was claimed that high concentration of salt negatively affected hatching success of *Buergeria japonica* eggs (Haramura 2007). Our results supported as in previous studies that high concentrations of salt have decreased the amphibian species richness.

Horne and Dunson (1995) and Blaustein et al. (2003) implied that total hardness, pH and heavy metals such as, manganese (Mn) are important determinants of toxicity, and may adversely affect amphibian populations. According to our results, total hardness and manganese (within acceptable limits) were found as explanatory factors of amphibian habitat selection and these factors showed a positive effect on species richness (Table 3). However, results of our study did not support pH effect on amphibian species richness because a minimum of two species found to inhabit any habitat, and pH values were close to each other (mean=7.8; range 7.0-9.6).

On the other hand, as regional landscape variables, habitat type, introduced fish and altitude also show negative effect to amphibian species richness in this study (Table 3). The species richness has decreased in higher altitudes and presence of introduced fish. Also, habitat type, one of the important explanatory factors of species richness, because, species richness was found to be high in lakes and ponds compared to streams and puddles. Altitudinal limits of our species were described by Özeti and Yılmaz (1994) and Baran and Atatür (1998). Recently, introduced fish species have became a global problem in the freshwater ecosystems. Many studies explained their roles of predation, competition and species decline with native species on habitats (Gillespie 2001, Kats and Ferrer 2003, Lawyer et al. 1999, Moore et al. 2004).

According to our results, variables of vegetation showed positive relationships with amphibian species richness. Particularly *H. arborea*, *L. vulgaris* and *T. karelinii* were detected in habitats with luxuriant vegetation, which provides good oviposition sites, shelter from predators, and source of food (Giacoma 1988). Clearly, there is no single component of water chemistry and regional landscape variables that can be an explanatory factor of ponds, lakes or streams from the viewpoint of amphibian species richness.

Our results support the possibility that the amphibians could be useful indicator species for changes in wetland ecology. Accordingly, monitoring amphibian communities in areas may provide valuable information on the extent of the problem and on the ecological changes. The results reported here indicate that six regional landscape and nine water chemistry variables can be explanatory factors for amphibian species richness at western Aegean Region. Future studies are needed to better understand the processes that underlie the patterns reported here and to directly examine changes in amphibian diversity in freshwater ecosystems.

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