Review of Hydrobiology
www.reviewofhydrobiology.com
2: 73-80 (2008)

Prediction of global climate change impact on structure of aquatic insect assemblages by using species optimum and tolerance values of temperature

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ABSTRACT

1. There is increasingly clear evidence of climate change impacts on the aquatic ecosystems of Turkey. There appeared to be strong warming trends and decrease in mean flow rate of rivers located in Mediterranean climate regions.
2. On the basis of results obtained through scenarios, for the year 2030, it can be concluded that an increase of 1.2°C in mean annual temperature and a decrease of 5% in mean annual precipitation may be expected. In 2050, the mean annual temperature increases around 2°C, and mean annual precipitation decreases around 10% in Büyük Menderes River basin.
3. Chemical variables change and interact with temperature. Warmer water can lead to lower dissolved oxygen concentrations as well as higher potential evaporation, thus deteriorating river water quality and quantity.
4. The using of aquatic insects as indicators of climate change impacts on running waters provides valuable information for habitat degradation.
5. Prediction of impact of future climate change on aquatic insect distribution and community structure in a Mediterranean running water ecosystem, Büyük Menderes River by using values of species optima and of species tolerance levels to temperature increase was given.
6. On the basis of results obtained through this research, for the year 2030 the mean annual temperature increases around 1.2°C. Therefore it can be concluded that the selected taxa had tolerance value lower than 1.2°C will be eliminated. In 2050 the mean annual temperature increases around 2°C. Therefore the selected taxa had tolerance value lower than 2°C will be eliminated

KEY WORDS: Aquatic insects, benthic macroinvertebrates, Büyük Menderes River, global climate change, Mediterranean climate, species optimum, species tolerance, temperature, Turkey.

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Global iklim değişikliğinin sucul böcek topluluklarının yapısı üzerine etkisinin türlerin optimum ve tolerans sıcaklık değerlerinin kullanılması ile öngörülmesi

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ÖZ

1. Türkiye'de sucul ekosistemler üzerine iklim değişikliğinin etkisi açıklıkla görülmektedir. Akdeniz iklim bölgelerindeki nehirlerde kuvvetli bir ısınma eğilimi ve ortalama akış hızlarında düşüş görülmektedir.
2. İklim değişikliği senaryolarına göre Büyük Menderes Nehri havzasında, ortalama yıllık sıcaklık değerlerinde 2030 yılında 1.2°C'lik artış ve yıllık ortalama yağışta %5'lik bir azalma beklenmektedir. Gene ortalama yıllık sıcaklık değerlerinde 2050 yılında 2°C civarında artış ve yıllık ortalama yağışta %10 civarında bir düşüş beklenmektedir.
3. Kimyasal değişkenler, sıcaklıkla etkilenir ve değişir. Sıcak sularda oksijen konsantrasyonunun azalması, buharlaşmada artışa neden olur. Böylece nehrin su kalitesinde ve miktarında düşüş ortaya çıkar.
4. İklim değişikliğinin, akarsular üzerine etkilerini belirlemek için sucul böceklerin gösterge olarak kullanılmaları, akarsu habitatlarının bozulmaları ile ilgili değerli bilgiler sağlar.
5. Gelecekteki iklim değişikliğinin, bir Akdeniz akarsu ekosistemi olan Büyük Menderes Nehri'nde sucul böcek türlerinin dağılımı ve komünite yapısı üzerine etkisi, sıcaklık artışı ile ilgili optimum ve tolerans değerleri kullanılarak öngörülmüştür.
6. Bu araştırma sonuçlarına göre, 2030 yılında yıllık ortalama sıcaklık artışı 1.2°C civarında olacaktır. Bu nedenle, 2030 yılında bu çalışmada ele alınmış olan taksonlardan tolerans değeri 1.2°C den düşük olanlar ortamdan eleneceklerdir. Yıllık ortalama sıcaklık artışı 2050 yılında 2°C civarında olacaktır. Bu nedenle, 2030 yılında bu çalışmada ele alınmış olan taksonlardan tolerans değeri 2°C'den düşük olanlar ortamdan eleneceklerdir.

ANAHTAR KELİMELER: Akdeniz iklimi, bentik makro omurgasızlar, Büyük Menderes Nehri, küresel iklim değişikliği, sıcaklık, Türkiye, tür optimumu, tür toleransı.

INTRODUCTION

According to IPCC (Intergovernmental Panel on Climate Change) emission scenarios, global average temperature are projected to rise by 1.4°C to 5.8°C between 1990 and 2100 (IPCC 2001). But temperature increases will be higher in Mediterranean climate regions. According to Giannakopoulos *et al.* (2005) a global temperature rise of 2°C is likely to lead to a corresponding warming of 1-3°C in the Mediterranean region. The significant increases are prevalent in western, central and the eastern Mediterranean (Giannakopoulos *et al.* 2005). Such changes in global climate will seriously affect inland freshwater ecosystems (lakes, running waters, wetlands) caused by habitat loss leading to a reduction of biodiversity (species extinction).

The aim of this study, to predict future climate change impact on aquatic insect distribution and community structure in Büyük Menderes River by using values of species optima and of species tolerance levels to temperature increase.

SITE DESCRIPTION

Büyük Menderes River is located at the southeastern part of Turkey in Mediterranean climate region, between the latitute of 37°12’- 38°40’ north and longitude of 27°15’- 30°15’ east. Basin is surrounded by the provinces of İzmir, Manisa and Uşak at north; Muğla at south; Afyon and Burdur at east and Aegean Sea at west. It covers the %3.2 of surface area of Turkey with an areas of 24.873km^2.

Büyük Menderes River which is the longest river in the Aegean region meanders for 584km through western Turkey before reaching the Aegean Sea with a large delta, consisting of several lagoons, extensive salt steppes and mudflats (the biggest in Turkey). The delta extends approximately 16km seawards and the Delta region is an important bird area.

Büyük Menderes has a total drainage area of 24 000km^2, and the annual runoff is in the order of 3km^3, which accounts for 1.6% of Turkey’s water potential.

The first detailed limnoecological survey presenting physico-chemical characteristics, benthic macroinvertebrate fauna and relationships between physico-chemical variables and macroinvertebrates in Büyük Menderes River was prepared by Dügel and Kazanci (2004) using multivariate analysis.

Climate change impacts on Büyük Menderes River Basin were given in Kazancı and Dügel (2006), Kazancı (2007), Deu-Sumer (2007).

METHODS

The experimental design included collections of physicochemical and biological data from 17 sites on first through third order tributaries of the Büyük Menderes River as well as the main stem of the river. Complementarily to the biological survey in each point, a general abiotic characterisation was accomplished. The 17 sites were sampled for one year between 1998-1999 in seven sampling periods.

Estimated species optima and tolerance levels were calculated with weighted averaging values using CALIBRATE, a program for species-environmental calibration by weighted averaging partial least squares regression (Ter Braak and Barendregt 1986, Birks *et al.* 1990, Cajo *et al.* 1993).

RESULTS AND DISCUSSION

The impact of climate change on water resources of Büyük Menderes River Basin was evaluated, using a parametric water budget model by Dokuz Eylül University in 2007. The global change scenarios were downscaled to the regional scale. In the regional analysis, changes in the temperature and precipitation were examined.

On the basis of results obtained through scenarios, for the year 2030, it can be concluded that an increase of 1.2°C in mean annual temperature and a decrease of 5% in mean annual precipitation may be expected. In 2050, the mean annual temperature increases around 2°C, and mean annual precipitation decreases around 10%.

Simulation results of the water budget model, based on the prescribed climate change scenarios, show that nearly 20% of surface water will be reduced by the year 2030. By the years 2050 and 2100, this amount will rise to nearly 35% and more than 50%, respectively (Due-Sumer 2007).

Freshwater organisms have to exist within a narrower range than their terrestrial equivalents, few species can survive throught their life cycle over the whole temperature range (0-25°C). Benthic macroinvertebrates especially aquatic insects will therefore be affected by any temperature changes that occur as a result of climate change (Elliot 1991). Temperature may be one of the main variables effecting the distribution of aquatic insect species (Ward 1992). They will also be affected by possible changes in the temporal distribution of rainfall. Therefore benthic macroinvertebrates especially aquatic insects are useful indicators and useful predictors of the ecological effects of climate changes (Elliot 1991).

Chemical variables change and interact with temperature. Warmer water can lead to lower dissolved oxygen concentrations as well as higher potential evaporation, thus deteriorating river water quality and quantity. Rivers have less capacity to dilute pollution discharges when their water volume decreases. Therefore it can be concluded that water quality will decrease with temperature increase as a result of climate change. Projected changes in aquatic habitat under climate change are based on the fact that water temperature is highly related to air temperature (Poff *et al.* 2002).

Increases in water temperature and changes in flow regime as a result of global climate change will also affect the geographic distribution of aquatic species, extinction of species and loss of biodiversity. Climate change will alter hydrologic characteristics and water quality of running waters and will affect species composition and ecosystem functions.

On the basis of results obtained through this research, for the year 2030, it can be concluded that the selected taxa had tolerance value lower than 1.2°C will be eliminated. In 2050 the mean annual temperature increases around 2°C. Therefore the selected taxa had low optimum and tolerance value lower than 2°C will be eliminated (Table 1). For example *Baetis rhodani* (tolerance value was 2.753°C), *Caenis macrura* (tolerance value was 2.620°C), *Epallage fatima* (tolerance value was 3.006°C), *Calopteryx virgo* (tolerance value was 3.063°C), *Hydropsyche* spp. (tolerance values were 3.004°C and 3.012°C), *Polypedilum scalaenum* (tolerance value was 2.828°C), *Rheotanytarsus* sp. (tolerance value was 3.323°C) had high tolerance for temperature. Therefore they will exist by the years 2030 and 2050.

Elmis spp. (tolerance values were 0.990°C and 1.061°C), *Hydropsyche exocellata* (tolerance value was 0.849°C), *Atherix ibis* (tolerance value was 0.071°C), *Brilla longifurca* (tolerance value was 0.849°C), *Rheotanytarsus exiquus* (tolerance value was 0.279°C) had low tolerance for temperature. Therefore they will extinct by the years 2030 and 2050.

Table 1. Estimated species optima and tolerance levels for the temperature. “N,” effective number of occurrences, “X,” species which may extinct by the years 2030 and 2050.

		Temperature			
	N	Optimum	Tolerance	2030 (1.2°C)	2050 (2°C)
Baetis rhodani	15	17,123	2,753		
Ephemerella ignita	9	16,632	1,934		X
Caenis macrura	11	19,058	2,620		
Epallage fatima	3	15,850	3,006		
Calopteryx virgo	6	15,382	3,063		
Platycnemis pennipes	9	18,122	2,153		
Gomphus sp.1	4	19,147	0,672	X	X
Elmis sp.1	2	14,783	0,990	X	X
Elmis sp.2	2	14,525	1,061	X	X
Hydropsyche sp.1	9	17,237	3,004		
Hydropsyche sp.2	12	16,926	3,012		
Hydropsyche fulvipes	2	15,933	1,838		X
Hydropsyche exocellata	2	19,000	0,849	X	X
Cheumatopsyche lepida	3	16,676	2,832		
Atherix ibis	2	13,475	0,071	X	X
Brilla longifurca	2	18,800	0,849	X	X
Cricotopus sp.1	2	19,800	1,414		X
Orthocladius saxicola	3	17,725	2,519		
Chironomini sp.	2	21,475	1,414		X
Cryptochironomus defectus	2	14,080	2,404		
Polypedilum sp.1	4	19,435	2,990		
Polypedilum sp.3	3	17,331	1,794		X
Polypedilum convictum	3	19,000	1,255		X
Polypedilum laetum	5	18,181	2,364		
Polypedilum scalaenum	2	18,800	2,828		
Rheotanytarsus sp.	2	18,817	3,323		
Rheotanytarsus exiquus	3	19,413	0,279	X	X

The monitoring of benthic macroinvertebrate communities with aquatic insects is necessary to understand the population and running water ecosystem change over several years. These results can be used for conservation and management of the ecosystems. Climate change effects on aquatic ecosystems are not fully understood, and in many cases inherently unpredictable. Long-term biomonitoring of reference habitats is necessary to understand climate change effects on aquatic ecosystems (IPCC 2001). Reference habitat concept applied for the first time to running waters in Yedigöller National Park in Turkey according to Water Framework Directive (WFD) criteria. Also indicator species of Ephemeroptera were given (Kazancı and Türkmen 2008). But the long term data of animal populations in various ecosystems are missing in Turkey. Therefore we try to predict climate change effects on aquatic insects community structure by using the recent data in this study.

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