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PROOF RESEARCH PAPER

Seasonal Changes of Malacostraca (Crustacea) Fauna of the Upper Coruh River Basin (Bayburt Province, Turkey) and its Ecological Characteristics

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Abstract

A three samplings were carried out between September 2014 and August 2015, at twelve stations to determine the seasonal changes of species, relations with water quality parameters, and the Malacostraca fauna of the Upper Coruh River Basin. A hand net was used to collect the biological samples. Dissolved oxygen, temperature, pH, electrical conductivity, and total dissolved solids were measured using a portable water meter. Nitrite, ammonium, phosphate, and biochemical oxygen levels were also measured. Seven taxa were identified (five of them belong to Amphipoda, one to Isopoda, and one to Decapoda). *Gammarus birsteini* was the continuous, while *G. kischineffensis* and *Asellus aquaticus* are common. *G. fossarum, G. balcanicus, Gammarus* sp. and *Potamon ibericum* were rarely found. AF (Aydıncık Foundation) and DF (Değirmencik Foundation) stations had first class water quality while other stations had second and third quality according to the Quality Criteria According to Classes of Inland Water Resources.

Keywords: Malacostraca, water quality, upper Coruh basin, bioecology.

Introduction

Malacostraca is a large subgroup covering two-thirds of all Crustacea species, represented by more than 22,000 taxa, including economically important marine and freshwater species. Malacostraca includes many huge groups, such as decapods, isopods, and amphipods (Özbek & Ustaoğlu, 2006; Pechenik, 1996). Malacostracans are important components of aquatic ecosystems because they are used as bioindicators. Malacostracans contribute to the food web by being consumed by birds, fish and amphibians (Pechenic, 1996; Uğurlu, Ünlü, Satar, 2015). The order of Amphipoda are often found in high densities and have wide distributions, hence amphipods often play major roles in the ecology of these habitats (Conlan, 1994; Thomas, 1993). Amphipoda are ecologically and thropically important group.They are numerically dominant and can be sampled throughout the year. They exhibit a high degree of niche specificity, tolerant to varying physicochemical characteristic in sediment and water. However, they have relatively low dispersion and mobility capabilities and live in direct contact with the sediment. On the other hand, this group is sensitivity to pollutant and organic pollution compared to other bentic organisms (Uğurlu *et al*. 2015; Reish, 1993; Thomas, 1993; Gomez Gestaira and Dauvin, 2000; Dauvin and Ruellet, 2009).

Coruh River, with its flow reaching 570 m^3/s, is one of the fast running rivers in the world. It rises from Civilikaya Hill in the Mescit Mountains and flows towards the Bayburt plain. It merges with the other rivers flowing in the Bayburt borders and passes from İspir, reaches to Artvin City, and flows into the Northeastern Black Sea from Georgian City, Batum (Kobya, Taşkın, Yeşilkanat, Varınlıoğlu, Korcak, 2015).

Studies on the distribution of Malacostraca species inhabiting the inland waters of Turkey began with the record of Heller (1863), which was on the record of *Potamon fluviatilis* Herbst, 1785 from İstanbul. Later, Vavra (1905) identified a new amphipod species, *Gammarus argaeus*, from Erciyes Mountain. *Potamobius leptodactylus* was reported from Lake Sapanca by Ninni (1923). Coifmann (1938) reported *Potamon edule* from Kuşadası and İzmir province. This was followed by Geldiay (1949), who reported *Potamobius (Astacus) fluviatilus* in Cubuk Reservoir. Bott (1950) reported the presence of *Astacus astacus* and *Astacus pallipes* from Lake Apolyont and Manyas. Birstein (1951) studied freshwater isopoda of the USSR and Turkey and described the species found. Çamur and Kırgız (2000) identified freshwater Isopoda fauna of Turkish Thrace Region. Özbek and Ustaoğlu (2005) studied Lake District inland water Malacostraca fauna and reported 26 taxa belonging to Decapoda, Amphipoda, Isopoda, and Mysidacea. Studies on Malacostraca species revealed 126 taxa inhabiting inland waters of Turkey (Özbek and Ustaoğlu, 2006). Majority of the studies on Malacostraca species were conducted in the western regions of Turkey, however, few studies were carried out in the Northeastern Black Sea region.

Here, we aimed to determine the Malacostraca species found in the Bayburt Province, which is the part of the upper Coruh River Basin, to reveal seasonal variations of species and to determine the environmental parameters affecting the species distribution.

Materials and Methods

Samplings and Laboratory Procedures

Twelve stations were chosen to determine the Malacostraca fauna of Bayburt province around the upper Coruh River Basin, and the stations were sampled in three seasons. Samplings were carried out between 2014 (September) and 2015 (May-August). Sampling stations are consist of two ponds, one irrigation canal, and nine streams (Figure. 1). Sampling dates, locations, and altitudes of the sampling stations are shown in Table 1. In the winter season, we could not perform sampling because of surface freezing of the streams and the inconvenient field conditions. Bentic organisms were sampled using a deep hand net (30×30 cm in size, 500-μ mesh size) and fixed with 4% formaldehyde in the field. After washing with fresh water in the laboratory, the samples were kept in alcohol (70%). Species were selected under a stereo microscope, and extremities were fixed on a microscope slide. For taxonomic identification of decapoda, the identification keys of Geldiay and Kocataş (1970), Pretzman (1983) and Fischer (1973) were used. For Isopoda identification, the keys of Birstein (1951) and Naylor (1972) and for Amphipoda identification, keys of Karaman and Pinkster (1977 a,b,1987), Karaman (2017), Barnard and Barnard (1983 a,b), Carausu et. al. (1955), Ruffo (1993) and Özbek (2003) were used.

Water samples were taken using 2-liter sterile bottles to determine the water quality parameters, and they were carried to the laboratory using cold storage methods. Water temperature, pH, electrical conductivity, total dissolved solids, and dissolved oxygen values were measured in the field using a HQ40D water measurement device. Nitrite (NO_2-N), ammonium (NH_4-N) and phosphate (PO_4-P) were determined according to Parson *et al* (1984). Biochemical oxygen demand (BOD_5) was determined by standard methods (APHA, 1975).

Statistical Analyses

Canonical Correspondence Analysis (CCA) by applying the Log_{10} (N+1)-transformed abundance data was performed to analyze the relationship between the Malacostraca species and environmental factors (CANOCO 4.5, Braak and Smilauer, 2002). Community parameters such as the number of species, number of specimens, the diversity index (log2 base) (H') (Shannon and Weaver, 1949), evenness index (J') (Pielou, 1975), frequency index (F %) (Soyer, 1970) and quantitative dominance index (DI %) (Bellan-Santini, 1969), were also calculated. Similarity matrices were constructed by calculating similarity coefficients between samples or species according to the Bray-Curtis method using the PRIMER package (Clarke & Warwick, 2001).

Results

In the benthic samples taken from upper Coruh Basin (Bayburt) during the research, one species belonging to order Decapoda (*Potamon ibericum*), one to order Isopoda (*Asellus aquaticus*), and five species belonging to order Amphipoda (*Gammarus birsteini, Gammarus kischineffensis, Gammarus balcanicus, Gammarus fossarum, Gammarus sp*.) were identified. The study was carried out on 6762 (ind/m^2) individuals. Table 2 shows both the seasonal variations of the individual numbers determined and the frequency index values according to the stations. We found that the highest numbers of individuals are recovered in autumn, with lowest numbers recovered in spring.

The dominancy index of Malacostraca species showed that *Gammarus birsteini* (14.28) is continuous, *Gammarus kischineffensis* and *Asellus aquaticus* (28.57) are common, and *Gammarus fossarum*, *Gammarus balcanicus*, *Gammarus sp* and *Potamon ibericum* (57.14) are rare species. (Figure. 2). The index values according to the seasons and the numbers of individuals per m^2 are shown in Figure 3.

Cluster and MDS analyses showed that the stations constituted of three main groups (Figure. 4 and 5). The difference between these groups was confirmed by the ANOSIM test (Global R = 0.9963; p <0.01(p=0.0008). The similarity/disagreement ratios of the groups in the separation of groups are given in Table 3. According to this table, 50.00% for group A, 57.67% for group B, and 59.43% for C showed similarity. *P. ibericum* contributed 100% for the formation of group A, *G. fossarum* contributed 87.23% for the formation of group B, and *G. birsteini* contributed 61.44% for the formation of group C.

By conical conformity analysis, we found that the PO_4-P value was positively correlated with *Potamon ibericum* abundance. *G. fossarum* was found in stations with higher dissolved oxygen levels and pH values. *G. fossarum* prefers relatively abundant oxygenated waters.

G. birsteini, *G. kischineffensis*, and *Aselllus aquaticus* species were found at the stations with high NO_2-N, BOD_5, and NH_4-N values. Thus, these species are more tolerant to organic contamination. *G. balcanicus* and *Gammarus sp.* species were detected at the stations where temperature and TDS were low (in all three seasons), and organic pollution was relatively low.

According to the CCA analysis, the eigenvalues for the first and second axis are 0.242 and 0.113, respectively. These values explain the cumulative variance in the Malacostraca data. The species-environment relationship was high (0.877; 0.764) for the first two axes. Malacostraca species constituted 79% of the environment-related variance. According to stations, the seasonal variation of Malacostraca species was determined by CCA analysis and 50.9% of these changes were explained by four axes, 28.1% by axes 1 and 13.1% by axis 2. These data indicate that the measured environmental variables are important factors on distribution of the determined Malacostraca species.

When the data were evaluated according to the Monte Carlo test, it was seen that the significance test of all conical axes values was 2.783 for the F-value and 0.0020 for the p-value. These values show that the relationships between environmental parameters

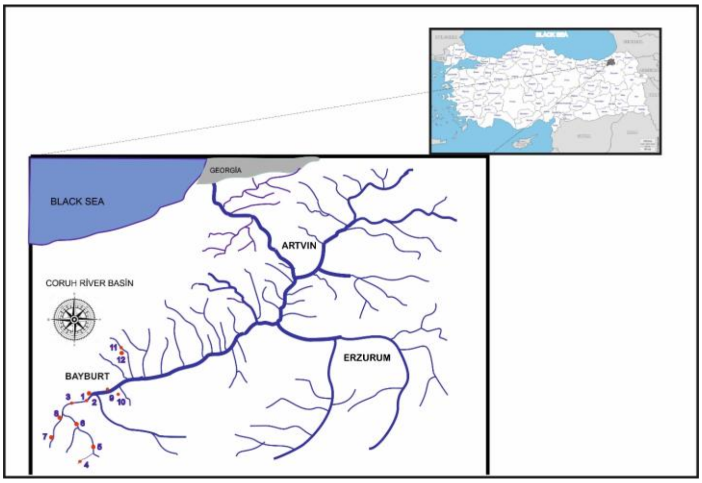

Figure 1. The sampling stations of the Bayburt Province.

Table 1. Sampling date, coordinate and altitude properties belonging to sampling stations

Stations	Sampling Date	Coordinates (Decimal)	Altitude (m)
NP-1	16.09.2014 18.05.2015 21.07.2015	40.36194 N 40.0416 E	2028
NP-2	16.09.2014 18.05.2015 21.07.2015	40.3452 N 40.0369 E	1978
KS	16.09.2014 18.05.2015 21.07.2015	40.2796 N 39.9766 E	1615
SGC	16.09.2014 18.05.2015 21.07.2015	40.0541 N 40.1441 E	1959
SS	16.09.2014 18.05.2015 21.07.2015	40.0736 N 40.1441 E	1959
GS	17.09.2014 19.05.2015 22.07.2015	40.1125 N 40.1475 E	1842
OS	17.09.2014 19.05.2015 22.07.2015	39.975 N 39.9805 E	1950
GIC	17.09.2014 19.05.2015 22.07.2015	40.0972 N 39.8911 E	
CRD	17.09.2014 19.05.2015 22.07.2015	40.3663 N 40.2438 E	1905
DF	17.09.2014 19.05.2015 22.07.2015	40.3663 N 40.2438 E	1905
AS	17.09.2014 19.05.2015 22.07.2015	40.5469 N 40.0772 E	
AF	17.09.2014 19.05.2015 22.07.2015	40.5469 N 40.0772 E	

Table 2. Individual numbers and F-index values of species according to seasons (m^2)

	Stations	*G.birs.*	*G.kisc.*	*G.foss.*	*G.balc.*	*Gm.sp.*	*A.aqua.*	*P. iber.*
Autumn	NP1-1	261	122	0	0	0	27	0
	NP2-1	168	103	0	0	0	37	6
	KS-1	74	147	0	0	0	96	2
	SGC-1	111	63	0	9	1	48	0
	SS-1	149	141	53	44	1	2	2
	GS-1	230	42	28	17	0	96	0
	OS-1	99	0	0	343	0	28	0
	GIC-1	108	0	21	0	0	44	0
	CRD-1	0	0	0	0	0	0	4
	DF-1	0	0	52	0	0	11	0
	AS-1	0	0	0	0	0	0	0
	AF-1	0	0	15	0	0	0	0
Spring	NP1-2	42	31	0	0	0	13	0
	NP2-2	62	27	0	0	0	19	6
	KS-2	50	24	0	0	0	26	2
	SGC-2	56	34	0	11	1	8	2
	SS-2	94	49	31	14	1	6	4
	GS-2	99	54	47	46	0	30	0
	OS-2	72	0	0	307	0	7	0
	GIC-2	57	0	60	0	0	32	0
	CRD-2	0	0	0	0	0	0	0
	DF-2	0	0	37	0	0	12	0
	AS-2	0	0	0	0	0	0	0
	AF-2	0	0	8	0	0	2	0
Summer	NP1-3	224	86	0	0	0	29	0
	NP2-3	101	128	0	0	0	25	0
	KS-3	51	23	0	0	0	26	2
	SGC-3	78	37	0	22	1	14	4
	SS-3	318	33	15	47	0	2	1
	GS-3	206	67	52	53	0	33	0
	OS-3	221	0	0	311	0	7	0
	GIC-3	153	0	48	0	0	26	0
	CRD-3	0	0	0	0	0	0	2
	DF-3	0	0	0	0	0	4	0
	AS-3	0	0	0	0	0	0	2
	AF-3	0	0	18	0	0	4	0
F Index		45.56	15.89	7.17	18.09	0.07	10.63	0.57

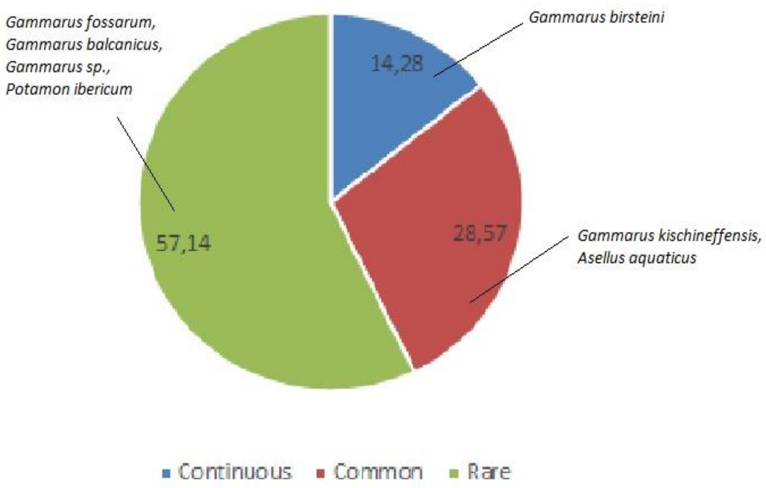

Figure 2. Dominancy index of the determined taxa.

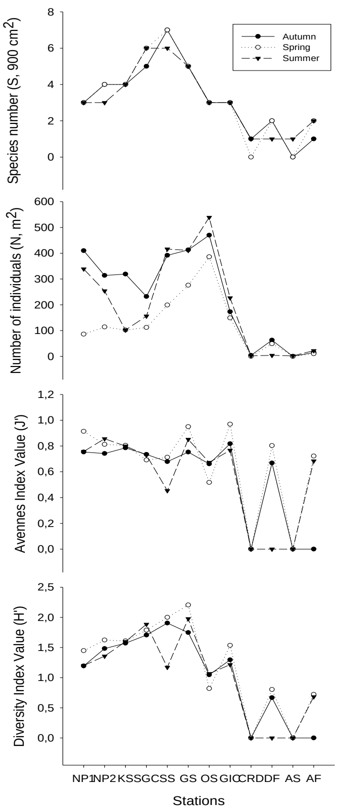

Figure 3. Some descriptive indices of the stations.

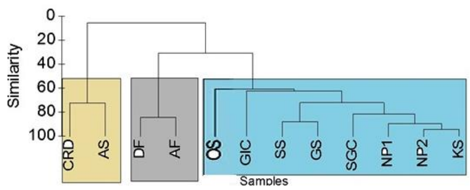

Figure 4. Bray-Curtis similarity analyses.

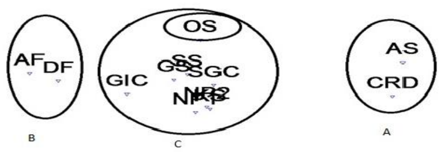

Figure 5. MDS similarity analyses.

Table 3. Species percentage contribution to similarity/dissimilarity according to SIMPER analysis and their average index values

	Similarity			Dissimilarity		
	A	B	C	C-A	C-B	A-B
Average similarity/Dissimilarity	50.00	57.67	59.43	99.37	90.88	100
G. birsteini			61.44	48.13	47.68	
P. ibericum	100					
G. fossarum		87.23				77.35

and species are significant (Table 4, Table 5).

The relationship between malacostracan species and environmental parameters is illustrated in Figure 6. The graph shows that the NP-1, NP-2 and KS stations showed a positive correlation with the first axis in three seasons and the NO_2-N, BOD_5, and NH_4-N values were high in these stations (Table 5; Figure. 6). In the three seasons, GIC and DF station showed a

Table 4. Canonical correspondence analysis of malacostraca-environment relationships

Axes	CCA1	CCA2	CCA3	CCA4	Total İnertia
Eigenvalue	0.242	0.113	0.058	0.026	0.862
Species-environment correlations	0.877	0.764	0.514	0.606	
Cumulative percentage correlations					
	28.1	41.2	47.8	50.9	
• Species data	53.9	79.0	91.8	97.6	
• Species-environment relation					0.862
					0.449
• Sum of all eigenvalues					
• Sum of canonical eigenvalues					

Table 5. Interest correlation between axes and environmental parameters

Parameters	AXIS1	AXIS 2	AXIS 3	AXIS 4
Temp.	-0.0597	-0.2584	0.3200	0.5091
DO	-0.2757	-0.1183	0.3430	0.3045
pH	-0.0667	-0.0726	0.3519	0.0944
EC	-0.0674	-0.0417	0.0250	0.8099
TDS	-0.0434	-0.0529	0.0033	0.7133
NO2-N	0.6301	-0.0272	0.5977	0.2543
NH4-N	0.7197	-0.4619	-0.0742	0.2393
PO4-P	0.5784	0.3313	-0.0141	0.6592
BOI5	0.3987	-0.2168	0.1829	0.2599

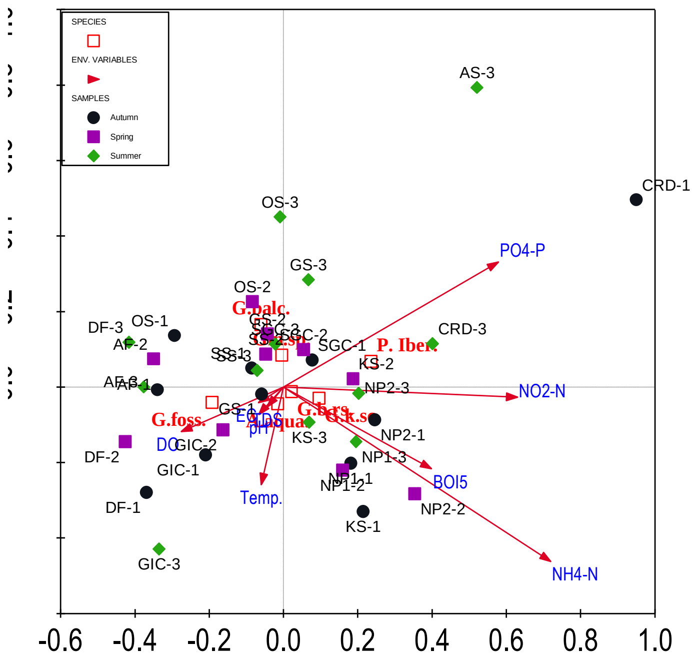

Figure 6. CCA analysis between the environmental variables and the determined species (G.foss: *Gammarus fossarum*; G.balc: *Gammarus balcanicus*; G.brs: *Gammarus birsteini*; G.ks: *Gammarus kischineffensis*; G.sp.; *Gammarus sp.*; P.ıber.: *Potamon ıbericum;* A.aqua*:* *Asellus aquaticus*).

negative correlation with axis 1 and axis 2, and parameters such as DO, pH, EC, TDS were found to be relatively effective in these stations. Although NO_2-N, NH_4-N, and PO_4-P showed a positive correlation with axis 1 (0.63, 0.71, and 0.57 respectively), NH_4-N had a negative correlation with axis 2 and PO4-P had a positive correlation with axis 2 (Table 5).

Discussion

In this study conducted in the Bayburt province the water quality of tributaries of the Coruh River was determined, the species belonging to the Malacostraca group were identified, and the relation of the species with the water quality parameters was discussed. *G. birsteini* was firstly recorded by Karaman (2003) from Artvin, Trabzon and Rize/Kalkandere. In the present study, this species was identified from the stations of Bayburt province, and it is inferred that it is the most dominant species. *G. birsteini* was reported from high altitudes of rivers, and we obtained the species from stations with high altitude (greater than 1500 m). Our findings are concur with previous reports. *G. fossarum* was firstly recorded by Karaman (2003) from Artvin. In our study, the species was also obtained from stations in Bayburt. *G. kischineffensis* was determined by Karaman (2003) from Erzurum and has usually been found in the same locations with *G. balcanicus*. In our study, *G. kischineffensis* was detected in the Bayburt, which is in line with the literature. *G. balcanicus* has been detected from many different basins within the borders of Turkey, and has been recorded from Trabzon, Erzurum, and Ordu in the Eastern Black Sea region. In this study, *G. balcanicus* was collected from four stations in Demirözü area, Bayburt.

Whitehurst (1991), Hawkes (1979), and Hargeby (1990) remarked that *A. aquaticus* is tolerant of lower oxygen conditions and tends to survive even at pH levels lower than 6.0. In our study, according to the CCA analysis, *A. aquaticus* was found to be more tolerant to water quality changes.

In a study by Bawa (2015), the Gammarus:Asellus ratio was related to organic pollution, showing a significant positive correlation with nitrate, phosphate, conductivity, calcium, and pH. In this study, *G. birsteini* and *G. kischineffensis* showed a positive correlation with BOD_5 and NH_4-N values, while *G. fossarum, G. balcanicus,* and *Gammarus. sp* showed a negative correlation with nitrate, ammonium, and phosphate, which it can be assesed as an indicator of organic pollution.

G. fossarum showed a positive correlation with dissolved oxygen, and it can be considered that this species prefers relatively clean waters. The graphs of the water analyses performed in the study are given in Figure 7. AF and DF stations showed first class water

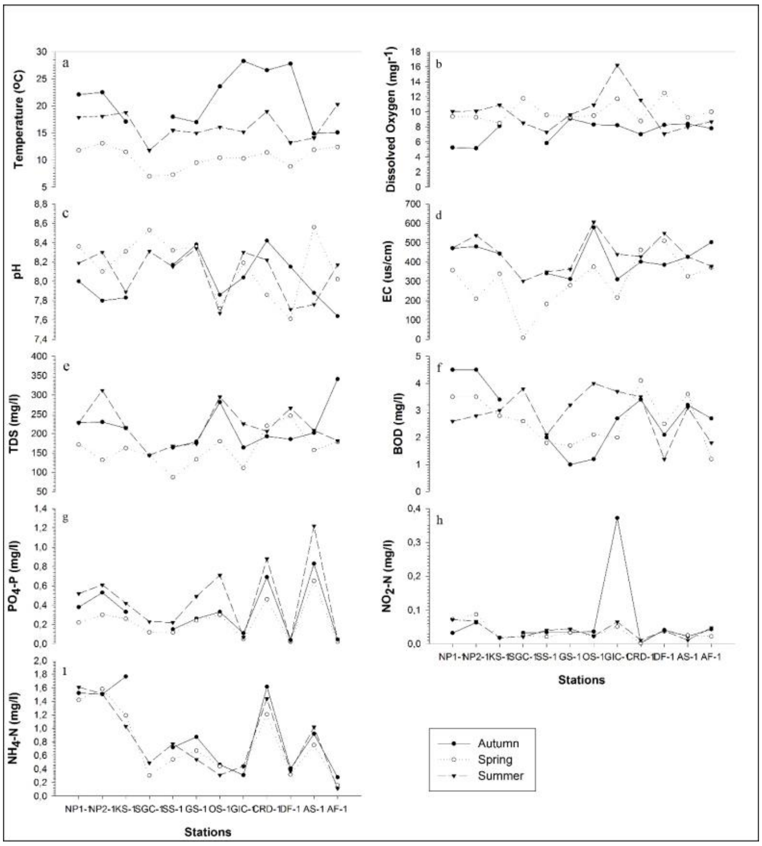

Figure 7. Seasonal change of water parameters according to the stations (a: Temperature; b: Dissolved oxygen; c: pH; d: Electrical conductivity; e: Total dissolved solution; f: Biochemical oxygen demand BOD_5; g: PO_4-P; h: NO_2-N; ı: NH_4-N)

quality characteristics in all three seasons (Sağlam, 2003), whereas the other stations showed second and third class water characteristics.

Studies conducted on Malacostraca have tended to focus on toxicology tests and fauna information. To our knowledge, this is the first study to reveal the relationships between Malacostraca species and water quality parameters in the Coruh Basin. The data presented here will likely be useful for planning future research and management efforts for the mentioned basin.

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