Erzincan Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
2022 15(1), 204-216
ISSN: 1307-9085, e-ISSN: 2149-4584
Araştırma Makalesi

Erzincan University
Journal of Science and Technology
2022, 15(1), 204-216
DOI: 10.18185/erzifbed.997093
Research Article

Abundance and Distribution of Fish in the Zilan Stream (Van/ Turkey) Its Relationship with Some Physicochemical Parameters

Mustafa AKKUŞ[1*], Mehmet Tahir HUYUT[2]

[1]Van Yüzüncü Yıl University, Faculty of Fisheries, Van, Turkey.

[2]Erzincan Binali Yıldırım University, Faculty of Medicine, Department of Biostatistics and Medical Informatics, Erzincan, Turkey.

Abstract

In the recent decades, river regulation attempts, dams and wastewater discharge have not only influenced the water quality and physical habitat structures of the rivers in a bad way but they have also threatened fish stocks. The aim of this study is to examine the multi-relationship structure between the fish species density living in the Zilan Stream, the largest stream of Lake Van, and the physicochemical parameters in this stream. Fish density was found out with the records from the 12 stations located on Zilan Stream. From the stations, water temperature, habitat score, pH, conductivity, dissolved oxygen (DO), phosphate (PO_4), nitrate (NO_3), turbidity and height values were obtained. The correlation structure of the obtained parameters with fish density was analyzed by canonical correspondence analysis (CCA). CCA axes fully explained the response of fish-density to physicochemical-parameters. As a result of the CCA, it was observed that the species concentrated in environments with less conductivity and low nitrate/pH levels. Species were hypersensitive to altitude, and were found more intensely at mid/low altitudes. In addition, it was observed that the species concentrated in high habitat score and oxygen-rich stations. It was observed that the species prefer medium/low temperature more and concentrate in environments with low-solids content. It is expected that the data obtained from this study will contribute to the management of areas to be protected in Zilan Stream.

Keywords: Zilan Stream, fish density, physicochemical parameters, habitat variables, canonical correspondence analysis (CCA).

Zilan Çayındaki (Van/ Türkiye) Balık Bolluğu, Dağılımı ve Bazı Fizikokimyasal Parametrelerle İlişkisi

Öz

Son yıllarda, nehir düzenleme girişimleri, barajlar ve atık su deşarjı nehirlerin su kalitesini ve fiziksel habitat yapılarını olumsuz etkilemekle kalmadı, aynı zamanda balık stoklarını da olumsuz etkiledi. Bu çalışmanın amacı, Van Gölü'nün en büyük akarsuyu olan Zilan Çayı'nda yaşayan balık türlerinin yoğunluğu ile bu akarsudaki fizikokimyasal parametreler arasındaki çoklu ilişki yapısını incelemektir. Balık yoğunluğu Zilan Çayı üzerinde yer alan 12 istasyondan alınan kayıtlardan öğrenildi. İstasyonlardan su sıcaklığı, habitat skoru, pH, iletkenlik, çözünmüş oksijen (DO), fosfat (PO_4), nitrat (NO_3), bulanıklık ve yükseklik değerleri elde edildi. Elde edilen parametrelerin balık yoğunluğu ile korelasyon yapısı kanonik uyum analizi (KUA) ile incelendi. KUA eksenleri, balık yoğunluğunun fizikokimyasal parametrelere tepkisini tam olarak açıkladı. KUA sonucunda türlerin daha az iletken, düşük nitrat ve pH seviyelerine sahip ortamlarda yoğunlaştığı gözlemlenmiştir. Türler irtifaya aşırı duyarlıydı ve orta/düşük irtifalarda daha yoğun bulundu. Ayrıca türlerin habitat skoru yüksek ve oksijenden zengin istasyonlarda yoğunlaştığı gözlemlendi. Türün orta/düşük sıcaklığı daha çok tercih ettiği ve düşük katı içerikli ortamlarda yoğunlaştığı gözlemlenmiştir. Bu çalışmadan elde edilen verilerin Zilan Çayı'nda korunacak alanların yönetimine katkı sağlaması beklenmektedir.

Anahtar Kelimeler: Zilan Çayı, balık yoğunluğu, fizikokimyasal parametreler, habitat değişkenleri, kanonik uyum analizi (KUA).

*Corresponding Author: makkus@yyu.edu.tr

1. Introduction

Streams are composed of sections containing different water quality and physical characteristics from the point where they are originated to the downstream point where they end up. Of these sections, areas with good water quality and physical structure may create suitable areas for fish breeding and feeding. As it is known, fish tend to respond to changes in their environments, which might be human-induced or natural (Han et al., 2007). Knowing the quantitative characteristics of the fish populations in rivers, such as density and biomass, is important in terms of two main areas; preserving the biological diversity and utilizing the water resource economically (Korkmaz, 2005). Freshwater ecosystems are the most valuable water resources; however, numerous types of human activities influence water qualities and ecological conditions (Şahin et al., 2016) negatively affect them. The occurrence, diversity, distribution, and habitat use of fish represent the basic information for fisheries, in terms of conservation and restoration, which are fruitful for management of river systems (Kerschbaumer et al., 2020). Particularly, spatial and temporal patterns of fish assemblages are central themes in stream ecology (Matthews, 1998). In recent years, there has been a rapid deterioration in river ecosystems around the world. Converting riverbeds into concrete canals, sand removal activities, dams and discharge of wastewater have led to bad water quality levels and deteriorated physical habitat structures of rivers. Anthropogenic activities are also known to alter riverine ecosystems (Jennings et al., 1999; Korkmaz, 2004 among others). In other words, it might be asserted that significant deterioration occurs in the water quality and ecological structure of rivers because of human-oriented effects (Tapia et al., 2009; Pizarro et al., 2010).

The abovementioned deteriorations in the water quality and physical structure of rivers, fish and other aquatic species are partially or completely withdrawn from certain parts of the streams. It is possible to claim that aquatic creatures might be used as indicators because of these problems (Specziar and Eros, 2020; Ticiani and Deleriva, 2020; Zucchetta et al., 2020). Revealing the relationships among physical and chemical parameters of rivers, fish density and distribution is of high importance for conservation and renewal studies.

Canonical Correspondence Analysis (CCA) is one of the most widely used methods to reveal the relationships between organisms in the aquatic ecosystem and physicochemical parameters (Ter Braak and Verdonschot, 1995). In the literature, the CCA method has already been used to identify the relationship between physicochemical parameters, density and distribution of aquatic organisms (Lara and Gonzalez, 1998; Marchetti and Moyle, 2001; Dodkins et al., 2005; O'Connell et al., 2005; Qadir et al., 2009; Kumar et al., 2020). It can also be used to determine how fish with different ecological characteristics react to increasing habitat degradation over time.

The relationships between sets of variables are often asymmetrical, and the analysis of these sets of variables pursues two main purposes: First, to determine which dependent variables or their combinations are the most. Second, it is to estimate the external factors that most affect the explanatory variables and their combinations. Multivariate Methods (methods such as multivariate regression or multivariate analysis of variance (MANOVA)) can only provide secondary purposes. On the other hand, multivariate methods (such as canonical correlation analysis) that do not take into account the asymmetrical relationship between the explanatory and response variable groups cannot achieve the second goal (Mardia et al., 1979). However, one of the methods that achieve the two goals described above is Canonical Compliance Analysis (Ter Braak, 1986; Saporta, 1990; Huyut and Keskin, 2021). CCA combines multivariate regression, MANOVA and principal components analysis (PCA) methods.

Lake Van Basin, which is a closed basin, is rich in streams, and there are 111 streams flowing into the lake. Zilan Stream is one of the largest streams pouring into the lake, and it is located in the north of the lake. In Zilan Stream, it is known that Van barb (*Capoeta kosswigi*), Pearl mullet (*Alburnus tarichi*), Van loach (*Oxynoemacheilus ercisianus*), Kura barbel (*Barbus lacerta*) and Common carp (*Cyprinus carpio*) species live. In addition, Zilan Stream is one of the vital breeding areas of pearl mullets. There are nearly 15.000 people migrating to the regions of the streams between April and July in that these fish are their economical sources (Sarı and Akkuş, 2016). In the light of the abovementioned information, the present study investigates the relationships between the distribution and density of fish species and their physicochemical parameters in Zilan Stream via using Canonical Correspondence Analysis (CCA).

2. Material and Methods

The study was carried out between June 2018 and September 2019 in Zilan Stream located in Erciş district of Van (Fig.1).

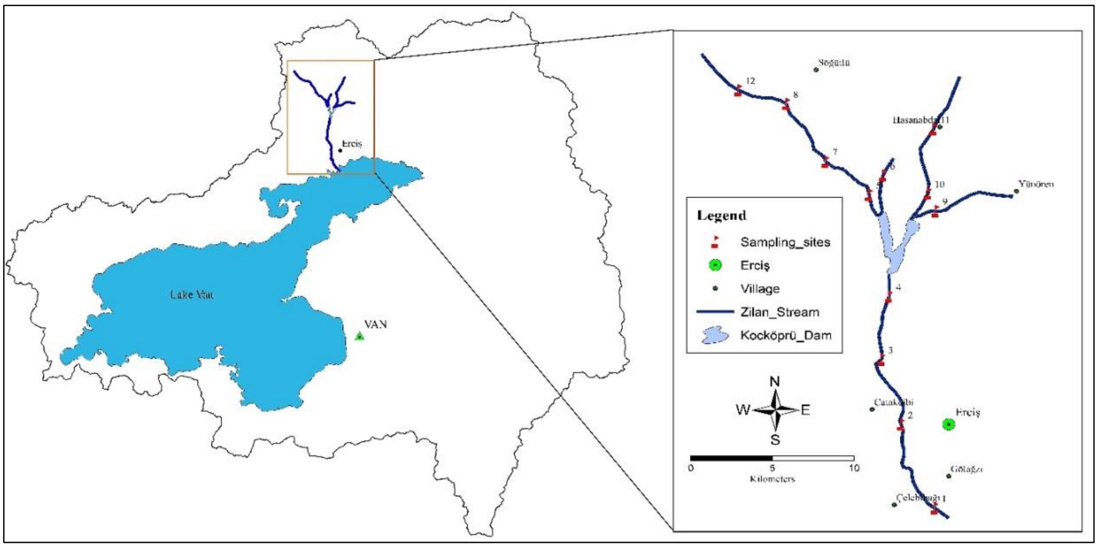

Figure 1. Zilan Stream and its sampling sites.

2.1. Study design and workflow

In the study, some physicochemical parameters were measured by sampling fish at 12 stations identified on the stream. Fish sampling was carried out with an electroshock device with 650 W output power, which worked with 12 Volt DC and 7-14 amp batteries, and fish scoops (with 2-4 mm mesh size). In deep areas, where the electroshock device was not effective, the sampling was done with a cast net with a mesh size of 5 mm. Water temperature, pH, conductivity and dissolved oxygen values were measured on-site via measuring device (YSI is the brand of the device). Phosphate (PO4), nitrate (NO3) and suspended solids were made with a spectrophotometer by using standard methods (Rice et al., 2017). To evaluate fish species of the habitat, Rapid Habitat Assessment Index-RHA method was used (Plafkin et al., 1989). With the method applied in Zilan Stream, sampling stations were assessed, in accordance with scores ranging from 1 to 5, in terms of appropriateness related to the survival of fish species. So as to identify the fish density at the workstations, the total amount of fish in the station was first identified. The total amount of fish was found from the equation N = Ci / (1-qk) (Zippin, 1956; Seber, 1973). For this equation, N refers to the total fish quantity, while Ci refers to the number of samples sampled in each fishing operation (C1 + C2 + C3… k). On the other hand, the value of “q” shows the fishing efficiency, and it is calculated separately for each station q = (T-C1) / (T-C3). For the fish density, calculation was done by dividing the number of fish in the stations by the area (km^2) of the station, while The Global Positioning System (GPS) obtained altitude data of the areas.

2.2. Statistical analysis

Continuous variables were summarized as mean and standard error. Canonical Correspondence Analysis (CCA) was used to find the structure of the unimodal relationship between fish density and environmental variables (physicochemical parameters). (Ter Braak, 1995). A CCA ordination diagram shows how the composition changes with environmental conditions by combining data for samples, species, and environmental variables into a two-dimensional diagram (Ter Braak and Verdonschot, 1995). Unimodal responses of response variables to environmental gradients can be predicted using CCA, which was developed as an extension of cohesion analysis (Makarenkov and Legendre, 2002). CCA has quite explanatory power about the relationship between the response variable and environmental or explanatory variables (Oksanen, 2004). The XLSTAT (version: 2018. 5) package program was used for the application of the CCA method used in the analysis of the data obtained.

2.3. Canonical Correspondence Analysis (CCA)

As a community variation model, CCA aims to visualize the main features of its distribution between response variables and environmental variables (Ter Braak, 1987). The Maximum Likelihood (ML) Method is used to obtain the estimates in the analysis. Although the solution of CCA is usually obtained with the weighted average algorithm, the method is basically an eigenvalue analysis (Ter Braak 1986, 1987). Therefore, the solution of CCA can be obtained with an eigenvalue algorithm (Huyut and Keskin, 2021). The statistical model in the basic approach of CCA refers to the presence or frequency of the response variable along environmental gradients as a function of unimodal position. CCA is a Gaussian regression approach under certain assumptions and is strong against the failure of these assumptions (Ter Braak and Prentice, 1988).

In calculating the site scores obtained by taking the weighted average of the response variables, the site scores show the dependent variables (response variables), while the environmental variables show the independent variables (explanatory variables). New site scores are values estimated by regression analysis (Palmer, 1993).

Multiple regressions or correlation coefficients of site scores on environmental variables can be calculated as follows (Ter Braak, 1986).

$$x_i = b_0 + \sum_{j=1}^{q} b_j \, z_{ij} \tag{1}$$

Equation (1) graphically relates the ordination axis to the explanatory (environmental) variables. In equation (1), b_0 is the constant term and b_j represents the regression coefficient for the j th environmental variable. By keeping x_i and u_k constant, the regression coefficient (b_j) can be estimated. With this process, the response variable is indirectly associated with the environmental variables through the ordination axis. In this context, the transition equations from the gaussian ordination process to the correspondence analysis can be summarized as follows (Huyut and Keskin, 2021).

$$\lambda u_k = \sum_{i=1}^{n} \frac{y_{ik} x_i}{y_{+k}} \tag{2}$$

$$x_I^* = \sum_{k=1}^{m} \frac{y_{ik} u_k}{y_{i+}} \tag{3}$$

$$\boldsymbol{b} = (Z'RZ)^{-1} Z'Rx^* \tag{4}$$

$$x = Z\boldsymbol{b} \tag{5}$$

In Equation (2 and 3); u_k is the weighted average of the k th (except m) explanatory variables; x_i is the value of the i th (except n) site (eg temperaturevalue); y_{ik} r shows the abundance (density) of the response variables (k) in the i th site; y_{+k} represents the total intensity of the response variable (k) and y_{i+} indicates the total sites.

R is nxn diagonal matrix consisting of y_{i+}. Z={Z_{ij}} is an nx(q + 1) dimensional matrix containing environmental data. $\boldsymbol{b}$, x and $\boldsymbol{x}^*$ are column vectors. $\boldsymbol{b} = (b_0, b_1, ..., b_q)'$, $\mathbf{x} = (x_0, x_1, \ldots, x_n)'$ and $\boldsymbol{x}^* = (x_1^*, \ldots, x_n^*)'$.

3. Results and Discussion

The results of the present study pave the way for obtaining vital information regarding the area. Accordingly, the values of physical and chemical parameters measured in the study are illustrated in Table 1.

Table 1. The fish density and average values along with physicochemical parameters from the stations in Zilan Stream

Sta.	pH	DO (mgl)	T ºC	PO_4 (mg/l)	NO_3 (mg/l)	Elev.	Habi sco.	Fish dens. (ind /km^2)	Conduct. (µS /cm)	Turbid. (NTU)
1	8.4±0.3	9.4±2.3	13±2.4	0.05±0.02	11±10	1660	5	58	830±10.2	10±2.4
2	8.3±0.2	10.2±2.4	13.4±3.2	0.03±0.10	5±2	1690	4	44	820±67.3	13±3.1
3	8.4±0.4	11.4±3.5	12.4±2.8	0.01±0.04	8±10	1710	5	48	835±10.4	11±2.8
4	8.6±0.6	10.8±1.9	15.4±4.2	0.21±0.09	10±14	1740	4	40	856±10.1	14±4.1
5	8.5±0.2	10±2.5	12.3±3.5	0.34±0.14	4±6	1792	4	42	852±82.4	15±3.8
6	8.4±0.4	11.5±3.8	14.2±2.8	0.23±0.14	12±4	1805	4	44	880±84.4	12±3.5
7	8.3±0.4	9.8±3.4	14.8±1.3	0.11±0.08	9±8	1872	4	41	790±53.2	11±4.2
8	8.6±0.6	11.5±2.8	15±4.2	0.15±0.03	12±6	1909	5	48	865±58.8	18±5.2
9	8.4±0.4	6.4±4.7	12.8±3.1	0.50±0.02	45±18	1849	2	0	890±92.4	42±6.4
10	8.4±0.3	6.8±3.5	13.8±2.4	0.42±0.14	44±21	1800	2	0	885±65.3	41±5.7
11	8.3±0.4	8.4±2.8	14±2.3	0.33±0.20	18±11	1841	4	35	870±64.2	38±6.2
12	8.2±0.2	9.2±4.4	14.5±4.1	0.28±0.08	3±2	1972	4	42	856±10.1	30±6.1

Sta: station number; DO: dissolved oxygen; T ºC: temperature (celcius); PO_4: phosphate; NO_3: nitrate; Elev: elevation; Habi sco: habitat score; Fish dens: fish density; Conduct: conductivity; Turbid: turbidity.

In the study, the highest temperature was measured as 21°C at Station 3 in the summer, and the lowest temperature was measured at the station 11 in the winter season with 3°C. It was found out that the pH value in Zilan Stream ranged from 8.2 to 8.6. The average dissolved oxygen value was measured as the highest level of 11.5 ± 2.8 mg / L at Station 6, and the same value was measured as the lowest value of 9.2 ± 4.4 mg / L at Station 12. To identify the suitability of the sampled habitat for fishes, the highest score "5" was used as "very good" with Stations 1 and 3. The habitat score of the 9th and 10th stations, which were noted down as the stations with no fish in the study, was calculated as 2 "bad". It was understood that the electrical conductivity at the stations varied between 890 ± 92.4 µS / cm and 790 ± 53.2 µS / cm. The average nitrate (NO3) value at the stations was found to be 45 ± 18 mg / L at the highest station 9, and it was 3 ± 2 mg / L the lowest at Station 1. On the other hand, it was noted down that phosphate (PO_4) value was found to vary between 0.01 ± 0.04 mg / L and 0.50 ± 0.02 mg / L in the measurements made in Zilan Stream. In the study, the average turbidity value was measured at the 9th station with 42 ± 6.4 NTU, and the lowest was at the 1st station with 10 ± 2.4 NTU. The distribution of fish species according to stations is illustrated in Table 2. Fish density was found at Station 1 with the highest 58 units / km2. It was concluded that no fish lived in the 9th and 10th stations during the sampling.

Table 2. Presence-absent data of sampling sites

Species/station	1	2	3	4	5	6	7	8	9	10	11	12
Cyprinus carpio								+	+	+	+	+
Alburnus tarichi			+	+	+	+	+	+	+	+	+	+
Capeota cossiwigi	+	+	+	+	+	+	+	+	+	+	+	+
Barbus lacerta			+	+	+	+	+	+	+	+	+	+
Oxynoemacheilus ercisianus		+	+	+	+	+	+	+	+	+	+	+

CCA analysis and correlation analysis were applied to grasp the relationship between physicochemical parameters highlighted in the study and fish density. Firstly, in the analysis, the eigenvalues of the constrained ordination axes of the CCA (Canonical Correspondence Analysis) diagram were found as 0.208 and 0.003, respectively. It is possible to note down that the first constrained axis explained the total variation by 98.5%; meanwhile, the axes explained 100% of the total variation. This shows that the two-dimensional CCA diagram is sufficient to analyze the relationships between fish density and physicochemical parameters (see Table 3).

Table 3. Eigenvalues and percentages of inertia (CCA)

	F1	F2
Eigenvalue	0.208	0.003
Constrained inertia (%)	98.492	1.508
Cumulative %	98.492	100.0

As a consequence of the correlation analysis, a high rate of positive relationship among fish density, habitat score and dissolved oxygen (DO) was found out with 88.1% and 83.1% percentages, respectively, while a highly negative correlation was found between phosphorus, turbidity and nitrate with 81.0%, 82.8%, 96.7% percentages, respectively. In addition, CCA analysis explained the entire variation in the first two axes. It was illustrated that 98.49% of the fish density variance might be explained according to physicochemical parameters put forward by the first CCA axis.

When the CCA diagram was examined (Fig 2), it was observed that the species concentrated in environments with less conductivity and low nitrate/pH levels. Species were hypersensitive to altitude, and were found more intensely at mid/low altitudes. In addition, it was observed that the species concentrated in high habitat score and oxygen rich stations. It was observed that the species prefer medium/low temperature more and concentrate in environments with low solids content.

Also, it was clear that while phosphorus and height parameters provided the highest contribution to the first axis, nitrate value provided the least contribution. According to the first main axis, a positive relationship was understood among fish density, temperature, habitat score, phosphate, DO, whereas a negative relationship was shown among nitrate, pH and environment.

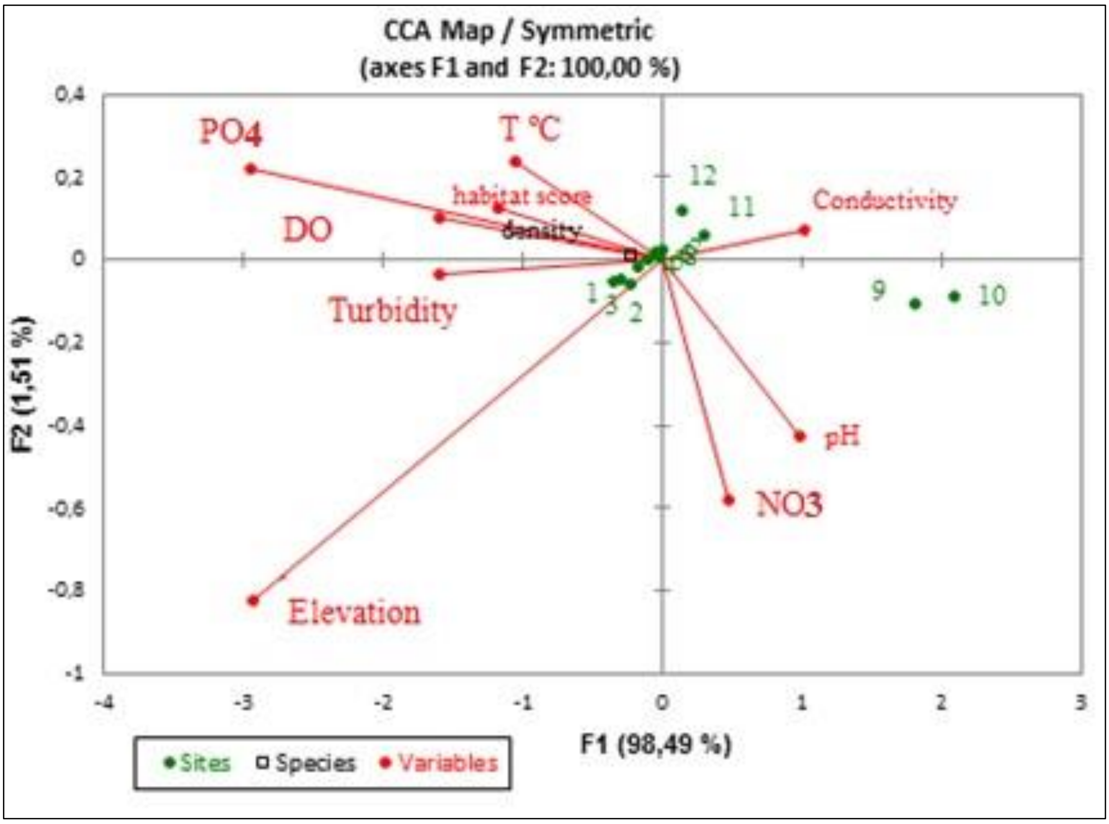

Figure 2. The relationships between fish density and physicochemical parameters in line with CCA.

4. Discussion

A study in a similar vein, O'Connell et al. (2005) pointed out that the fish living in the demersal and pelagic regions, according to the results of CCA analysis in Lake Pontchartrain, were displaced due to habitat degradation. In aquatic ecosystems, growth and nutrient intake slows down in fish due to insufficient dissolved oxygen; therefore, fish prefer the oxygen-rich parts of the streams (Kramer, 1987). In such a context, it is expected that fish gather in areas that are rich in dissolved oxygen. Fish are cold-blooded creatures, and their body temperatures change depending on the temperatures of the environment. Furthermore, it is also known that temperature is an effective parameter on the distribution and density of fish. However, in the present study conducted, it was seen in the CCA analysis that the temperature did not have an effect on the fish density in Zilan Stream. This situation is thought to happen due to the appropriateness of the temperature values for the fish species in the stream.

In the correlation analysis made between physicochemical parameters and fish density, it was displayed that there is a negative relationship between nitrate, phosphate and turbidity. The fish density tends to decrease at the stations where these values increase. Nitrate, phosphate and turbidity are parameters that increase in aquatic ecosystems as a result of deterioration of water quality and habitat structure, and it has been reported by different researchers that they negatively affect fish stocks (Qadir et al., 2009; Adeosun, 2019, Palacios-Sánchez et al., 2019). When the CCA diagram is examined (Fig 2), it is seen that the density of fish tends to increase with decreasing altitude. In addition, when Table 2 is examined, it can be understood that although all the species were observed in Station 1 with the lowest altitude in the study, only 3 species in the study were found at Station 12 with the highest altitude. It was noted down that the low altitude parts of the streams are rich in nutrients, and the environmental conditions are more suitable. On account of the abovementioned reasons, the number and density of species increase with a decrease in altitude of the rivers (Gard and Flittner, 1974; Carvajal and Quintero et al., 2015).

Author contributions:

AKKUŞ, M.: conceived and designed the study, scanned the literatüre, collected the material, interpreted the results, wrote the study.

HUYUT, M. T.: conceived and organized the study, scanned the literature, determined and implemented the method, analyzed and interpreted data.

Competing interests:

Authors state no conflict of interest.

Ethical approval:

The study protocol was approved by the Institutional Ethics Review Board of Erzincan Binali Yıldırım University (30/09/2020 Meeting Number: 12, Protocol number:26) after being approved by the Ministry of Health of the Republic of Turkey in accordance with the Declaration of the Helsinki World Medical Association.

References

Adeosun, F. I. (2019). Effects of anthropogenic activities on water quality, and phosphate and nitrates in the sediment of River Ogun at Ijaye, Isabo and Oke-sokori, Ogun State. Int. J. Of Biological and Chemical Sci. 13(3), 1261-1270.

Carter, M. G., Copp, G. H., Szomlai, V. (2004). Seasonal abundance and microhabitat use of bullhead *Cottus gobio* and accompanying fish species in the River Avon (Hampshire), and implications for conservation. Aqu. Conservation: Marine and Freshwater Ecos. 14, 395-412. DOI: 10.1002/aqc.617

Carvajal-Quintero, J. D., Escobar, F., Alvarado, F., Villa-Navarro, F. A., Jaramillo-Villa, Ú., Maldonado-Ocampo, J. A. (2015). Variation in freshwater fish assemblages along a regional elevation gradient in the northern Andes, Colombia. Ecology and Evolution, 5(13), 2608-2620. DOI: 10.1002/ece3.1539

Dikov, T., Zivkov, M. (2004). Abundance and biomass of fishes in the Veleka River, Bulgaria. Folia Zoologica, 53(1), 81-86.

Dodkins, I. A. N., Rippey, B., Hale, P. (2005). An application of canonical correspondence analysis for developing ecological quality assessment metrics for river macrophytes. Freshwater Bio. 50, 891-904. DOI:10.1111/j.1365-2427.2005.01360.x

Erös, T., Botta-Dukát, Z., Grossman, G. D. (2003). Assemblage structure and habitat use of fishes in a Central European submontane stream: a patchbased approach. Eco. of Freshwater Fish. 12, 141-150. DOI: 10.1034/j.1600-0633.2003.00009.x

Fu, C., Wu, J., Chen, J., Wu, Q., Lei, G. (2003). Freshwater fish biodiversity in the Yangtze River basin of China: patterns, threats and conservation. Biodiversity & Conservation, 12, 1649-1685.

Gard, R., Flittner, G. A. (1974). Distribution and abundance of fishes in Sagehen Creek, California. J of Wildl. Manage, 38, 347-358.

Han, C. C., Tew, K. S. Fang, L. S. (2007). Spatial and temporal variations of two cyprinids in a subtropical mountain reserve a result of habitat disturbance. Eco. of Freshwater Fish, 16, 395–403.

Huyut, M. T., Keskin, S. (2021). The Success of Restricted Ordination Methods in Data Analysis with Variables at Different Scale Levels. Erzincan University, Journal of Science and Technology, 14(1), 215-231.

Jennings, M. J., Johnson, K., Staggs, M. (1996). Shoreline protection study: a report to the Wisconsin state legislature. Wisconsin Department of Natural Resources, Publication PUBL-RS-921–96, Madison.

Kerschbaumer, P., Tritthart, M., Keckeis, H. (2020). Abundance, distribution, and habitat use of fishes in a large river (Danube, Austria): mobile, horizontal hydroacoustic surveys vs. a standard fishing method. ICES J. of Marine Sci., 77 (5), 1966-1978. DOI: 10.1093/icesjms/fsaa081.

Korkmaz, A. Ş. (2005). Density and Biomass of Fish in Kadıncık (Çamlıyayla-Mersin) Brook. Journal of Agricultural Sci., 11, 91-97.

Kramer, D. L. (1987). Dissolved oxygen and fish behavior. Environmental Bio. of fishes, 18(2), 81-92. DOI: 10.1007/BF00002597

Kumar, S. D., Santhanam, P., Krishnaveni, N., Raju, P., Begum, A., Ahmed, S. U., Perumal, P., Pragnya, M., Dhanalakshmi, B., Kim, M. K. (2020). Baseline assessment of water quality and ecological indicators in Penaeus vannamei farm wastewater along the Southeast coast of India. Marine Poll. Bull., 160, 111579. DOI: 10.1016/j.marpolbul.2020.111579.

Lara, E. N., Gonzalez, E.A. (1998). The relationship between reef fish community structure and environmental variables in the southern Mexican Caribbean. J. of Fish Bio., 53, 209-221.

Makarenkov, V., Legendre, P. (2002) Nonlinear Redundancy Analysis and Canonical Correspondence Analysis Based on Polynomial Regression. Ecology, 83(4), 1146-61.

Mardia, K. V., Kent, J. T., Bibby, J. M. (1979). Multivariate analysis. Academic Press. London. England.

Marchetti, M. P., Moyle, P. B. (2001). Effects of flow regime on fish assemblages in a regulated California stream. Ecological Appl., 11(2), 530-539.

Matthews, W. J. (1998). Patterns in freshwater fish ecology. Rev. in Fish Bio. and Fish, 8, 495-497. DOI: 10.1007/978-1-4615-4066-3

O'Connell, M. T., Cashner, R. C., Schieble, C. S. (2004). Fish assemblage stability over fifty years in the Lake Pontchartrain estuary; comparisons among habitats using canonical correspondence analysis. Estuaries, 27(5), 807-817.

Oksanen, J. (2004). Multivariate Analysis in Ecology (Lecture notes). Department of Biology. University of Oulu.

Palacios-Sánchez, S. E., Vega-Cendejas, M. E., Hernández-de-Santillana, J. M., Aguilar-Medrano, R. (2019). Anthropogenic impacts in the nearshore fish community of the Yucatan Coastal Corridor. A comparison of protected and unprotected areas. J. for Nature Cons., 51, 125721.

Palmer, M. W. (1993). Putting things in even better order: the advantages of canonical correspondence analysis. Ecology, 8(74), 2215-30.

Pinto, B. C. T., Araujo, F. G., Hughes, R. M. (2006). Effects of landscape and riparian condition on a fish index of biotic integrity in a large southeastern Brazil river. Hydrobiologia, 556, 69-83.

Pizarro, J., Vergara, P. M., Rodriguez, J. A., Valenzuela, A. M. (2010). Heavy metals in northern Chilean rivers: spatial variation and temporal trends. The J. of Hazardous Materials, 181, 747-754. DOI: 10.1016/j.jhazmat.2010.05.076.

Plafkin, J. L., Barbour, M. T., Porter, K. D., Gross, S. K., Hughes, R. M. (1989). Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA 440-4-89-001

Qadir, A., Malik, R. N., Ahmad, T., Sabir, A. M., (2009). Patterns and distribution of fish assemblage in Nullah Aik and Nullah Palkhu Sialkot, Pakistan. Bio. Diversity and Cons., 2, 110–124

Rice, E. W., Baird, R. B., Eaton, A. D. (2017). Standard Methods For The Examination of Water and Wastewater. 23 st Ed. American Public Health Association, American Water Works Association, Water Environment Federation; Washington, DC, (USA). P. 1015.

Saporta, G. (1990). Probabilites. analyses de don&es et statistiques. Editions Technip. Paris, 492-93.

Sarı, M., Akkuş, M. (2016). Investigation of the effects on freshwater fish of flood control studies in Ilıca and Kömürcü Streams (Erciş-Van). Ege J Fish Aqua Sci, 32(3),127-134.

Specziar, A., Eros, T. (2020). Development of a fish-based index for the assessment of the ecological status of Lake Balaton in the absence of present day reference condition. Knowl. Manag. of Aqut. Ecosyst, 421, 1-11. DOI: 10.1051/kmae/2020002.

Şahin, S. K., Zeybek, M. (2016). Distribution of Mollusca fauna in the streams of Tunceli Province (East Anatolia, Turkey) and its relationship with some physicochemical parameters. Turkish J. of Fish. and Aquatic Sci., 16 (1), 187-195.

Tapia, J., Bertrán, C., Araya, C., Astudillo, M. J., Vargas-Chacoff, L., Carrasco, G., Letelier, L. (2009). Study of the copper, chromium and lead content in mugil cephalus and eleginops maclovinus obtained in the mouths of the maule and mataquito rivers (maule region, chile). J. of the Chil. Chem. Soc., 54 (1), 36-39.

Ter Braak, C. J. F. (1986). Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecological Society of America, 5(67), 1167-79.

Ter Braak, C. J. F. (1987). The Analysis of Vegetation-Environment Relationships by Canonical Correspondence Analysis. Vegetatio, 64, 69-77.

Ter Braak, C. J. F., Prentice, I. C. (1988). A theory of gradient analysis. Adv. Ecol. Res., 18, 271–317.

Ter Braak, C. J. F., Verdonschot, P. F. (1995). Canonical correspondence analysis and related multivariate methods in aquatic ecology. Aquatic sci., 57, 255-289.

Ticiani, D., Delariva, R. L. (2020). The biotic condition of dams run-of-the-river in sequence: adaptation of a multimetric index based on the Neotropical fish fauna. Environmental Monitoring and Assessment, 192, 1-15. DOI: 10.1007/s10661-020-08367-2.

Zucchetta, M., Scapin, L., Franco, A., Franzoi, P. (2020). Uncertainty in developing fish based multi-metric indices. Eco. Indi. 108: 105768. DOI: 10.1016/j.ecolind.2019.105768.