International Journal of Fisheries and Aquatic Studies 2018; 6(5): 10-19

E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2018; 6(5): 10-19

www.fisheriesjournal.com
Received: 03-07-2018
Accepted: 04-08-2018

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Effects of stream hydraulic characteristics on habitat suitability for rapid habitat assessment of rainbow trout (*Oncorhynchus mykiss*)

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Abstract
Description of velocity and depth attributes of stream channel is a basic goal of theoretical and applied hydrology, and is also critical for modeling the distribution of biological processes ranging from algal production to fish distribution. In the present research one dimensional hydraulic habitat model (PHABSIM) is used to simulate physical habitat of rainbow trout. The effect of three main hydraulic properties of the stream, including the top width of the flow, slope and stream roughness, on rainbow trout habitats was investigated. These factors can be assessed with rapid habitat survey. The present research results can be used for rapid assessment of rainbow trout habitat without need for hydraulic habitat modeling.

Keywords: Habitat suitability, hydraulic habitat, rapid habitat assessment, rainbow trout

1. Introduction

The science of environmental flow assessment in streams in recent years is developed towards the use of hydro-ecological methods. In these methods the environmental flow requirement for maintaining the sustainable condition of the ecosystem is determined by creating a relationship between hydraulic properties of the stream and ecological characteristics of the target species. In the late 1970's the U.S. Fish and Wildlife Service (FWS) established the Cooperative Instream Flow Service Group and also a major change in terminology regarding maintaining stream flow to protect aquatic organisms in streams was introduced. The change was from the common usage of low flow or minimum flow to the common usage of the term instream flow. This change was an instrument through which fish and associated environmental values were viewed as legitimate water users among many, instead of merely a residual, after the water users had been served. The result of the concerted effort on the part of the Instream Flow Group was the Instream Flow Incremental Methodology (IFIM) [1, 2], of which the Physical Habitat Simulation System (PHABSIM) is a major component. PHABSIM is a set of hydraulic and hydro-ecological models that define changes in physical habitat availability for target species given a change in river flow or channel geometry [3].

Describing the velocity and depth attributes of stream channel is a basic goal of theoretical and applied hydrology, and is also critical for modeling the distribution of biological processes ranging from algal production to fish distribution [4, 5]. Simple empirical approaches like hydraulic geometry predict how channel average velocity and depth change with increasing discharge, and are extremely useful shortcuts methods for estimating how average hydraulic conditions change with flow [6, 7]. Frequency distributions were applied to assess the usefulness of depth and velocity frequency distributions for modeling habitat suitability for cutthroat trout at low and high flows in a small trout stream [8]. It was found that modeling variance in velocity and depth, in conjunction with simple hydraulic geometry provided accurate estimates of reach average habitat suitability for trout. Physical habitat complexity is important because it influences the daily and long-term dynamics of fish in streams [9, 10].

Habitat selection and preferences vary depending on habitat availability [11, 12]. It is therefore necessary to study habitat selection over a wide range of hydro-physical habitat conditions. Habitat availability and habitat selection by young atlantic salmon and brown trout in a spatially and temporally heterogeneous Norwegian west coast river were studied [13]. It was concluded that the fish selected habitats substantially different from the available habitat.

PHABSIM technique is transformed to the UK from America, and is now being tentatively used by the Environment Agency to support water resources decision making in England and Wales [14]. Applications to date have concentrated mainly on fish habitats, investigating the potential relative impacts of changing reservoir or borehole releases, abstractions, and water transfers.

Phabsim can be used to assess instream habitat availability over a range of flows and therefore make predictions of physical changes to channel structures such as those incorporated into river rehabilitation schemes. PHABSIM was applies for an urban river [15] and it was found that there is greater suitable physical habitat over a wide range of flows in a less engineered river channel when compared to a more engineered channel.

The extent and availability of fish habitat varies in relation to changing streamflow. High-flow events scour streams, redistributing sediment and large woody debris, which is an important refugee for fish [16]. Low-flow events can cause of habitat bottlenecks in streams [2], and extreme low flow events can reduce fish populations to well below the carrying capacity of the environment [1].

Due to the complexity of the interactions between hydraulic conditions of the flow and ecology of target species the preliminary and total evaluation of these interactions is always a very difficult process and intricate modeling is needed. Rainbow trout is one of the most important riverine species which was remarkable in several studies and can be used as a suitable index in stream environmental studies. The habitat suitability curves that describe the instream suitability of the variables related to stream hydraulics and channel structure (velocity, depth and substrate) for each major life stage of rainbow trout are presented by Raleigh *et al*. (1984) [17].

This study has two main goals, including investigation of interaction between hydraulic characteristics of the stream and rainbow trout habitat; and presenting expert advices in order to preliminary evaluation of the rainbow trout conditions without using complex habitat simulation. With providing the second goal one can evaluate the suitability of habitats for different life stages of rainbow trout (including: fry, juvenile and adult) in calculations of the stream environmental flow with evaluating the principle parameters of the stream such as slope, bed roughness and top width of the flow (as the estimation of wetted perimeter) in future investigations. In other words, the present research results can be used for primary and rapid assessment of rainbow trout habitat without need for hydraulic habitat modeling. Also in developing countries, where eco-hydraulic sciences have not been developed using the expert advices of this research can create more accurate assessment of the environmental flow requirements (EFR). Although it is difficult to justify the extrapolation of the empirical results from this study to other streams, it would appear that the proxy variables can, at best, be used for the study site, under the assumption that no major changes in channel morphology occur.

2. Materials and Methods

2.1 Habitat simulation technique

In the present research one dimensional hydraulic habitat model (PHABSIM) is used to simulate physical habitat for rainbow trout. Hydraulic habitat models describe flow-dependent changes in physical components of the system and translate them into an estimate of the quality and quantity of microhabitat for aquatic organisms [3]. The general theory behind the hydraulic habitat models is based on the assumption that aquatic species will react to changes in the hydraulic environment. These changes are simulated for each cell in a defined stream reach [3].

In a hydraulic habitat analysis, at first the needed hydraulic model is applied to determine characteristics of the stream in terms of depth, velocity and channel index (cover or substrate) as a function of discharge for the full range of discharges to be considered for the study. In the habitat modeling process, this information is integrated with habitat suitability criteria (HSC) to produce a measure of available physical habitat as a function of discharge. Physical habitat suitability information for target species and distinct life stages of those species can be derived from scientific literature or direct field sampling [2, 3].

Cell values of each of the physical parameters are combined with species preference curve information through a selected functional relationship, termed the Combined Suitability Index (CSI, which has a range of 0-1), to develop the combined habitat index, termed Weighted Usable Area (WUA). WUA is expressed in units of microhabitat area per unitized distance along a stream (e.g., square feet per 1000 feet of stream or m^2 per 1000 m) and is the most commonly used output from these types of models [2, 3]. WUA is computed within the reach at a specific discharge from:

$$WUA = \left(\left(\sum_{i=1}^{n} A_i \times CSI_i \right) \Big/ L \right) \times 1000 \qquad (1)$$

Where A_i is the surface area of cell i and CSI_i is the combined suitability of cell i (i.e., composite of depth, velocity and channel index individual suitabilities.)

Typical CSI functional relationship is multiplicative, but any alternative can be devised.

2.2 Study stream

This study was carried out on Delichai stream in Iran (Fig. 1). Delichai stream is one of the important tributaries of Hablerood, source of this stream is the drain of Tar and Havir lakes and joins to Hablerood in Simindasht plane. Hablerood continues its way to south direction and finally enters to Garmsar region. The stream has a watershed area of approximately 340 km^2. Mean altitude of the region of this stream is 2182 m. The average slope of the stream is 2% and is a mountainous stream. The length of the stream that is simulated and evaluated in the present research is approximately 32 km. The researches have been carried out on this stream showed that currently qualitative parameters of the stream are not in a critical condition. Due to the morphological and hydraulic conditions, self purification of the river is possible. Because of the special topographic condition of the region, the stream is morphologically undisturbed and maintains its natural condition [18].

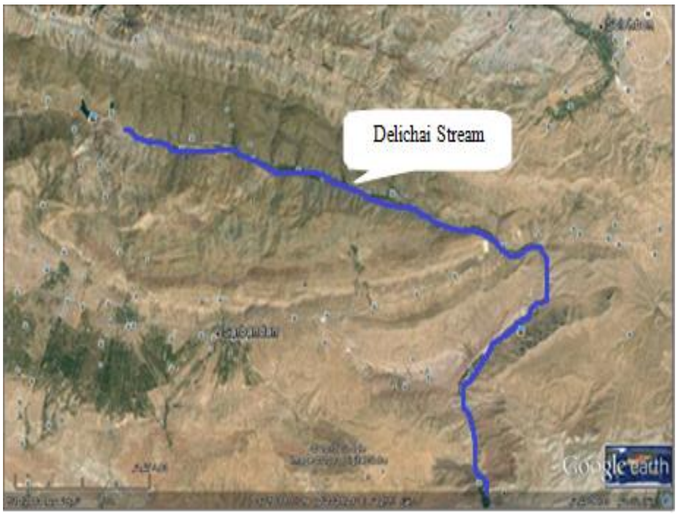

Fig 1: Location of Delichai stream in Google Earth

2.3 Methods of this research

The hydraulic simulation of the stream was carried out by HEC-RAS model. This model is one-dimensional hydraulic model. HEC-RAS is chosen based upon its widespread use and reliability. The step-backwater computational process and relevant equations including continuity, Bernoulli and Manning's equations are used for water surface profile simulation:

$$Q = AV \tag{2}$$

$$H = Z + d + \frac{V^2}{2g} \tag{3}$$

Where Q is the flow, A: area, V: velocity, Z: elevation of channel bottom, d: depth of water and $V^2/2g$: velocity head.

$$S_{ei} = \left[\frac{Q_i * n_i}{R_i^{\frac{2}{3}} * A_i} \right]^2 \tag{4}$$

Where Q_i is discharge, n_i: roughness coefficient, A_i: Cross section area, R_i: hydraulic radius (area divided by wetted perimeter), S_{ei} is the energy slope. And subscripts refer to any cross section i.

$$H_2 = H_1 + S_{el} + (otherlosses) \tag{5}$$

Where $H_{1,2}$ is total energy at each cross section, S_{el}: energy losses over the distance L and other losses referred to losses due to expansion or contraction.

And finally using the following equation the water surface elevation at the second cross section (WSL_2) is computed:

$$WSL_2 = H_2 - \frac{V^2}{2g} \tag{6}$$

In order to evaluate the validity of the hydraulic simulation statistical parameters of R^2 and root mean square error (RMSE) for mean velocity and depth were calculated. Then water surface elevations calculated from HEC-RAS model were manually entered to PHABSIM. The second major step of hydraulic modeling within PHABSIM involves simulating velocity distribution profiles at each cross section within the stream. Within PHABSIM the VELSIM model was used for all velocity predictions.

For velocity simulation, since slope, water surface and observed velocity are given as part of the calibration data, Manning's equation can be solved for n_i at each vertical:

$$n_i = \left[S_e^{1/2} \times d_i^{2/3} \right] / v_i \tag{7}$$

Where n_i is the estimated Manning's n value at vertical i, S_e: energy slope for transect, d_i: depth at vertical i and v_i: measured velocity at vertical i.

Having obtained individual Manning's n values at each vertical, individual cell velocities can be computed at any alternative discharge by solving Manning's equation for velocity and using the initial Manning's n value derived from the calibration velocity set:

$$v_i = \frac{1}{n_i} * d_i^{\frac{2}{3}} S_e^{\frac{1}{2}} \tag{8}$$

Then those velocity values were subsequently used in the habitat modeling portion of PHABSIM. The HABTAE model in PHABSIM was used for habitat simulation in the present research.

Prior to this investigation, no Iranian site-specific or regional HSCs for rainbow trout were available and the application of PHABSIM was limited to the uncritical use of literature HSCs. Due to the fact that rainbow trout is native to the rivers in North America, thus habitat suitability curves from Raleigh *et al*. (1984) [17] were used for three effective factors on physical habitat including depth, velocity and substrate for fry, juvenile and adult life stages of rainbow trout in this study. The end product of the habitat modeling was a description of habitat area (WUA) as a function of discharge using a relationship that is presented in eq.1 in the previous part for three life stages of rainbow trout in Delichai stream.

Finally, using the output from hydraulic habitat model (PHABSIM), suitability curves of the mean velocity and depth for three life stages of rainbow trout in the study stream were extracted. Using the existing habitat model outputs in order to obtain the habitat suitability curves for the study area is carried out by the following equation [19]:

$$HSI = \frac{Existing\ model\ output\ for\ area\ of\ interest}{Defined\ Standard\ of\ Comparison} \quad (2)$$

Where, HSI is the habitat suitability index. In the present research, WUA was used for model output and maximum WUA in each life stage of the target species was selected for the standard of comparison. In order to determine the suitability indices in each life stage, at first the suitability indices of flow discharge were extracted. In this regard for each life stage WUA-discharge curves were normalized by dividing the WUA values by the maximum WUA for that life stage at each discharge, and the discharge suitability index (SI) curves having the range between 0 and 1 for the stream in each life stages of the target species were obtained (Fig. 2). Then using the results of the hydraulic simulation of the stream, the equivalent values of mean velocity and depth for each discharge were calculated and mean velocity and depth suitability curves for the target species in the stream were plotted (Fig. 3). In the next step using the mean velocity and depth suitability curves extracted for the stream and also using the hydraulic simulation results, the suitability curves for top width of the flow (B), average slope (s), and roughness coefficient (Manning's coefficient. (n)) for three life stages of the target species of the study stream were obtained, too. In order to extract the suitability curves for top width of the flow, stream slope and bed roughness, firstly using the results of hydraulic simulation for the stream the average values of these parameters for the stream were extracted, then these values were classified in defined groups, such that top width of the flow was classified in three classes of (4.5-6), (6-7.5), (7.5- 9) m, stream slope in three classes of (0.01-0.02), (0.02-0.03), (0.03-0.04) and roughness coefficient in three classes of (0.016-0.023), (0.023-0.03), (0.03-0.037). And then the center of each class was determined and values presented for each of these parameters in the relevant plots are the center of each class. Considering the fact that depth and velocity will change with changing these parameters, thus for each of these parameters two curves based on depth suitability index and velocity suitability index are plotted.

3. Results

Values of RMSE and R^2 for verification of the hydraulic simulation results are presented in Table 1.

Table 1: Evaluation of hydraulic simulation results

Parameter	R^2	RMSE
Mean Velocity	0.91	0.13
Mean Depth	0.80	0.01

The discharge suitability curve for three life stages of rainbow trout is shown in Figure 2.

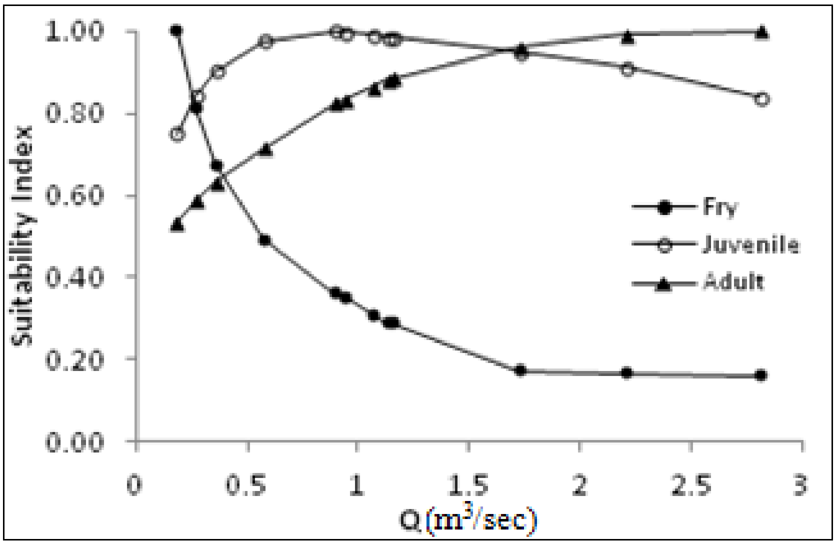

Fig 2: Discharge suitability curve for three life stages of *rainbow trout*

Mean velocity and depth suitability curves for three life stages of the target species are shown in Figure 3.

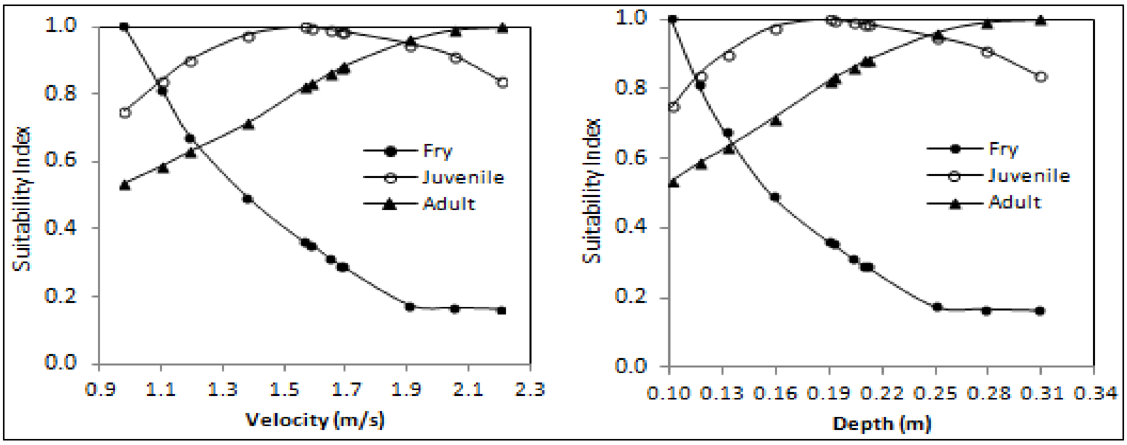

Fig 3: Mean velocity and depth suitability curve for three life stages of *rainbow trout*

The suitability curves for top width of the flow are presented in Figure 4 and 5.

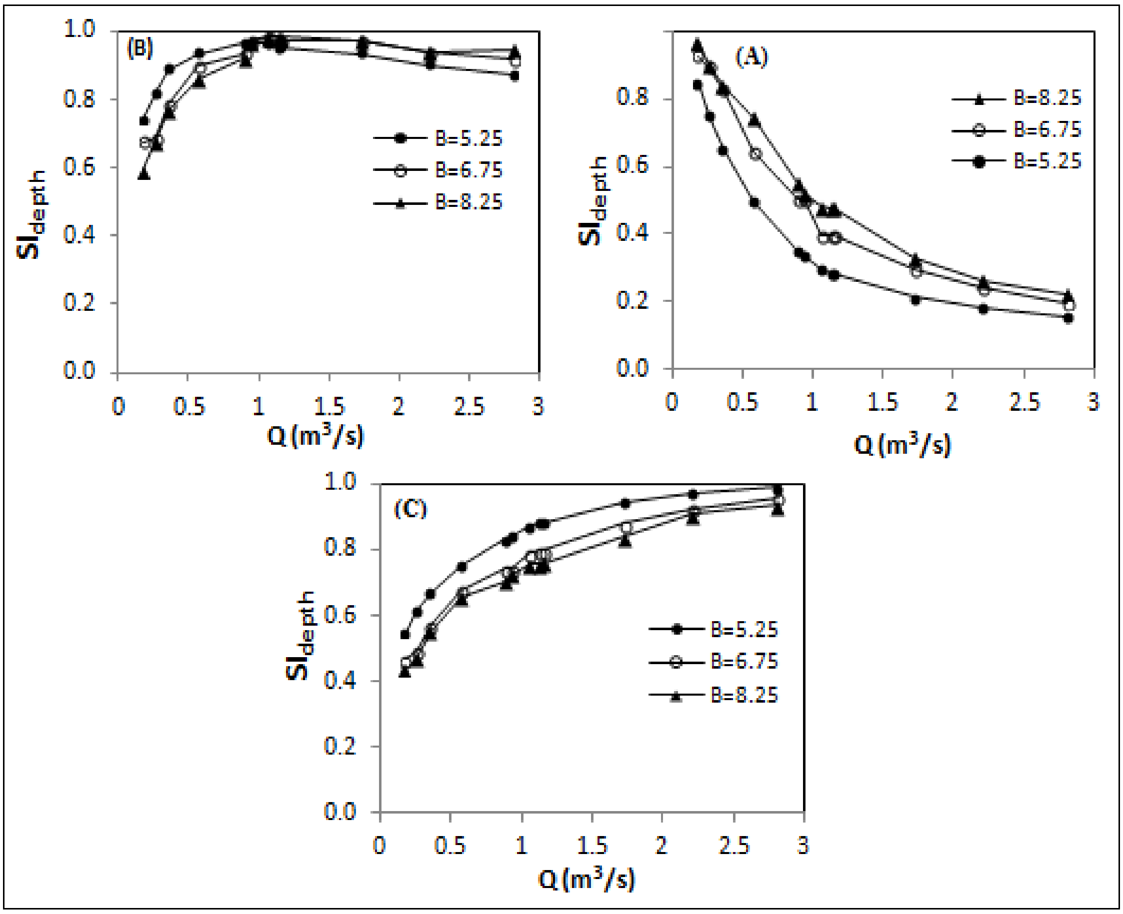

Fig 4: Effect of top width on depth suitability index; (A): fry, (B): juvenile, (C): adult

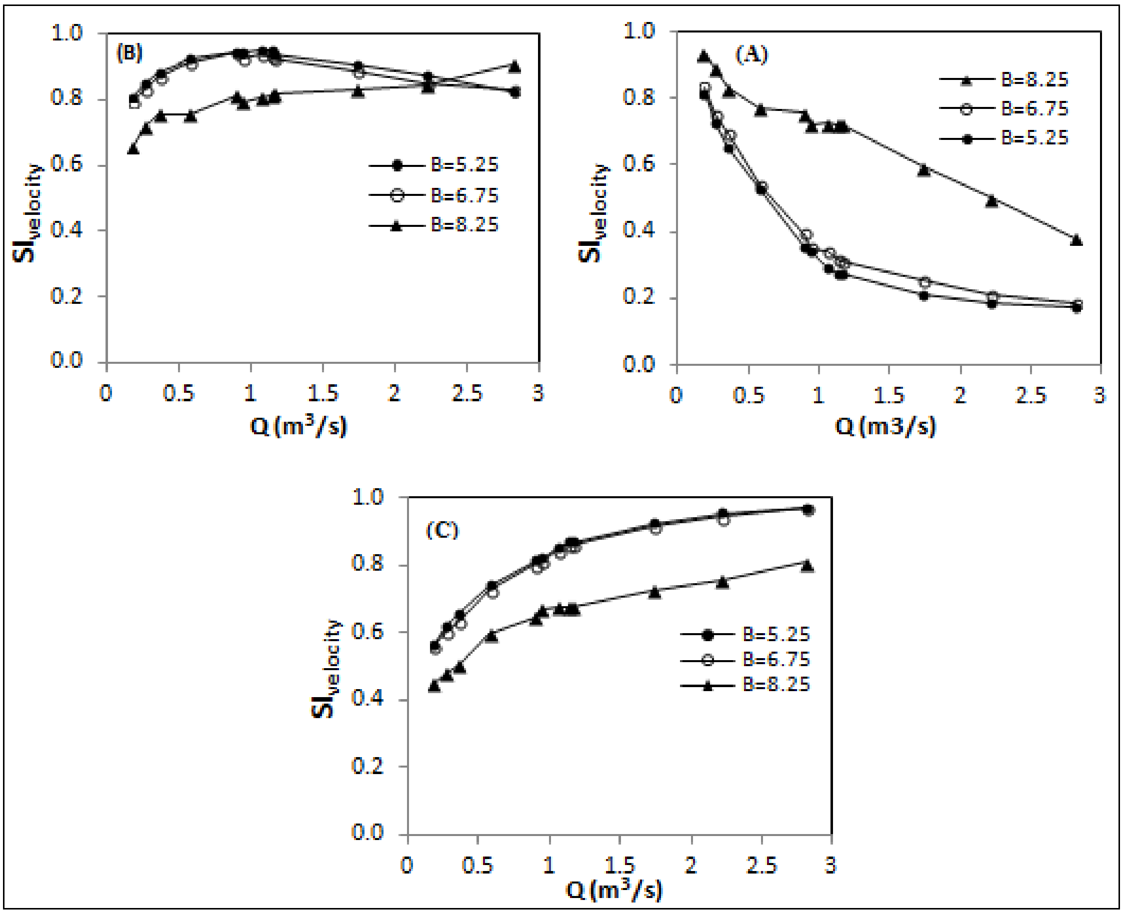

Fig 5: Effect of top width on velocity suitability index; (A): fry, (B): juvenile, (C): adult

The suitability curves for stream slope are also presented in Figure 6 and 7.

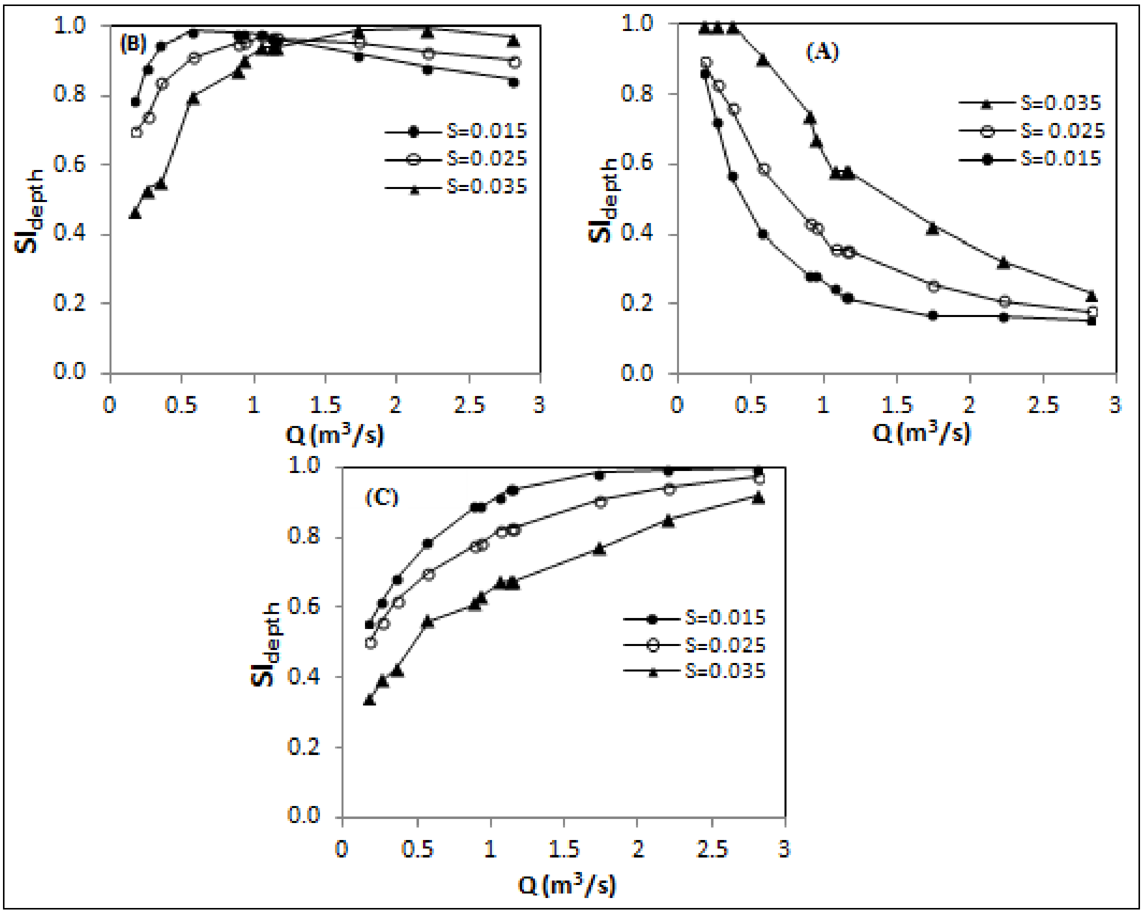

Fig 6: Effect of slope on depth suitability index; (A): fry, (B): juvenile, (C): adult

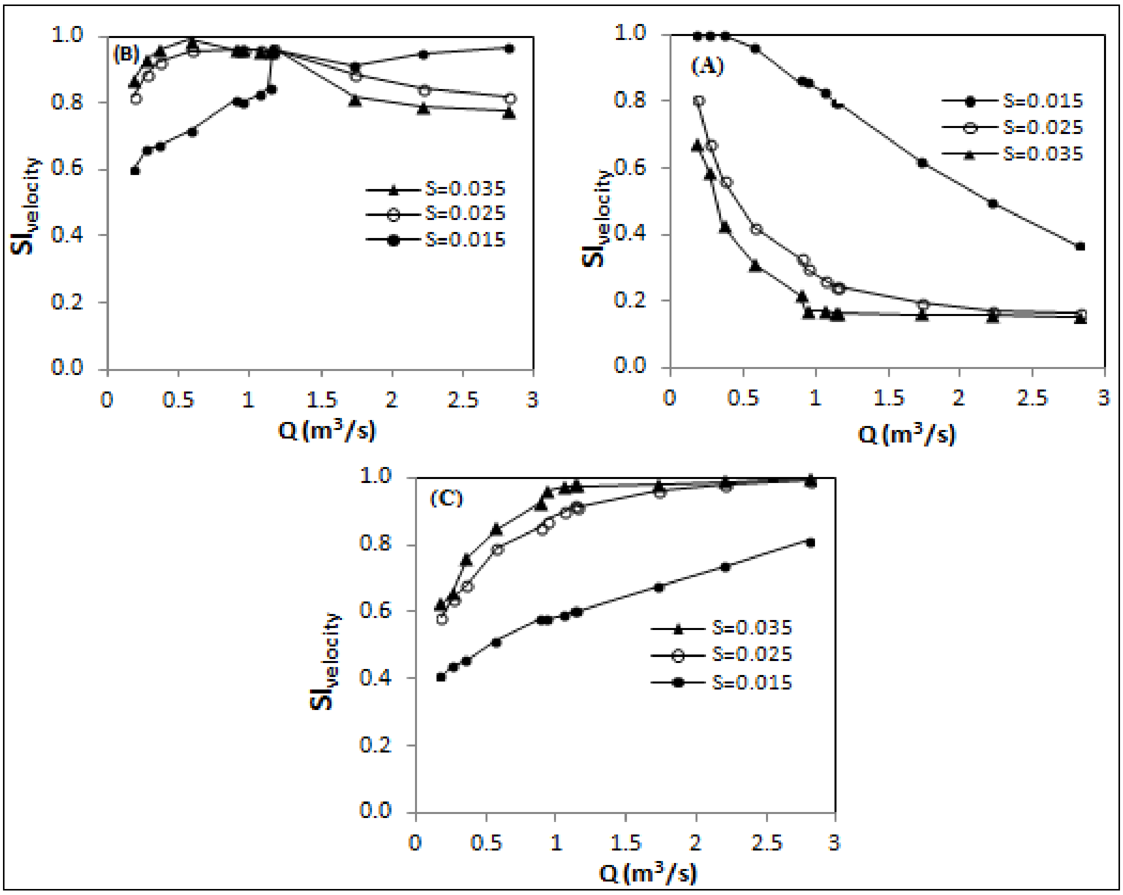

Fig 7: Effect of slope on velocity suitability index; (A): fry, (B): juvenile, (C): adult

The suitability curves for roughness coefficient (Manning's n values) are presented in Figure 8 and 9.

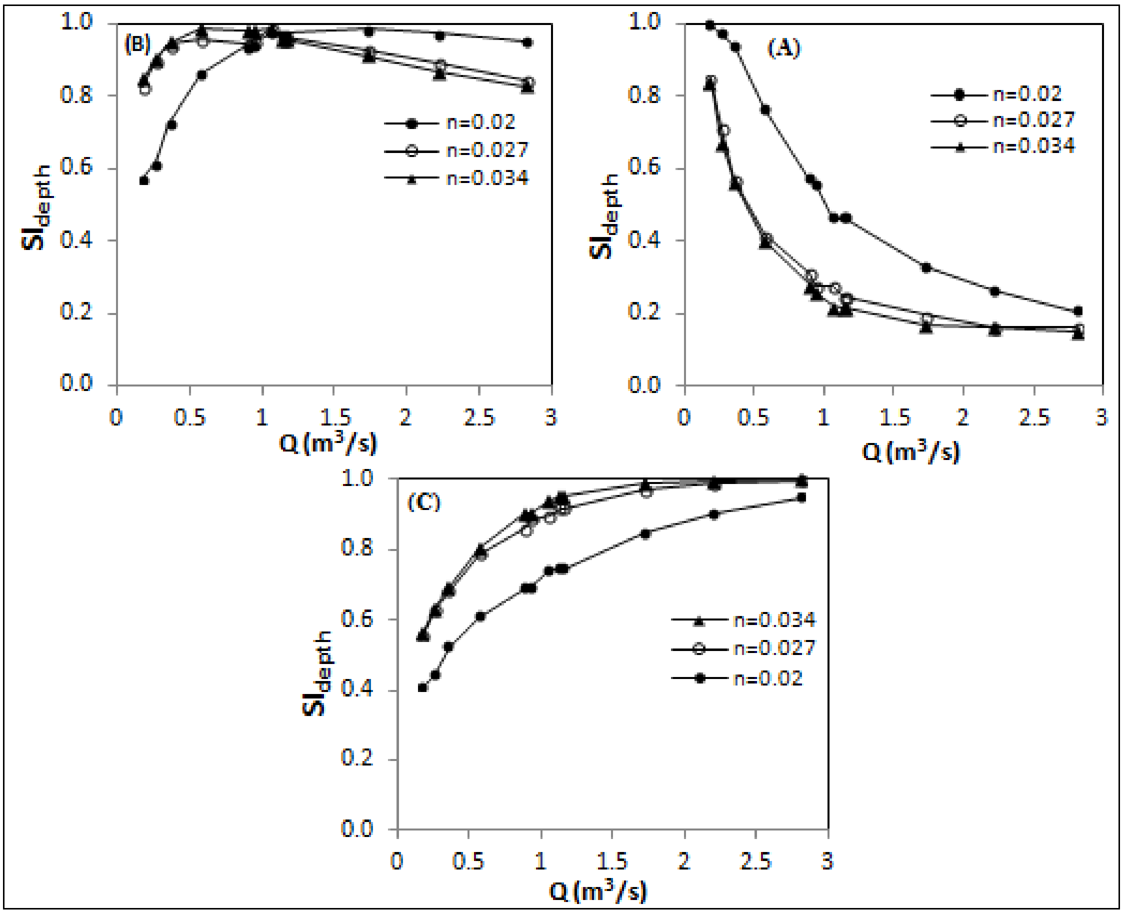

Fig 8: Effect of roughness coefficient on depth suitability index; (A): fry, (B): juvenile, (C): adult

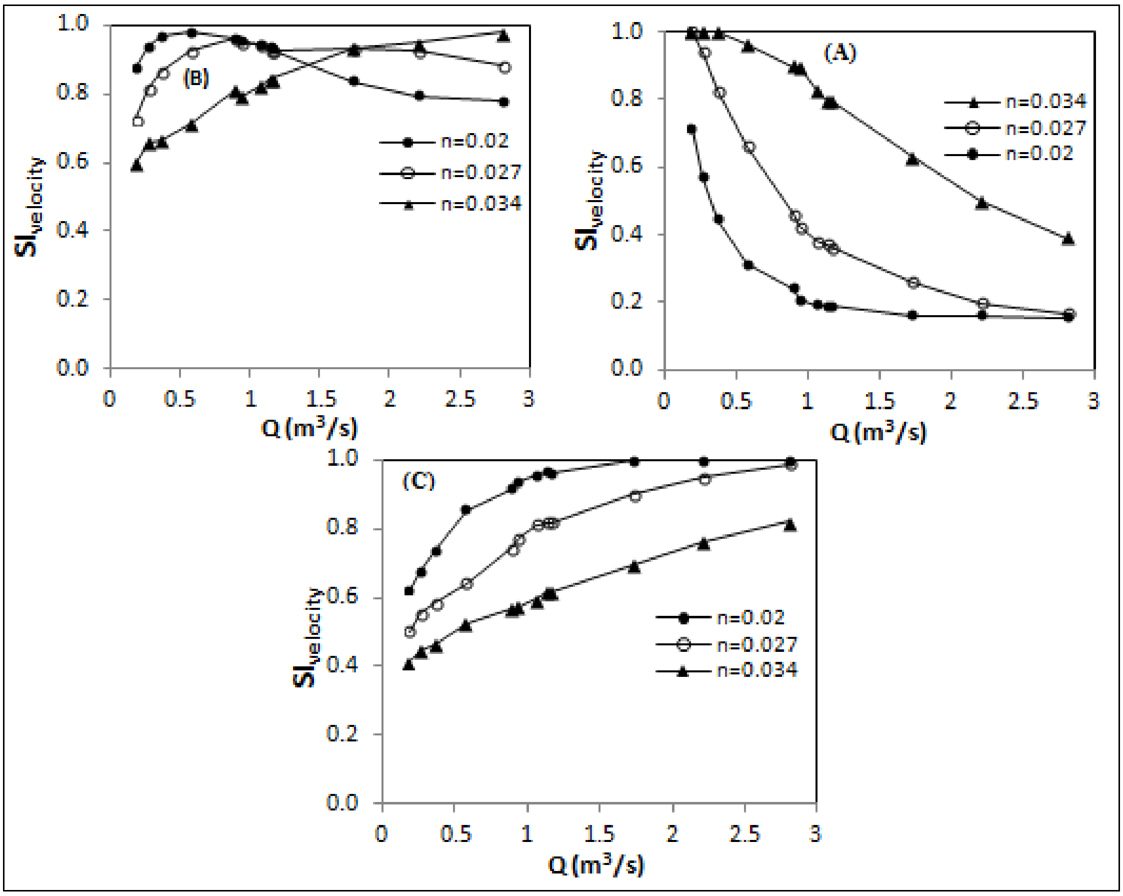

Fig 9: Effect of roughness coefficient on velocity suitability index; (A): fry, (B): juvenile, (C): adult

4. Discussion

It can be seen that the model has relatively desirable functionality in hydraulic simulation and suitable agreement was found between observed and simulated data (Table 1).

As can be seen in Figure 2, the suitability of the habitats for fry life stage is decreased with increasing discharge of the stream, in other words it can be said that although the total habitat of the stream is increased with increasing discharge, suitable habitats for fry life stage is decreased and in the average annual flow of the stream (1.11 m^3/s) suitable habitat has been decreased up to 65%. At the maximum discharge (2.813 m^3/s) suitable habitat has been decreased approximately 90% for fry. In juvenile life stage the suitability condition is completely different from fry life stage. The total suitable habitat area is increased with increasing discharge and the maximum suitability occurs at about the average annual flow. At discharges greater than 1.2 m^3/s, the suitability of the habitat tends to decrease. Generally speaking, during many months of the year the habitat condition is suitable for juvenile life stage. In adult life stage the habitat condition is in a way that the suitable habitat area is increased with increasing discharge, and this increasing trend shows the direct effect of increasing discharge on increasing the suitable habitat over the total range of the investigated flows.

As can be seen in Figure 3, for fry life stage at about the velocity range of 0.97-1.1 m/s the suitable habitat area is decreased only 20%, and in this range of velocity the depth is about 0.10 – 0.11 m. Then as the depth and velocity is increased the suitability is decreased with a sharp slope, and in the velocity range of 1.5-1.7 m/s and the depth of 0.19-0.21 m the habitat suitability condition has been decreased up to 60%. And in the range of velocities more than 1.9 m/s and depth greater than 0.25 m, the most unsuitable condition occurred. For juvenile life stage in the depth range of 0.19-0.21 m and velocity range of 1.3-1.7 m/s the habitat condition is in its most suitable condition. In adult life stage suitability is increased at higher discharges and therefore higher velocities and depth. In the velocity range of 1.5-1.7 m/s and depth range of 0.19-0.21 m habitat condition is suitable and the area of available habitat has been decreased only 15% relative to maximum condition.

Generally speaking, with analyzing three life stages of fry, juvenile and adult rainbow trout in a mountainous stream the most suitable range which causes the least damage to the suitability of habitat is the depth range of 0.19-0.21 m and velocity range of 1.5- 1.7 m/s. Of course it should be noted that in the most sensitive life stages such as fry and in critical stages of species life, it is better that has the depth in the range of 0.10-0.12 m and velocity in the range of 0.9-1.1 m/s.

Figure 4, shows that the suitability of depth for fry rainbow trout increased with increasing the top width of the flow. As the discharge increases in all three classes of top width, the trend of variation for depth suitability is the same and approximately has the same amount of decrease. But velocity suitability condition in the stream is different from depth (Fig. 5). While in top width classes of 5.25 and 6.75 m (center of the classes) the condition of decrease in suitability with increasing discharge is approximately the same, but it can be seen that in the top width class of 8.25 m at the discharge range of 0.182 to 1.15 m^3/s the suitability of velocity has been decreased less than 20% (Fig. 5). Thus it can be said that in top width of the flow more than 7.5 m the condition of the velocity is suitable in a wide range of discharges.

About the effect of top width of the flow on suitability of depth in habitat for juvenile life stage, it can be seen that at discharges less than 0.7 m^3/s the decrease of the top width and at discharges more than this value the increasing of top width will improve the habitat suitability for this life stage. According to the Figure 5, the suitability condition of velocity is relatively different from the depth. In top width of less than 7.5 m the effect of this parameter on velocity suitability at different discharges is negligible, but in top widths greater than 7.5 m the suitability condition is different and the effect of this parameter on velocity suitability is remarkable. It can be seen that at discharges greater than 2.2 m^3/s in the present research, increasing of discharge will cause the change in the effect of top width on velocity suitability.

According to the results of the present research the trend of variation for top width of the flow with discharge on depth suitability in adult life stage is similar for all classes of this parameter (Fig. 4), and for top widths greater than 6 m this effect is negligible. Generally, the suitability of depth will increase with decreasing the top width. Figure 5, shows sudden changes in suitability of velocity. For top widths less than 7.5 m the effect of top width on the velocity suitability is negligible. But as the top width increases more than this value, the suitability of velocity will decrease and the value of this reduction is about 20% in the present research.

Figure 6 shows that as the slope of stream increases, the suitability condition of depth for fry life stage will be improved. The trend of variation for depth suitability at different slopes over the range of the present research shows that the decrease of depth suitability will be more severe with decreasing slope. And on lower slopes the depth suitability of habitats will decrease sharply. At the discharge range from 0.182-0.9 m^3/s decrease of depth suitability is severe, but at higher discharges the suitability condition of depth will be approximately constant. It can be seen that at slope of 0.035 the trend of variation is more regular and at the discharge range of 0.182-2.8 m^3/s gradual decrease in suitability of habitat will occur.

It can be seen that as the slope decreases the suitability of velocity increases for fry life stage (Fig. 7). According to the results of the present research at slopes of 0.025 and more the trend of variation for velocity suitability is approximately the same, and at discharges more than about 1 m^3/s will reach to a constant condition. At the slope of 0.015 the trend of variation is completely different and the decrease of the velocity suitability is not remarkable up to the discharge range of 1.2 m^3/s. But at higher discharges sudden decrease in velocity suitability can be seen.

As can be seen in Figure 6, at the discharge range of 0.182-1.063 m^3/s the suitability of depth for juvenile life stage has been increased with decreasing the slope. And at higher discharges as the slope increases, depth suitability has been increased. At the slopes of more than 0.025 the effect of this parameter at different discharges on the velocity suitability is not remarkable (Fig. 7). At the slopes of less than 0.025 the sudden decrease in the velocity suitability up to the discharge of 1.157 m^3/s can be seen. But at higher discharges the trend of variation changed, and at lower slopes the velocity suitability is increased. Generally speaking, at discharges less than 1.15 m^3/s the increase of slope, and at higher discharges the decrease of slope will improve the velocity suitability.

As the slope increases the depth suitability for adult life stage will have relatively gradual decrease (Fig. 6). The trend of depth suitability variation for all three classes of slope is also increasing with discharge. Sudden changes in velocity suitability can be seen for slopes less than 0.025 (Fig. 7). Generally, it can be seen that the increase of slope over the range of 0.025-0.035 will have not remarkable effect on velocity suitability, but at the slope of 0.015 the sudden decrease of suitability with average value of 30% can be seen.

For bed roughness coefficient range of 0.027-0.034 the effect of roughness coefficient on depth suitability is approximately negligible for fry life stage (Fig. 8). But in Manning's roughness of 0.02 at the discharge range of 0.182-1.15 m^3/s remarkable effect on the depth suitability can be seen, and the amount of this effect over this range is approximately about 53%. The effect of roughness coefficient on the velocity suitability for this life stage is different relative to depth and as the roughness increases more gradual variation trend in the velocity suitability can be seen (Fig. 9). In the roughness coefficient of 0.034 the decrease of velocity suitability at the discharge range of 0.182-1.15 m^3/s is moderate and is about 20%. Thus in the rivers which have more bed roughness coefficient (in the range of the present research about 0.03 and more) as the discharge increases the roughness coefficient has less effect on the decrease of velocity suitability for fry life stage, and it is a notable point for river restoration and rehabilitation projects in rivers that are the habitats of coldwater fish.

It can be seen that the depth suitability for juvenile life stage at discharges less than 0.8 m^3/s in the roughness coefficient range of 0.027-0.034 is the same. But in roughness coefficient of 0.02 sudden decreases in the depth suitability can be seen, and at discharges more than 1.15 m^3/s this condition is vice versa (Fig. 8). Generally speaking, the effect of roughness coefficient for the roughness of more than 0.027 on the variation of depth suitability in juvenile life stage is negligible. At discharges less than 1.3 m^3/s sudden decreases in the velocity suitability can be seen with increasing roughness but at higher discharge the trend of variation becomes vice versa and as the roughness increases velocity suitability will be improved (Fig. 9).

As the roughness coefficient increases over the range of 0.027-0.034, there is no effect on the depth suitability for adult life stage (Fig. 8). And as the roughness coefficient decreases, sudden decreasing effect on depth suitability can be seen for adult life stage. According to the results of the present research the effect of roughness coefficient on velocity suitability at different discharges is gradual for adult life stage (Fig. 9), and as the roughness increases the velocity suitability decreases.

Flow regimes in the western USA and other semi-arid regions have been altered by the many dams and diversions constructed to meet water demands [20, 21]. The consequences for stream ecosystems have included the collapse of fisheries [22] and extinction of native fishes [23]. Predicting how water depth and velocity respond to flow alteration is possible using hydraulic models such as PHABSIM. A major hurdle for the implementation of these models is the cost [24, 25]. If science is to keep pace with development then more rapid and cost-effective models are needed. A generalized habitat model (GHM) for brown and rainbow trout were developed by Wilding *et al*. (2013) [26] that makes similar predictions to PHABSIM models but offers a demonstrated reduction in survey effort for Colorado Rocky Mountains streams. This model combines the best features of GHMs developed elsewhere, including the options of desktop (no-survey) or rapid-survey models. They found that the rapid-survey GHM produced better predictions of observed habitat than the desktop GHM.

It should be noted that, hydraulic and geometric parameters considered in this research are among the parameters that have been introduced and used by other researchers as the most important parameters affecting habitat suitability condition of aquatic ecosystems [5]. Although it is difficult to justify the extrapolation of the empirical results from this study to other streams, it would appear that the proxy variables can, at best, be used for the study site, under the assumption that no major changes in channel morphology occur. Considering the fact that mountainous streams are indeed morphologically stable, especially in conditions of low sediment supply.

5. Conclusion

In the present research one dimensional hydraulic habitat model is used to simulate physical habitat of rainbow trout. Using the mean velocity and depth suitability curves extracted for the stream and also using the hydraulic simulation results, the suitability curves for top width of the flow, average slope, and roughness coefficient for three life stages of the target species of the stream were obtained. The present research results can be used for initial and rapid assessment of rainbow trout habitat without needs of hydraulic habitat modeling and also they can be used for environmental flow assessment in planning phase. Based on the results, the effect of the top width of the flow on habitat condition is similar for adult and juvenile life stages. But for fry life stage the top width has different role in suitable habitat condition, and this fact represents that the stream management condition must change in fry life stage related to adult and juvenile life stages. According to the variation trend of stream slope for adult and juvenile life stages the slope range of 0.025- 0.035 will create the most suitable habitat condition, but for fry life stage the slopes less than 0.015 will create the most suitable habitat condition. According to the results of the present research the roughness coefficient in the range of 0.02- 0.027 will create the most suitable habitat condition for adult and juvenile life stages, but for fry life stage roughness coefficients of more than 0.034 will create suitable habitat condition.

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