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Fish assemblages as influenced by environmental factors in Taleghan River (the Caspian Sea basin, Alborz Province, Iran)

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ABSTRACT

The relationship between some habitat factors and fish assemblage was analyzed in the Taleghan River, Alborz Province, Iran. Fish specimens from thirty-three sites were sampled by electrofishing device in October 2014. The habitat parameters, including elevation (m), water depth (cm), river width (m), river slope (%), current velocity ($m.s^{-1}$), number of large stone (> 15 cm), average stone diameter (cm), substrate index (SI%), level of potamal cover, level of periphyton cover, pH, electrical conductivity, total dissolved solid and temperature (°C) were measured in all sampling sites. Canonical correspondence analysis was performed to study the relationship between fish assemblage and environmental factors. The results showed that the fish assemblages of the Taleghan River are organized by the environmental variables. Based on the results, the abundance of *C. gracilis* did not show any distinctive relationship with examined habitat variables, whereas the presence and abundance of *B. cyri* showed a rise with increasing substrate index and bed stone diameter and a decline with increasing river width and flow velocity. The presence and abundance of *O. bergianus* rises with the increasing current velocity and river width and showed a decline with increasing slope, depth and substrate index. The results of this study provides insights into the ecology of fishes in the Taleghan River and can help an effective fisheries management of other rivers of the Caspian Sea basin.

Key words: Fish, Environmental variables, Diversity, Canonical correspondence analysis.

INTRODUCTION

The relationship between habitat parameters and fish assemblage is one of the main themes in aquatic ecology (Angermeier & Davideanu, 2004). The structure of fish assemblages is generally dependent on many biotic (e.g. habitat biodiversity, dispersal, competition, and predation) and abiotic (e.g. pH, alkalinity, DO, elevation, stream size, depth, and climate) factors (Ricklefs, 1987; Jackson & Harvey, 1989; Persson, 1997; Brown, 2000; Angermeier & Davideanu, 2004). These factors can also act independently and constrain the presence and distribution of stream fishes through a hierarchy of nested environmental filters. In addition, the features of fish assemblages in riverine ecosystems are dependent on the interaction of multiple ecological processes over changing temporal and spatial scales (Poff, 1997). Furthermore, the anthropological activities can affect riverine ecosystems (Cowx & Gerdeaux, 2004; Van Zyll de Jong *et al.,* 2004) by changing the biotic and abiotic factors (Jennings *et al.,* 1999).

The relationships between abundance and distribution patterns of fish assemblage and environmental factors that are responsible for their organization, is essential for understanding the community dynamics and predicting how external (e.g. introduction of exotics) and internal (e.g. eutrophication) mechanisms could influence fish assemblage structure (Robinson & Tonn, 1989). In addition, understanding the temporal and spatial changes in fish assemblage can be useful as a basis for management of stream fisheries (Van zyll de jong *et al.,* 2004).

Since, there is no information available about the spatial and temporal patterns of fish assemblage and its relationship with environmental factors in any river of the Caspian Sea basin with 119 confirmed species (Esmaeili *et al.,* 2010); hence, this study was carried out to describe the relationship between several habitat characteristics and fish assemblage in the Taleghan River (a river in the Caspian Sea basin, Iran) to address the important and effective environmental factors on its fish assemblage using presence-absence and abundance data of fishes and measuring environmental factors in situ influences the variability of fish assemblage.

MATERIALS AND METHODS

Sampling

Thirty-three sampling sites distributed in elevation profiles were selected to cover all available habitats along the Taleghan River (Fig 1). Fish were collected by a backpack electrofishing device (Samus Mp750, 45 cm diameter, aluminium ring anode) and using upstream and downstream stop-nets with 0.2 cm mesh size in October 2014. For sampling, one-removal method with similar catch-per-unit effort strategy was employed (Klaar *et al.,* 2004). The fished sections were minimally 100 m long. All collected fish belonging to three species (**Error! Reference source not found.**) were returned to the river after identification and counting.

Habitat Data

The habitat data were measured immediately after sampling. The measured variables include (m), river slope (%), current velocity ($m.s^{-1}$), number of large stone (>25 cm), average stone diameter (cm), substrate index (SI%), Potamal Cover Index (PoCI), Periphyton Cover Index (PeCI), pH, electrical conductivity (EC) (µs), Total Dissolved Solid (TDS) (ppm), and temperature (°C). Elevation and geographical coordinates of the sampling sites were recorded by GPS (Global Positioning System; Garmin). Stream depth (cm) was measured at 20 points across sampling site using a measuring bar, and their average was considered as river depth (Lotfi, 2012). Width of river was measured using a tapeline by measuring anterior, middle and end of each sampling site and their average was considered as river width. River's slope (%) was measured by Sunto. Current velocity ($m.s^{-1}$) was measured by a simple float based on Hassan-lie (1999). Using Lotfi (2012) as the basis, the following measurements were carried out: number of large stones (> 25 cm) were calculated by counting large stone in 20 selected quadrates (50 × 50 cm), and stone diameter average also were calculated by measuring diameter of the bed stones in 20 selected quadrated (50 × 50 cm). Substrate index (SI) was calculated using the following formula: SI= (0.08 × area of bedrock) + (0.07 × area of boulder) + (0.06 × area of cobble) + (0.05 × area of gravel) + (0.035 × area of fines) (Jowett *et al.,* 2008). The potamal cover index and periphyton cover index were determined visually in site as percent of surface according to Platts *et al.* (1983) and Schultz *et al.* (2012). Finally, pH, EC and TDS were measured using a portable water quality instrument (WTW GmbH).

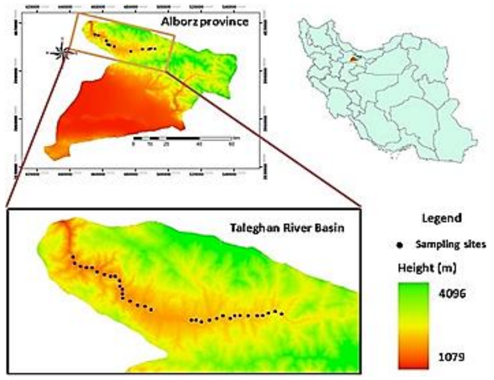

Fig.1. Map of sampling sites in the Taleghan River.

Table 1. The list of collected fish species, their scientific and English names.

Family	Scientific name	Abbreviation	English name
Cyprinidae	*Capoeta gracilis*	Cage	Lenkoran
	Barbus cyri	Baci	Kura barbel
Nemacheilidae	*Oxinemacheilus bergianus*	Oxbe	Sefidrud hillstream loach

Statistical Analysis

The direct gradient Canonical Correspondence Analysis (CCA) was applied to discover the relationship between fish assemblage and habitat factors. This method is a direct gradient ordination technique for describing the major trends in species distribution and correlated environmental factors. Initially, all habitat variables were included in the CCA. In addition, the variance inflation factor (VIF) was used to assess independence of included variables in the CCA. VIFs greater than 20 indicate correlation among variables (ter Braak & Verdonschot, 1995); nevertheless, the variables with VIFs more than 5 were removed from the CCA in this study. Other variables were removed from the post-hoc analysis if they did not explain variation along major axes in an easily interpretable way (Jongman *at el.*, 1995; ter Braak & Verdonschot, 1995).

The final CCA was used for explanation of fish assemblage-habitat factors relationship. An ordination biplot containing species and environmental variables was applied to extract the relationship between habitat factors and individual fishes of assemblage. The species abundance-environmental variables biplot is an ordination diagram in which species represented as points with respect to the explanatory variables represented as vectors. The vectors show the direction of maximum variation of the corresponding variable (ter Braak & Verdonschot, 1995).

RESULTS

Three species were included in the final CCA (Table 1). The variables in the final CCA were water depth (cm), river width (m), river slope (%), current velocity (cm/s), number of large stone (> 25 cm), average stone diameter (cm), substrate index (SI%), pH, EC (us), and TDS (ppm). The included variables in the final CCA were not redundant ($r < 0.60$); the removed variables with VIFs > 20 were elevation, temperature, PoCI, and PeCI. The relationships of ten habitat variables and structures of fish assemblage were depicted in Figs. 2 & 3. The position of a species relative to a vector of environmental variables indicates how a species is associated with the environmental variables (Figs. 2 & 3).

Presence-absence data

The first two axes of CCA explained 93.067% and 6.933% (100% in total) of the variation in fish assemblages, respectively. The eigenvalues, which range between 0 and 1, show the importance of each axis. The eigenvalues of axis 1 and 2 were 0.157 and 0.134, respectively. River width (0.50) and slope (-0.81) were highly correlated with the first ordination axis and have stronger gradients than the other variables.

Total dissolved solid (TDS) (-0.63) was the most correlated parameter with the second axis (Table 2).

The biplot generated for presence-absence data explained that (1) presence-absence of *O. bergianus* (Oxbe) is positively associated with current velocity and river width and negatively with pH, slope, depth and average of stone diameter; (2) presence-absence of *B. cyri* (Baci) is positively associated with substrate index and average of stone diameter, and negatively related with current velocity, river width, EC and TDS; (3) Presence-absence of *C. gracilis* (Cage) individuals are positively associated with slope, depth and number of large stone (Fig. 2).

Abundance data

The statistical significance of the CCA ordination was confirmed ($P < 0.0001$). The first two axes explained 97.480 % and 2.520 % of the variation in fish assemblages, and the

eigenvalues of axis 1 and 2 accounted as 0.380 and 0.010, respectively.
The flow velocity (-0.59) as negative and slope (0.61) as positive, were the two highly correlated factors with first ordination axis (Table 3). These factors represent the most important environmental factors related to the structure of fish assemblages. River width (-0.55) and number of large stone (-0.61) were negative and highly correlated with the second ordination axis (Table 3).

Table 2. Inter-set correlations of significant (P < 0.05) environmental variables with the first two ordination axes of the final CCA (presence-absence data).

	environmental variable	CCA axis 1	CCA axis 2
1	Depth (cm)	-0.23	-0.09
2	Width (cm)	**0.50**	-0.21
3	Slope	**-0.81**	-0.07
4	Velocity ($m.s^{-1}$)	0.37	-0.10
5	pH	-0.32	-0.02
6	EC	0.14	-0.22
7	TDS (ppm)	0.08	**-0.63**
8	Average of Stone Diameter	-0.40	0.12
9	Number of large stone	-0.06	-0.37
10	Substrate index	-0.13	0.17
	Eigenvalue	0.238	0.18
	Variance	93.067	6.933

Table 3. Inter-set correlations of significant (P < 0.05) environmental factors with the first two ordination axes of CCA (abundance data).

	environmental variable	CCA axis 1	CCA axis 2
1	Depth (cm)	-0.01	-0.42
2	Width (cm)	-0.49	**-0.55**
3	Slope	**0.61**	-0.08
4	Velocity ($m.s^{-1}$)	**-0.59**	0.02
5	pH	0.44	0.24
6	EC	-0.49	-0.43
7	TDS (ppm)	-0.32	-0.06
8	Stone Diameter	0.29	-0.42
9	Number of large stone	-0.01	**-0.61**
10	Substrate index	0.18	0.03
	Eigenvalues	0.380	0.10
	Variance	97.480	2.520

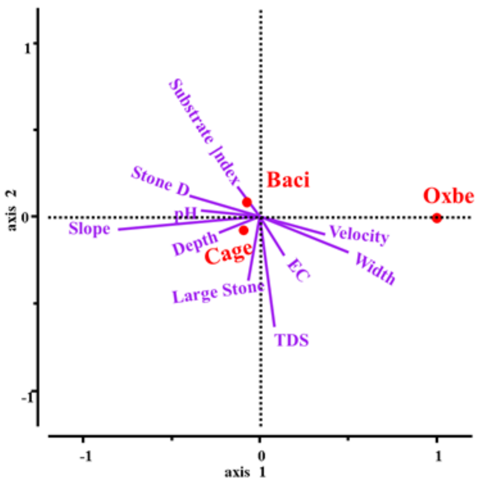

Fig. 2. CCA ordination diagram showing the effect of significant (P < 0.05) environmental factors on the structure of fish assemblages (presence–absence data).

The biplot obtained from abundance data revealed that (1) abundance of *O. bergianus* (Oxbe) is positively associated with current velocity and TDS and negatively with pH, substrate index and slope; (2) abundance of *B. cyri* (Baci) is positively associated with pH, substrate index and negatively with river width and EC; and (3) abundance of *C. gracilis* (Cage) has not distinctive relationship with any habitat variables (Fig. 3).

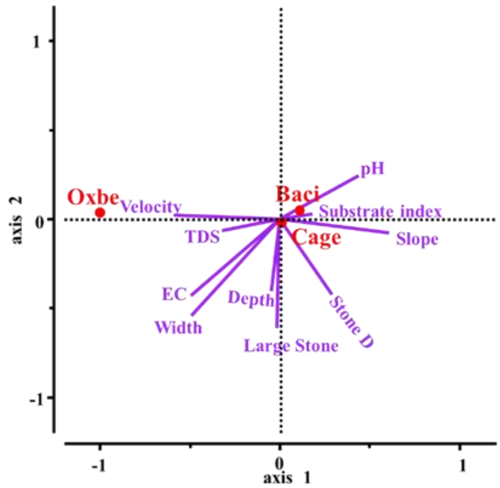

Fig. 3. CCA ordination diagram showing the effect of significant (P< 0.05) environmental factors on the structure of fish assemblages (abundance data).

DISCUSSION

The results showed that the fish assemblages of the Taleghan River are organized by the environmental variables affecting stream features, i.e. mainly by slope and river width, followed by reach-scale habitat conditions, including substrate properties (e.g. stone diameter, number of large stone, and substrate index), flow velocity, depth, TDS, EC, and pH. Based on the presence-absence and abundance data, we found that fish assemblage structure is most significantly affected by river width, slope, flow velocity and number of large stone, forming the fish assemblage intensely. The hydrological parameters affecting stream features e.g. flow velocity, substrate composition and depth (Angermeier & Winston, 1999) can be strongly related with fish assemblage's structure (Fischer & Paukert, 2008; Rowe *et al.*, 2009).

The relative importance of environmental factors suggests that both fish assemblages and local scale environmental variables were influenced by similar environmental factors present at broader spatial scales (Kautza & Sullivan, 2012). In this study, *B. cyri* and *C. gracilis* were dominated in the assemblage structure as they occupy all possible habitats due to their high adaptability, to a great range of environmental factors. These two cyprinid species are widely distributed in the Caspian Sea basin (Coad, 2014). Such extensive distribution and their high abundance suggest that these species are capable of tolerating a wide range of environmental conditions (Pusey *et al.*, 1993). In this regard, the abundance of *C. gracilis* did not show any distinctive relationship with examined habitat variables, whereas the presence and abundance of *B. cyri* showed a rise with the increase of the substrate index and stone diameter, and a decline with the increase of the river width and flow velocity. Coarse sediments in streams showed to be critical as they are utilized as velocity refuge and cover by many fishes (Fausch, 1993). These results can reveal higher capability of *C. gracilis* for tolerating a wide range of environmental conditions than *B. cyri*. Furthermore, presence and abundance of *O. bergianus* rises with increasing current velocity and river width and showed a decline with increasing slope, depth and substrate index. High flows increase habitat area and turbidity, which could decrease the potential for predation induced mortality of settled species and their progeny (Feyrer & Healey, 2003).

In addition, TDS, pH and EC showed a small effect on the fish assemblage structure in the present study. EC and TDS showed a negative relationship with the presence and abundance of *B. cyri.*

The species richness and abundance were higher in clear steams as penetration of sunlight into the water favored the algal growth supporting benthic feeders and algal scrapers (Shetty *et al.*, 2015) such as *B. cyri*.

The results of the present study can be used for the prediction of the species composition and structure of fish assemblages based on the measurable environmental variables. Based on the results, we can predict the presence of *C. gracilis* in all available habitats along the Taleghan River. Furthermore, we can predict abundance of *B. cyri* by increasing the current velocity and stone bed diameter, and abundance of *O. bergianus* by increasing current velocity and river width, and by decreasing stone bed diameter and slope. Many factors such as habitat availability, flow variability, water quality and nutrient supplies from riparian habitats control the abundance and distribution of river fishes (Shetty *et al.*, 2015). The results of this study confirmed the fact that environmental factors have a great impact on both species richness and the structure of fish assemblages (Pouilly *et al.*, 2006).

The distribution pattern of fish species observed in this study is likely because of variation in natural environmental features like geographic and geological conditions (Matthews & Robinson, 1998). Although habitat parameters in the Taleghan River have been altered by human activities such as damming over the last two decades (Husseini *et al.*, 2012). The results suggest that fish assemblages in this river are still affected by habitat factors.

The results of the present study provide insight into the ecology of fishes in the Taleghan River and might help in effective fisheries management of other rivers of the Caspian Sea basin.

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فاکتورهای محیطی موثر بر اجتماع ماهیان رودخانه طالقان (حوضه دریای خزر، استان البرز، ایران)

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چکیده

ارتباط بین برخی فاکتورهای زیستگاهی و اجتماع ماهیان در رودخانه طالقان واقع در استان البرز ایران مورد تحلیل قرار گرفت. نمونه‌های ماهی از ۳۳ ایستگاه توسط الکتروشوکر در اکتبر سال ۲۰۱۴ نمونه‌برداری شدند. فاکتورهای محیطی شامل ارتفاع (به متر)، عمق آب (به سانتی‌متر)، عرض رودخانه (به متر)، شیب رودخانه (به درصد)، شدت جریان (متر بر ثانیه)، تعداد سنگ های بزرگ (بزرگ‌تر از ۱۵ سانتی‌متر)، میانگین قطر سنگ (به سانتی‌متر)، شاخص بستر (به درصد)، سطح پوشش ناحیه حاشیه رودخانه، سطح پوشش جلبکی پریفتیون، PH، هدایت الکتریکی، کل مواد جامد محلول و درجه حرارت (سانتیگراد) در تمامی ایستگاه‌های نمونه‌برداری، اندازه‌گیری شدند. تحلیل تناظر کانونی برای مطالعه ارتباط بین اجتماع ماهی و فاکتورهای محیطی انجام شد. براساس نتایج، فراوانی *C. gracilis* هیچ رابطه مشخصی با متغیرهای زیستگاه مورد بررسی نشان نداد، در حالی‌که حضور و فراوانی *C. cyri* یک ازدیاد را با افزایش شاخص بستر و قطر سنگ بستر و یک کاهش را با افزایش عرض رودخانه و سرعت جریان نشان داد. حضور و فراوانی *O. bergianus* با افزایش سرعت و عرض رودخانه زیاد شد و یک کاهش را با افزایش شیب، عمق و شاخص بستر نشان داد. نتایج این مطالعه دیدگاه‌هایی را در مورد بوم‌شناسی ماهیان رودخانه فراهم می‌کند که می‌تواند به مدیریت شیلاتی موثر دیگر رودخانه‌های حوضه دریای خزر کمک نماید.

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