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Original Article

Assessment of habitat suitability index of *Capoeta* species in the Caspian Sea and Namak Lake basins, Iran

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Abstract: Habitat suitability index (HSI) models are usually used to forecast habitat quality and species distributions and are used to develop biological studies, management priorities and anticipate possible changes under different management or climate change situations. This study was conducted to identify the habitat suitability index of three species namely, Capoeta *buhsei*, *C. razii* and *C. alborzensis* in the Kordan, Taleghan and Jajrood Rivers, respectively. At each station, environmental variables including temperature, dissolved oxygen, pH, EC, TDS and hydrological parameters such as flow velocity, depth, width, average diameter of stones and amount of phosphate, nitrate and ammonium were measured. The results showed that suitable habitats for these species are those with a high stone diameter, high temperature, low flow velocity and in areas where the width of the river is low. With respect to the abundance of fishes sampled in this study, the central and lower regions of the Jajrood and Kordan Rivers and the stations far from the dam on the Taleghan River are favorable habitats for the studied *Capoeta* species.

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Introduction

Many habitats on the planet including rivers are seriously affected by human activities which strengthen the vitality of studies on these ecosystems especially those that investigating the relationship between habitat factors and their inhabitants (Bovee, 1986). Desirable habitats have significant impacts on species survival and reproduction, and are highly regarded in the wildlife management and conservation (Mack et al., 1997). The fish species distribution undergoes by the environmental factors and meanwhile the structure of fish communities can be highly impacted by these factors both at spatial and temporal scales (Hackradt et al., 2011). Each fish species prefers a particular habitat and this habitat is where a fish encounter desirable properties, such as sufficient oxygen, tolerable temperature, adequate food and hiding places (Thurow, 1997). The frequency of loss and fragmentation of these habitats due to the pollution, manipulation, and other human activities are common problems that threaten the ecological functions (Dong et al., 2013). Loss of habitat, in terms of quantity and quality, is an important factor decreasing the abundance of aquatic organisms and a major threat to biodiversity. Therefore, habitat is considered as one of the most important factors in species conservation (Rashleigh et al., 2004).

The quality of different habitats in a river for one species is defined by the relative abundance of its members. Usually, organisms are more abundant in places where the quality of the habitat is high, and few individuals are found in poor habitats, with no species in completely unsuitable habitats (Jowett et al., 2008). Endangered species can be assisted before extinction by focusing on the conservation of specific habitats and identification of suitable habitat types for these species.

The habitat suitability index is an analytical tool used to indicate the preference of different species for a combination of variables (Armour and Taylor, 1991; Jowett et al., 2008). Habitat suitability models (HSM)

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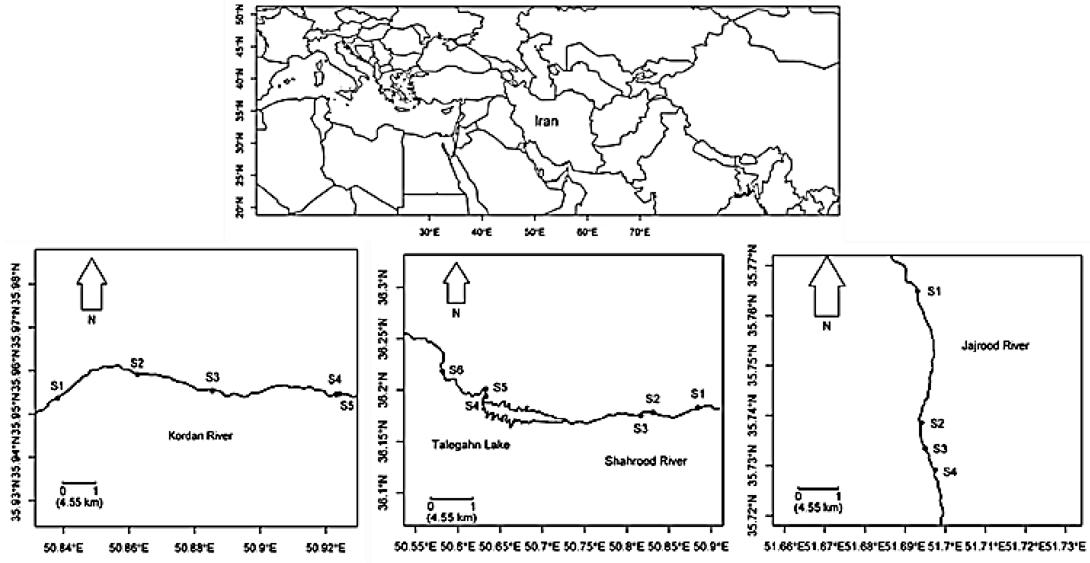

Figure 1. Map of study areas and location of sampling stations in, Kordan, Taleghan and Jajrood Rivers.

are used for a range of expected habitat conditions in a study area. In these models, a number of habitat stations are evaluated and habitat suitability index is calculated. The purpose of these studies can be to determine the high (0.7-1), medium (0.3-0.7) and low (0.3-0) quality stations, respectively (Brooks, 1997) to find the availability of habitat for many freshwater, brackish and saline water species or determine the species' habitat preferences which is generally intended to assess the effects of human activities (Brown et al., 2000).

The genus *Capoeta* consists of medium to large species that have a fusiform body, small scales and almost big and subterminal mouth (Eagderi et al., 2015; Coad, 2018; Çiçek et al., 2018). *Capoeta* species are important in terms of fishing in inland waters, aquaculture, sport fishing and animal geographical studies (Sammaee et al., 2006). Fish ecosystem conservation has a great importance, this study was thus conducted to identify the habitat suitability index of three species namely, *Capoeta buhsei*, *C. razii* and *C. alborzensis* in the Kordan, Taleghan and Jajrood rivers, respectively. *Capoeta buhsei* has a wide distribution in the Namak Lake and Dasht-e Kavir basins (Roudbar et al., 2017; Esmaeili et al., 2018), which can be an appropriate candidate for the study of intraspecific compatibility. All three rivers have similar latitude and the amount of anthropogenic effects, and almost are in the same situation, therefore this study stands for answering the question whether the greater distribution of *C. buhsei* is due to its more resilience in habitat suitability index compared to the other two species?

Materials and Methods

Sampling stations: Sampling of *Capoeta* species from the Kordan, Taleghan and Jajrood rivers was carried out in December 2017. First of all, a field survey was conducted to determine the places of sampling stations and examine their approximate situation in terms of river morphology and the variables such as the width, depth and vegetation type of the area. Then the exact coordinates of the stations were determined using Google Earth software and Garmin GPS device (Etrex 30x) (Fig. 1). Five sampling stations in the Kordan River, six stations in the Taleghan River and four stations in the Jajrood River were determined.

Fish Sampling: The specimens were sampled using an electrofishing device (Samus MP750). Samples were anesthetized in 0.1% clove solution after collection and the number of each species at each station was counted. After taking the pictures of the specimens, they were returned to the river (Price and Peterson, 2010).

Physicochemical analysis of water: Immediately after

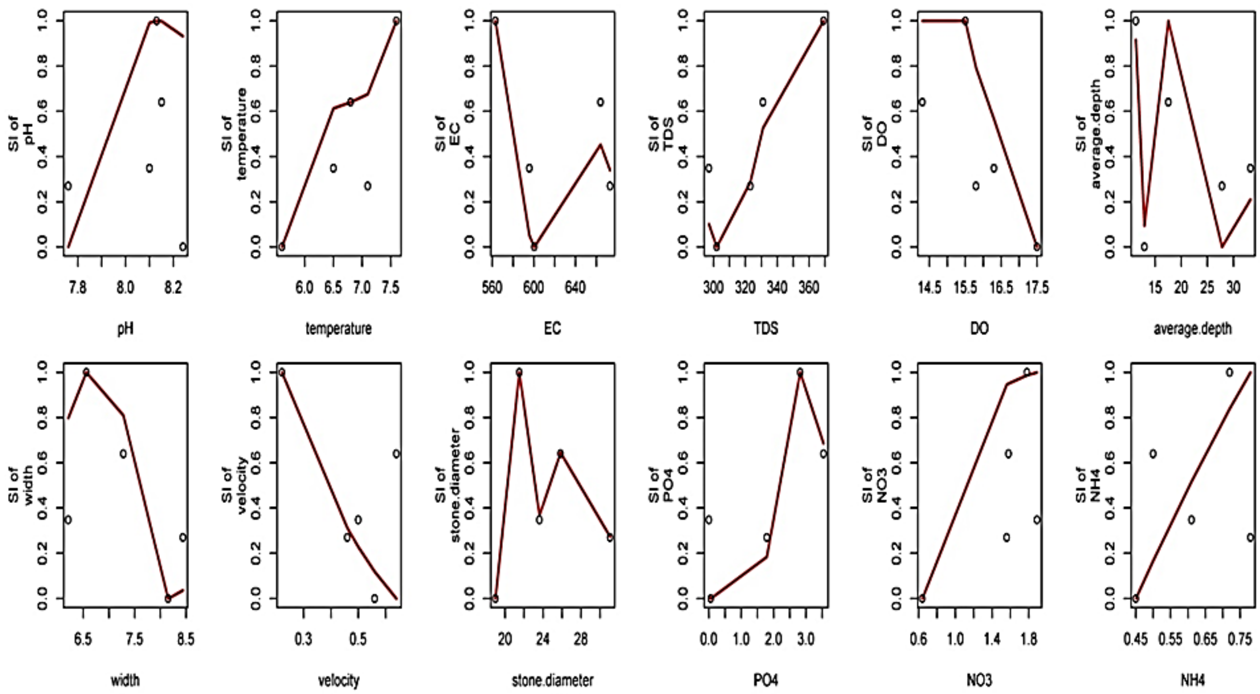

Figure 2. SI charts for environmental variables: pH, temperature, EC, TDS, dissolved oxygen, river depth, river width, water velocity, stone diameter, PO_4, NO_3, NH_4 in the Kordan River.

sampling, environmental variables, including temperature (°C), dissolved oxygen (ppm), pH, EC (µs), TDS (mg/l) and hydrological parameters such as flow velocity (cm/s), depth (cm), width (m) and average diameter of stones (cm) were measured at each station. Then the water samples were transferred to the laboratory to measure concentration of phosphate, nitrate and ammonium as the most important nutrients, using the standard methods. The width of the river was measured using a tape meter at three points; downstream, middle and upstream of each station and the mean of them was considered as the mean width of the river at each station. The depth of the river at each station was measured at 20 points and the mean of these numbers was considered as the depth of the river (Gorman and Karr, 1978; Pusey et al., 1993). Using a floating object, the flow velocity was measured three times in each station, and the mean value after the multiplication in the correction factor (0.88), was considered as the flow velocity (Hasanli, 2000). At each station, temperature, oxygen, pH, EC and TDS were randomly measured at three points the portable electronic device (WTW) and their average were calculated. The average stone diameter was recorded randomly using a quadrat (50 × 50 cm) (Platts et al., 1983).

Imaging and statistical analysis: To calculate the HSI, a nonparametric method namely kernel smoothing was used to examine the relationship between each environmental variable and the number of fish in each station.

SI graphs: First, to find the bandwidth of the kernel smoothing, a polynomial regression was calculated to model the predicted values. To find the SI graphs, the predicted values were standardized using the following equation:

$$\frac{x_i - \min(x)}{\max(x) - \min(x)}$$

Where, xi= the environment variable, min (x) = the minimum value of each variable and max (x) = the maximum value of each variable. Then, the graphs of these values were standardized and plotted for each environmental variables, including pH, temperature, EC, TDS, depth, width, velocity, stones diameter, PO_4, NO_3 and NH_4.

Calculating HSI: The mean of the arithmetic, the geometric, the minimum, and the maximum of the SI values from the SI graphs for each independent

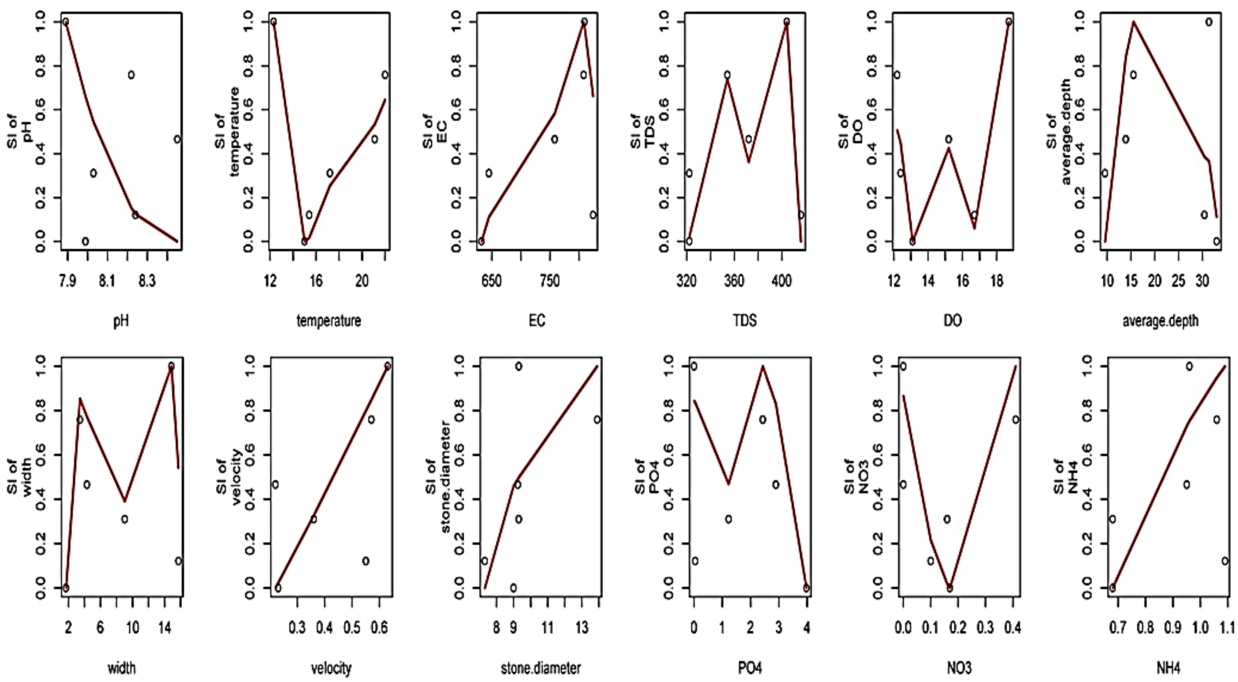

Figure 3. SI charts for environmental variables: pH, temperature, EC, TDS, dissolved oxygen, river depth, river width, water velocity, stone diameter, PO_4, NO_3, NH_4 in the Taleghan River.

variable were calculated and considered as HSI at each sampling station. The relationship between these values and the number of fish at each station was examined using a linear regression. After fitting the linear regression between the number of fish and HSI, the AIC value was calculated. Then, to illustrate the relationship between the number of fish and HSI obtained from different stations, four graphs were plotted based on four HSI calculation methods.

Results

SI graphs: SI graphs for the environmental variables in the Kordan River are shown in Figure 2. The number of fishes increased in pH = 8-8.2 and also an increase was found with rise of temperature and EC values. As TDS increased, the number of fish increased significantly and the highest number of fish was found in high DO concentration and a depth of 20 cm. In the river width of 6-7 m, the number of fish increased while the number of fish had negative correlation with flow velocity. The larger the stone diameter, the more fish were found and with increase of PO_4 to a certain extent, the number of fish increased. Also, increase of NO_3 and NH_4 concentration had positive effects on the number of fishes.

The SI graphs for the environmental variables in the Taleghan River are shown in Figure 3. In the range of pH = 7.9-8 and in the high temperatures, the number of fish increased. When the EC and TDS increased, the number of fish increased. In the stations with more DO, the more fish were available. Up to 15 cm depth, the number of fish increased, and then the number of fish decreased with increase of depth. The number of fish was more in the 2-5 m of the river width. At high velocity above 2 m/s, the number of fish decreased. More specimens were found by the stones with larger diameters. By increasing PO_4 to a certain extent, the number of fish increased and above that, the number of fish decreased. Both NO_3 and NH4 had positive correlation with the number of fish.

The SI graphs from the Jajrood River indicated that the number of fish increased in the range of pH = 7.5-8 and in high temperatures. When EC and TDS increased, a significant increase was found in the number of fish. The highest number of fish was found in high DO values. The maximum number of fish was found at the depth of 20 cm and declined by increase of depth. There was a large number of fish in the widths between 14 to 16 m while water velocity

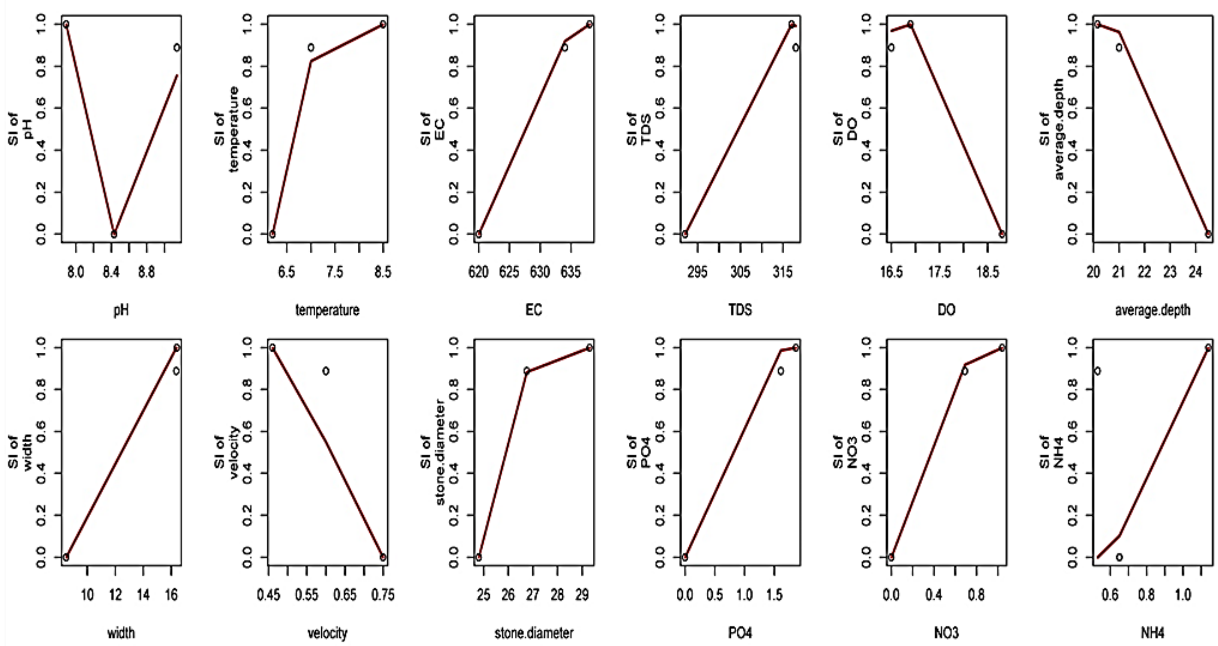

Figure 4. SI charts for environmental variables: pH, temperature, EC, TDS, dissolved oxygen, river depth, river width, water velocity, stone diameter, PO_4, NO_3, NH_4 in the Jajrood River.

Table 1. HSI index calculated with four methods of arithmetic mean, geometric, minimum and maximum.

River	Station	HSI (arithmetic mean)	HSI (geometric mean)	HSI (minimal SI)	HSI (maximal SI)
Kordan	1	0.095	NA	0.000	0.933
	2	0.454	0.249	0.004	1.000
	3	0.656	NA	0.000	1.000
	4	0.404	NA	0.000	1.000
	5	0.979	0.977	0.839	1.000
Taleghan	1	0.859	0.824	0.366	1.000
	2	0.387	NA	0.000	1.000
	3	0.536	NA	0.000	1.000
	4	0.106	NA	0.000	0.661
	5	0.257	NA	0.000	0.545
	6	0.808	0.736	0.152	1.000
Jajrood	1	-	-	-	-
	2	0.009	NA	0.000	0.103
	3	0.814	NA	0.000	1.000
	4	1.000	1.000	1.000	1.000

showed a negative effect on fish number. More fish were found in stations with large stone diameter and also the fish abundance increased by rise of PO_4, NO_3 and NH_4 (Fig. 4).

HSI results: The greatest HSI were found in the 5th station of the Kordan River, the 1st and 6th stations of the Taleghan and the 4th station of the Jajrood River (Table 1, Fig. 5).

Discussions

Rivers are amongst ecosystems which have been well-known to highly be affected by human activities. Fish communities are the organisms which reflect such effects through different ways, including theirs distribution and abundance (Ferreira, 2007). As a result, conservation of aquatic animals requires the recognition of the natural requirements of species and the study of habitat priorities (Garland et al., 2002). The results of SI graphs for environmental variables, including pH, temperature, EC, TDS, DO, river depth, river width, velocity, stone diameter, PO_4, NO_3 and NH_4 for assessing the habitat suitability of

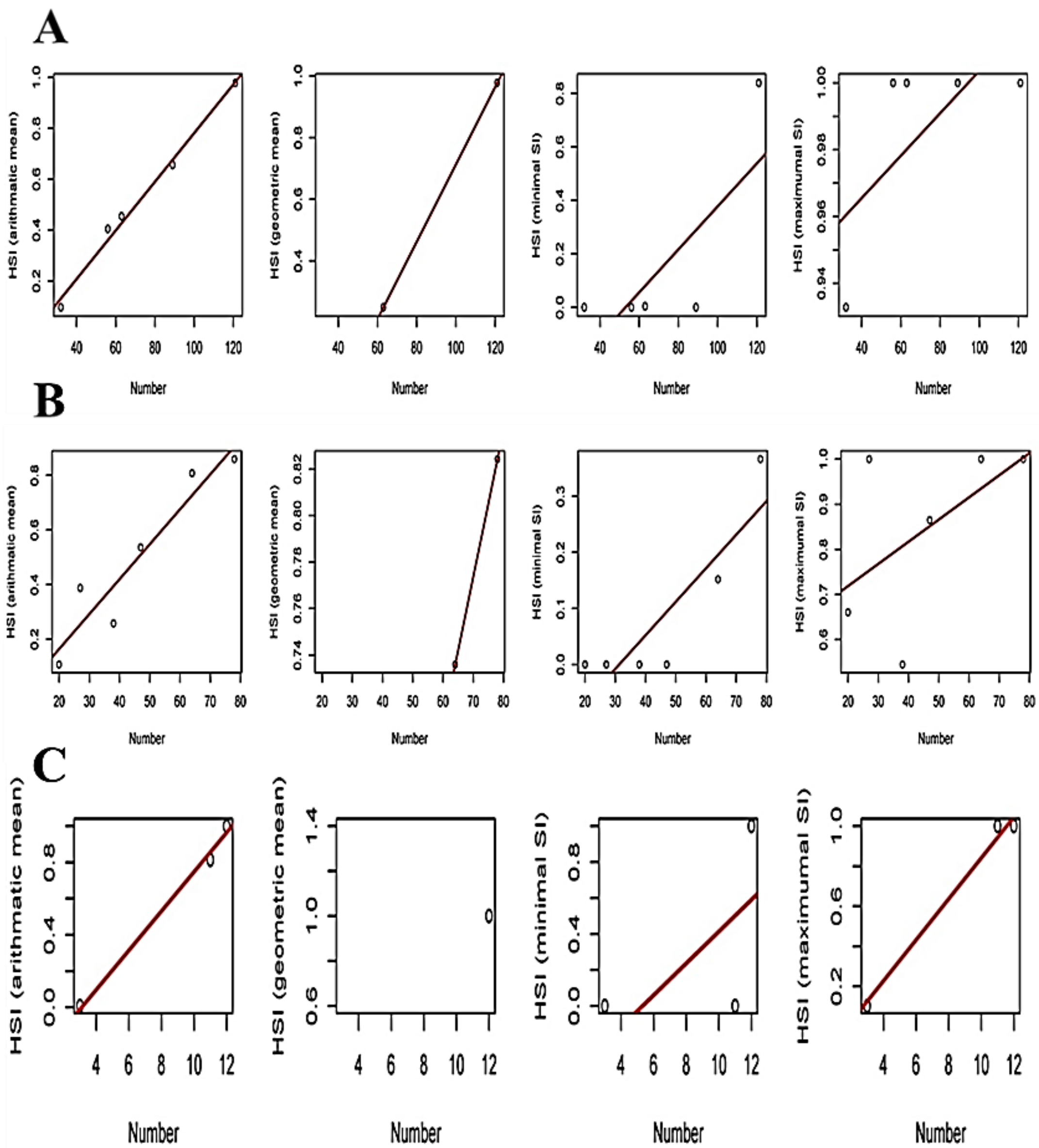

Figure 5. Relationship between number of fish and HSI in the A: Kordan, B: Taleghan and C: Jajrood Rivers.

three species, *C. buhsei* in the Kordan River, *C. razii* in the Taleghan River and *C. alborzensis* in the Jajrood River showed that for all three species the suitable habitat was a habitat with neutral pH, high temperature and sufficient DO. Several studies have been conducted on the effect of temperature on fish life. Nukazawa et al. (2010) used water temperature as an environmental index for *Plecoglossus altivelis altivel* as an annual migratory species. Smith and Sklarew (2012) also showed that the water temperature had a negative effect on *Salvelinus fontinalis* populations. Water temperature is an important factor in fish life and in some cases, its variation is a natural stimulant and indicates the beginning of some processes such as spawning and migration. Usually within optimum temperature ranges, an increase in temperature increases the digestibility rate of *Capoeta* species. Consequently, the digestion rate increases, the food intake also increases (Nikolski, 1963; Zamani Faradonbe et al., 2017) that may be the point that high temperature is more appropriate for *Capoeta* species.

Increasing the EC and TDS increased the number of fish but above it the number of fish showed an inverse trend. In this study, EC and TDS increased from upstream to downstream, which is consistent with the results of An et al. (2012). The electrical conductivity (EC) is the ability of a solution to carry electrical current, and associated with total dissolved solids (TDS) and concentration of many materials (Simonson et al., 1993). Differences in water discharge across the river can be the most relevant parameter changing these two factors.

According to our results, the suitable habitat for each of the three studied species is a habitat with lower velocity and depth. Depth and water velocity are two influencing factors in distribution and abundance of fishes (Baker and Ross, 1981). For example, McCain (1992) found that Chinook salmon (*Oncorhynchus tshawytscha*) in early life stages uses low-velocity areas, as these areas can be a good protector against predators and flood.

In the present study, the preferred points were the places with small width and large stone diameter. Habitats with great river width may decrease the survival rate, therefore fish species prefer to live in points of rivers with small width (Littlejohn et al., 1985). Preference of fishes to substrates with large stones is probably due to the fact that large pieces of stone are used as a shelter against the flow. In addition, due to the creation of a large surface and more dead space, the surface of such stones has a high density of food.

In all three rivers, the increase of water chemical factors such as PO_4, NO_3 and NH_4 increased the number of fishes to a certain extent. Nutrients in form of phosphorus and nitrogen increase the growth of phytoplankton and provide more natural food for fishes. In these cases, the increased amount of nutrients to a certain extent will result in an optimal increase in the number of fish and their size.

Similar to the present study, Zamani Faradonbe et al. (2015) evaluated the habitat suitability index of *C. razii* in the Taleghan River. The results showed that the suitable habitat characteristics of this species were the height of 1550-1400 m, the depth of 40-55 cm, the river width of less than 5 m, the flow velocity between 0.6 to 0.3 m/s, the average stone diameter of 30-45 cm and the temperature between 16-18°C. Then, the optimal habitat for this fish is low altitudes, large stone diameter, high water temperature, low flow velocity and small river width. Regarding the abundance of sampled fish in this study, it can be noted that the central and lower regions of the Kordan and Jajrood rivers and the far stations from the dam (1 and 6) in the Taleghan River provide the most favorable habitats for these species. This suggests that the habitat of a species is influenced by various factors and any change in each of the environmental variables can change the living conditions of the fish.

Conclusion

Preliminary studies and pre-sampling showed that among these species, *C. buhsei* has a higher distribution in Namak Lake and Dasht-e Kavir basins, which can be an appropriate candidate for the interspecific adaptability study. All three rivers in terms of latitude and the amount of anthropogenic effects almost are in the same situation, and the results of this study rejected the hypothesis that the wide distribution of *C. buhsei* is due to its different habitat preferences compared with those of the other two species. Therefore, the greater distribution of *C. buhsei* may be due to the ability of this species to adapt to environmental changes that requires further studies.

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