Investigation of the biological diversity of Trichoptera larvae in the streams of the Kastamonu (Cide)-Sinop (Ayancık) coastal region of Türkiye

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Abstract: This study was carried out to determine the biodiversity and densities of Trichoptera larvae at stations in the Kastamonu (Cide)-Sinop (Ayancık) coastal region. Benthic macroinvertebrate samples were collected from each of the 19 stations using the kick-net sampling method with a D-frame net (500-µm mesh). Using the data from collected Trichoptera larvae, the similarity, diversity, dominance and population density relationships among habitats were measured. According to the calculated Shannon-Wiener and Simpson diversity index results, the station with the highest Trichoptera diversity was determined at S2, and the station with the least diversity was S14. Similar results were obtained for the calculated population density values. Station S2 was the most balanced station in population density. Thus, biodiversity was directly related to habitat structure, anthropogenic impact and geographical conditions, and environmental factors suppress biological species diversity. It was concluded that species diversity is greater in undestroyed habitats and less in heavily destroyed habitats. In addition, the species that dominate in biodiversity similarity rates prefer their habitat.

Keywords: Trichoptera, biodiversity; Kastamonu; Sinop

Abbreviations: tation (S); Shannon-Wiener diversity index (H'); Simpson diversity index (1/*D*); Simpson dominance index (*Sd*); Shannon evenness (E_{sh}); Simpson evenness (E_{sm}); Unweighted Pair Group Means Averages (UPGMA); Multivariate Statistical Package (MVSP)

INTRODUCTION

Aquatic insects perform critical roles in ecosystem functioning through their numerical abundance and taxonomic diversity. Though aquatic insects make up only 3-5% of all insect species, they are taxonomically diverse [1] and play a critical role in the stability and maintenance of the ecosystem, especially in nutrient dynamics. Biodiversity refers to all living groups, organizational levels and the diversity of life [2-6]. Therefore, biodiversity is an important aspect in sustainable field use. Periodic calculation of species and ecosystem diversity are necessary for the protection of habitats and the continuity of their functions [7]. The order Trichoptera is likely the most widely distributed group of aquatic insects and their larvae are frequently observed in streams [8]. Numerous species of larvae live in flowing waters, and it is known that they have specific ecological and environmental needs [9]. Because of their diversity and wide range of sensitivity to aquatic conditions, Trichoptera larvae have been widely used in monitoring programs as bioindicators of organic pollution [10,11].

Trichoptera is a macroinvertebrate order that has a key role in the assessment of aquatic environments. Considering the importance of Trichoptera in their aquatic habitats, it is very important to study their biodiversity to understand their condition in nature, and studies are carried out on Trichoptera worldwide to determine biodiversity. No biodiversity studies have been carried out on Trichoptera before in the region selected. In this study, we determined the biological diversity and densities of Trichoptera at different stations in the Kastamonu (Cide)-Sinop (Ayancık) coastal region. We report that habitats exposed to environmental threats exhibit lower biodiversity than natural habitats.

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MATERIALS AND METHODS

Ethics statement

This study was carried out on Trichoptera larvae, which are considered invertebrates; therefore, ethics committee approval is not required.

Study area

The study was carried out to compare the Trichoptera biodiversity parameters in the streams in the coastal region between Kastamonu (Cide)-Sinop (Ayancık). Samples were collected from 19 stations on 9 streams within the borders of Kastamonu province, and 2 streams within the borders of Sinop province in June, July, August and September 2020-2021. Geographical and environmental information about the stations is presented in Supplementary Table S1.

Sampling and identification

Benthic macroinvertebrate samples were collected from each of the 19 stations using the kick-net sampling method with a D-frame net (500-µm mesh). The samples were collected by kicking the stones in front of the D-frame net placed at the bottom for 3 min from the downstream to the upstream in an area of 100 m^2, to include possible microhabitats at all stations. The benthic specimens and other materials (leaves, seeds, sand, stones, etc.) that were caught in the net were transferred to a container filled with water and the unused objects (leaves, seeds or some macroinvertebrates) were roughly cleaned. The material that was filtered with the help of a sieve was transferred to the container and preserved by adding 96% alcohol. In the laboratory, the Trichoptera larvae were separated and identified with the Leica S8 APO (Germany) stereomicroscope to the lowest possible systematic level using the Eutaxa Trichoptera 05 Key to Larvae from Central Europe program [12].

Data analyses

Clustering analysis of unweighted pair group mean averages (UPGMA) was used to determine differences among the stations. Diversity indices and UPGMA were conducted using the Multivariate Statistical Package (MVSP) program version 3.22 [13]. In biodiversity calculations, the Shannon-Wiener, Simpson and Simpson dominance indices were used. Shannon evenness and Simpson evenness were considered while calculating the density indices.

Diversity indices

Shannon-Weiner diversity index (*H'*)

The Shannon-Weiner diversity index is based on the calculation type and the percentage of each species within the given locality community. It integrates the richness, number of taxa (species), and equilibrium or distribution of individuals, and is calculated using the formula:

$$H' = -\Sigma\, p_i \ln(p_i),$$

where p_i is the ratio of the number of individuals of the species (i) to the total number of individuals; ln is the natural logarithm [14].

Simpson's diversity index (1/*D*)

The Simpson index is a formula used to measure the diversity of a community. In ecology, the Simpson index (among other indices) is often used to measure the biodiversity of a habitat. It considers the number of species found in a habitat and the abundance of each species. Simpson index is calculated using the formula:

$$1/D=1-\Sigma n_i/(n_i-1)/N(N-1),$$

where i is the number of species, n_i is the number of individuals belonging to a species, N is the sum of the individual numbers of the species in a region [14].

Simpson's dominance index (*Sd*)

Simpson's dominance index was used to determine dominance. Simpson's index is calculated using the formula:

$$Sd=\Sigma n_i(n_i-1) / N(N-1),$$

where i is the number of species, n_i is the number of individuals belonging to a species, N is the sum of the individual numbers of the species in a region [14].

Shannon evenness (E_{sh})

Shannon's Evenness and Simpson's Evenness indices were used to determine the population density relationships of the species:

$$E_{sh} = H'/\ln(N),$$

where H' is the Shannon-Wiener diversity index; ln – natural logarithm; N – the sum of the individual numbers of the species in a region [14].

Simpson evenness (E_{sm})

$$E_{sm} = (1/D) / S,$$

where 1/*D* is the Simpson diversity index, S is Total number of species [14].

Classification of selected habitats was also done using the MVSP 3.22 program [13]. In the evaluation of the data obtained, arithmetic group averages (unweighted pair group method with arithmetic mean (UPGMA)) were chosen as the classification method. The similarity or distance between the differences is shown by the percent similarity coefficient.

RESULTS

Sampling was performed at 19 stations on 11 streams in the Kastamonu (Cide)-Sinop (Ayancık) coastal region. The collected Trichoptera larvae were identified, and diversity indices and density indices were calculated to determine the biodiversity in habitats. In addition, the similarity of taxa between habitats is presented.

Family and taxa distributions

As a result of the study, 876 individuals and 21 taxa belonging to 8 families were recorded in the streams. Trichoptera taxa belong to the families Hydropsychidae (7), Glossosomatidae (2), Goeridae (1), Sericostomatidae (1), Hydroptilidae (1), Philopotamidae (1), Rhyacophilidae (4) and Beraeidae (1). The Hydropsychidae family was found to be the most dominant group among the collected samples. Distributions and dominance patterns, along with a list of the recorded Trichoptera taxa, are given in Table 1.

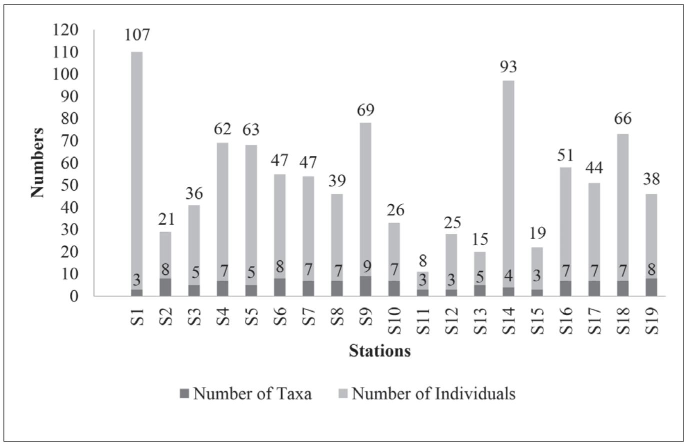

Fig. 1. Number of taxa and individuals of Trichoptera samples of the study area. In the figure, the number of individuals belonging to the taxa detected in the stations is presented. S – station.

The highest numbers of taxa were determined in S9 (8). The lowest numbers of taxa were determined in S1 (3), S11 (3), S12 (3), and S15 (3). The maximum number of individuals were collected at station S1 (107), while the fewest individuals were collected at station S11 (8) (Fig. 1).

Index results

The Shannon-Wiener and Simpson diversity indices were calculated for each station to determine species diversity. Both indices showed that the highest diversity values were observed at S2 with values of 2.021 (Shannon-Wiener) and 0.862 (Simpson). Both indices showed that the lowest diversity values were observed at station S14 with values of 0.411 (Shannon-Wiener) and 0.18 (Simpson). Simpson dominance values, which increased or decreased in inverse relationship with diversity, were calculated with a maximum of 0.905 at S2 and a minimum of 0.182 at S14, depending on the results of biodiversity parameters. Similar results were obtained for the calculated population density values. Station S2 was the most balanced station in population density with a value of 0.972 according to the Shannon evenness index, and a value of 0.985 according to the Simpson-evenness index. According to these indices, the station with the lowest taxa richness was S14 with values of 0.297 (Shannon evenness index) and 0.24 (Simpson evenness index) (Table 2).

Table 1. Distribution of Trichoptera taxa

Taxa List	Stations																		
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**
Beraeidae																			
Ernodes articularis (Pictet, 1834)									+										
Glossosomatidae																			
Glossosoma conformis (Neboiss, 1963)									+										
Glossosoma sp.				+													+		
Goeridae																			
Silo pallidus (Banks, 1897)								+											
Hydropsychidae													+						
Cheumatopsyche lepida (Pictet, 1834)				+	+	+	+	+		+	+					+		+	+
Cheumatopsyche sp.						+													
Hydropsyche sp.	+	+	+					+	+	+		+	+			+	+	+	+
Hydropsyche instabilis (Curtis, 1834)	+	+	+	+	+		+	+	+	+		+	+	+		+			
Hydropsyche incognita (Pitsch, 1993)		+	+	+	+	+	+	+	+	+				+	+	+		+	+
Hydropsyche bulbifera (McLachlan, 1878)									+		+					+			
Hydropsyche pellucidula (Curtis, 1834)	+	+	+	+	+	+	+		+					+		+	+	+	+
Hydropsyche dinarica (Marinkovic 1979)			+																
Hydropsyche botosaneanui (Marinković-Gospodnetic, 1966)		+				+											+		+
Leptoceridae																			
Athripsodes albifrons (Linnaeus, 1758)									+										
Athripsodes bilineatus (Linnaeus, 1758)													+						
Philopotamidae																			
Wormaldia subnigra (McLachlan, 1865)		+		+		+	+		+		+	+	+	+	+		+	+	+
Rhyacophilidae																			
Rhyacophila sp.										+								+	
Rhyacophila dorsalis (Curtis, 1834)				+	+	+	+	+	+	+					+		+	+	
Rhyacophila obliterata (McLachlan, 1863)		+					+									+			+
Rhyacophila fasciata (Hagen, 1859)																			+
Sericostomatidae																			
Sericostoma personatum (Spence in Kirby & Spence, 1826)		+																	

Table 2. Biodiversity and density indices at all stations.

Stations	Number of Taxa	Number of Individuals	Biodiversity Indices			Density Indices	
			H'	**(1/D)**	**Sd**	E_{sh}	E_{sm}
S1	3	107	0.868	0.549	0.554	0.79	0.824
S2	8	21	**2.021**	**0.862**	**0.905**	**0.972**	**0.985**
S3	5	36	1.177	0.613	0.63	0.732	0.766
S4	7	62	1.328	0.65	0.661	0.682	0.759
S5	5	63	0.883	0.423	0.43	0.549	0.528
S6	8	47	1.369	0.609	0.623	0.658	0.696
S7	7	47	1.819	0.828	0.846	0.935	0.965
S8	7	39	1.411	0.685	0.703	0.725	0.799
S9	9	69	1.807	0.806	0.818	0.822	0.907
S10	7	26	1.683	0.772	0.803	0.865	0.901
S11	3	8	0.974	0.594	0.679	0.887	0.891
S12	3	25	0.76	0.435	0.453	0.692	0.653
S13	5	15	1.205	0.596	0.638	0.749	0.744
S14	4	93	**0.411**	**0.18**	**0.182**	**0.297**	**0.24**

Supplementary Table S3. continued

S15	3	19	0.661	0.355	0.374	0.601	0.532
S16	7	51	1.319	0.637	0.649	0.678	0.743
S17	7	44	1.379	0.651	0.666	0.709	0.759
S18	7	66	1.3	0.663	0.673	0.668	0.773
S19	8	38	1.67	0.74	0.76	0.803	0.845

H' – Shannon-Wiener diversity index; 1/*D* – Simpson diversity index; Sd – Simpson dominance index; E_{sh} – Shannon evenness; E_{sm} – Simpson evenness.

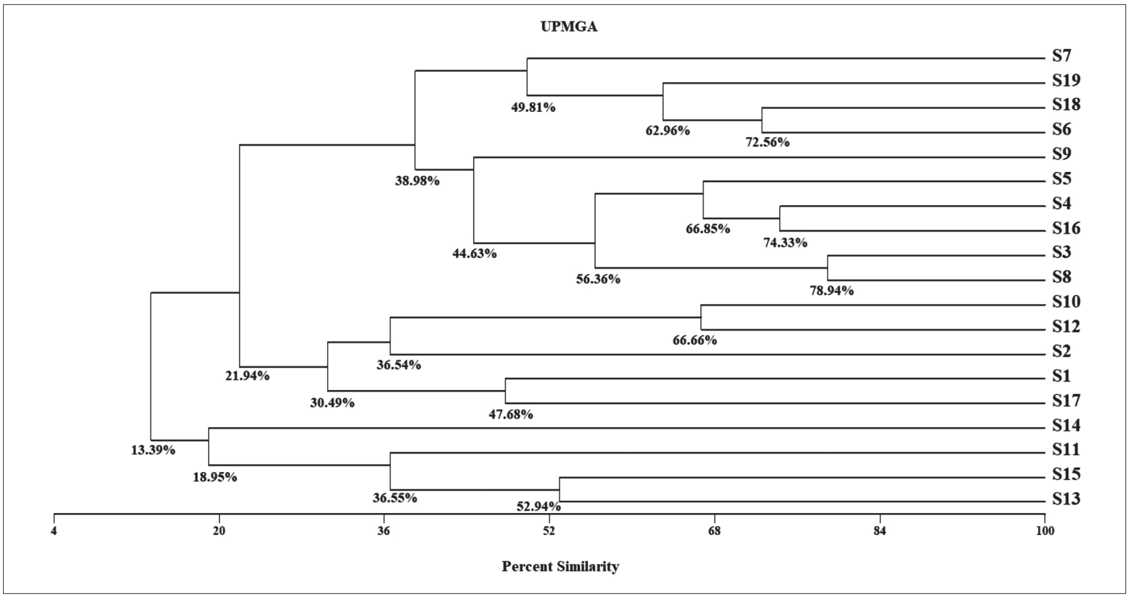

Fig. 2. Inter-station similarity percentage of taxa

UPGMA analysis

The percent similarities of each sampling station were detected using UPGMA analysis. According to this analysis, all stations within the scope of the research were similar at 13.39%. Among the stations selected based on the percent similarity index calculated according to differences of the larvae, the stations with the highest similarity of 78.94% were S8 and S3. The 2 stations with the least similarity rate were S1 and S17 with a value of 47.68%. Other similar dual stations were S4 and S16 with 74.33% (Fig. 2).

In this study, 876 individuals and 21 taxa belonging to 8 families were determined in the streams between Cide and Ayancık. Most taxa belong to the Hydropsychidae family. The highest number of taxa was recorded in S9 (8) while the least number of taxa was recorded in S1, S11, S12 and S15 (3). According to the results of calculations of the Shannon Wiener diversity, Simpson diversity and Simpson dominance indices, the highest diversity was determined in S2 and the lowest diversity in S14. The Shannon evenness and Simpson evenness index results are in parallel with the diversity index. According to the results of the UPMGA analysis carried out to determine similar habitats according to the presence of taxa, the stations with the highest similarity of 78.94% were S8 and S3. The 2 stations with the lowest similarity rate of 47,68% were S1 and S17.

DISCUSSION

This study was carried out to compare Trichoptera biodiversity parameters at stations in the coastal region between Cide (Kastamonu) and Ayancık (Sinop), while taking into account stream morphology and natural and anthropogenic effects. A total of 19 stations were identified on 11 streams. As a result of the identification of the collected larvae samples, a total of 876 individuals, 21 taxa and eight families were identified.

The family that best represents the study was found to be Hydropsychidae with 7 taxa. In the study conducted in Tunceli, the dominant family was recorded as Hydropsychidae with 9 taxa [15]. Also recorded was the Hydropsychidae family with a maximum of 6 taxa on the Araç Stream in Kastamonu [16]. Similarly, in other studies, the Hydropsychidae family was found to be the most dominant family, and the coexistence of species belonging to this family is the prominent feature of the family [17,18]. In addition, Hydropsychidae is recognized as a very tolerant family worldwide, with species separated according to different water quality characteristics along the stream [17,19,20].

The Shannon-Wiener and Simpson diversity indices were calculated to determine species diversity. Both indices showed that the lowest diversity value was in S14 and the highest was in S2. Similar results were obtained when population density values were calculated based on the biodiversity parameter results according to the Simpson dominance values. There is a close relationship between the degree of evenness and the Shannon-Wiener index. Evenness is the relative density of species found in a community. In other words, evenness expresses the ratio of the contribution of a species in a community or ecosystem as the number of individuals relative to each other [21,22]. As a result of the calculations, the highest density was found in S2 and the lowest in S14. Considering the stream morphology of S2, it has a natural coastal structure, consisting of small pebbles and is slow-flowing and shallow. In addition, this station is far from anthropogenic effects that negatively affect diversity. The physicochemical and hydrological features (pH, dissolved oxygen, the temperature of the water, etc.) of the streams may be effective in producing high diversity values. The combined effects of season, stream patterns and stream-bed morphology are known to have a significant impact on Trichoptera populations [23]. Station S14 has the least diversity according to the indices and has an artificial shore. There are camping and picnic areas along the stream banks. It was observed that the habitat was destroyed by construction equipment upstream of the station. In addition, this stream, which has a deep and wide bed, has a very high flow rate. While the species diversity was expected to be high in the station according to the stream morphology [24], it can be seen that the main reason for low species diversity is the significant pressure exerted by human impacts on species [25,26].

The taxa at all stations were similar with a rate of 13.39%. The main reasons for this similarity could be that the stations are located in the same geographical region, that they have the same climatic characteristics, and their altitude and environmental characteristics are similar. The two stations with the most similarity in the study were S8 and S3, with a rate of 78.94%. The diversity and dominance values of both stations are close to each other. The most dominant species at these stations is *Hydropsyche incognita*. In the similarity ratio calculations of the stations that were within the scope of the research, stations S11, S13, S14 and S15 are separate from the other stations and form a subgroup. The similarity rate of the S15 and S13 stations is 52.94%. According to UPGMA analysis, the S15 station shows 36.55% similarity with stations S13 and S11. Stations S15, S13 and S11 are 18.94% similar to station S14. The dominant species that distinguishes these 4 stations from the others is *Wormaldia subnigra*. *W. subnigra* shows dominance at 50% in station S11, 60% in S13, 90.32% in S14 and 78.95% in S15. The diversity values of the stations are listed as follows: for S11 – 0.974, S13 – 1.205, S14 – 0.411 and S15 – 0.661 according to the Shannon-Wiener diversity index. On the other hand, the diversity values of the stations according to the Simpson diversity index are listed as follows: for S11 – 0.594, S13 – 0.596, S14 – 0.18 and S15 – 0.355. According to the diversity indices of these stations, this result is indeed supported by the diversity index results [21,22]. The reason why *W. subnigra* is dominant compared to other species in these 4 stations may be due to the similar habitat structures. It was also proven in studies that natural habitats can be grouped among themselves in their similarity. This is mostly due to the specialization of insect species to habitats [7,25,27,28].

It was determined that biodiversity is directly related to habitat structure, anthropogenic impact and geographical conditions. Since it was established that environmental factors suppress biological species diversity, it was concluded that species diversity is greater in undestroyed habitats and that lower diversity characterizes heavily destroyed habitats. In addition, the taxa that dominate with regard to their biodiversity similarity rates prefer specific habitats. Finally, physicochemical parameters were not taken into account in this study. More detailed and comprehensive results can be obtained by using these parameters in future studies.

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Conflict of interest disclosure: The authors declare no conflict of interest.

Data availability: All data underlying the reported findings have been provided as part of the submitted article and are available at: https://www.serbiosoc.org.rs/NewUploads/Uploads/Ozalp%20et%20al_8329_Data%20Report.pdf

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SUPPLEMENTARY MATERIAL

Supplementary Table S1. The sampling sites with geographic coordinates, altitude, habitats, and riparian vegetation.

Station Code	Stream District Province	Latitude (°N) Longitude (°E)	Altitude (m)	Stream wide (m)	Habitat	Riparian vegetation
S1	Karacehennem Boğazı, İnebolu, Kastamonu	41°58'18.25" 33°36'46.28"	21.7	25	Rocks, gravel, big stones, and sand	-
S2	Söke, İnebolu, Kastamonu	41°56'39.26" 33°46'9.18"	77.4	10	Small gravel, gravel, sand and silt	+
S3	Evrenye, Gemiciler, Kastamonu	41°56'36.09" 33°53'33.60"	105	10	Big stones, coarse gravel and sand	+
S4	Ezine, Bozkurt, Kastamonu	41°55'9.78" 34°2'45.79"	121	5	Gravel, coarse gravel big stones and sand	+
S5	Ezine, Bozkurt, Kastamonu	41°56'23.54" 34°1'53.91"	72.2	30	Big stones, coarse gravel, gravel and sand	+
S6	Akçay, Çatalzeytin, Kastamonu	41°54'57.27" 34°14'13.41"	75.5	15	Big stones, coarse gravel and silt	+
S7	Akçay, Çatalzeytin, Kastamonu	41°52'41.71" 34°16'4.53"	154	1	Big stones, small and coarse gravel,	+
S8	Akçay, Çatalzeytin, Kastamonu	41°49'54.20" 34°16'19.15"	254	3	Big stones, coarse, small gravel and sand	+
S9	Meset, Doğanyurt, Kastamonu	41°59'29.16" 33°26'15.48"	36.2	5	Big stones, coarse, small gravel and sand	+
S10	Terme, Çayyaka, Kastamonu	41°52'59.18" 33°11'32.84"	168	2	Big stones, coarse gravel, small gravel	-
S11	Terme, Çayyaka, Kastamonu	41°56'47.95" 33°12'25.17"	24.6	5	Big stones, coarse gravel and sand	+
S12	Şehriban, Kumköy, Kastamonu	41°52'59.15" 33°6'51.60"	43.9	15	Big stones and coarse gravel	+
S13	Irmak, Cide, Kastamonu	41°52'5.69" 33°0'41.74"	59.2	2	Rocks, large stones, coarse gravel and sand	-
S14	Irmak, Cide, Kastamonu	41°52'5.87" 32°56'33.75"	8.41	30	Big stones, coarse gravel and sand	+
S15	Irmak, Cide, Kastamonu	41°49'45.35" 32°58'49.95"	28.3	25	Big stones, small, coarse gravel and sand	+
S16	Türkeli, Türkeli, Sinop	41°54'54.69" 34°21'16.06"	88	2	Big stones, small gravel and gravel	+
S17	Türkeli, Türkeli, Sinop	41°52'51.17" 34°24'29.17"	313	2	Big stones, small gravel, sand	+
S18	Ayancık, Ayancık, Sinop	41°51'20.20" 34°30'11.66"	196	5	Coarse gravel, gravel	+
S19	Ayancık, Ayancık, Sinop	41°53'51.61" 34°34'40.43"	53.9	5	Big stones, small, coarse gravel and sand	+