PRELIMINARY ASSESSMENT OF THE EFFECT OF WATER ABSTRACTION IN SPERCHIOS RIVER (GREECE)ON ITS ECOLOGICAL STATUS USING THE HYDRAULIC HABITAL MODEL PHABSIM

SERGEANT F.[1], PAPADONIKOLAKI G.[2], STAMOU A.I.[1,2], BUI M.[1], RUTSCHMANN P.[1], DIMITRIOU E.[3] and SKOULIKIDIS N.[3].

[1]Institute of Hydraulic and Water Resources Engineering, Technical University of Munich, Arcisstr. 21, 80333 Munich, Germany, [2]School of Civil Engineering, Department of Water Resources and Environmental Engineering, National Technical University of Athens, IroonPolytechniou 5, 15780 Athens, Greece, [3]Hellenic Centre for Marine Research, Institute of Marine Biological Resources and Inland Waters, 46.7 km Athens-Sounio Ave., 19013, Anavyssos, Greece.
E-mail: georgia.papadon@gmail.com

ABSTRACT

Water abstractions for irrigation purposes represent the highest freshwater consumption in many countries today; significant amounts of water are usually taken out from rivers and aquifers during the dry period of the year causing very often detrimental effects to the aquatic ecosystems. One of the methods to estimate these effects in rivers is via the use of Hydraulic Habitat Models (HHM); HHM relate the physical characteristics of the river with habitat suitability criteria for the aquatic organisms of interest to calculate the amount of in-stream habitat for these organisms for various flow rates (Q). The physical characteristics of the river, which commonly include water depth (D), flow velocity (U), depth averaged water temperature (T), and substrate quality (S), can be determined via modeling (hydraulic, sediment, thermal etc.), while the habitat suitability criteria are usually expressed via indexes for the frequency or abundance with which the aquatic organisms are found in the particular habitats, such as the Habitat Suitability Curves (HSC); the correspong indexes are SI_D for water depth, SI_U for flow velocity, SI_T for water temperature, and SI_S for substrate quality.The amount of in-stream habitat is usually calculated as 'area of usable habitat' or Weighted Usable Area (WUA).

In the present work we perform preliminary calculations using the PHABSIM model in Spercheios River to estimate the effect of local abstraction for irrigation purposes or simply the effect of Q on the WUA that is habitat for the prevailing fish in the river. The main conclusions of the present study are the following: (1) River conditions in the whole river are more appropriate for Chub than for Barbel. (2) In the abstraction location x=0-0.5 km WUA values are very low (this is mainly due to the low values of the Channel Index), while in the region x=20.6-28.4 km WUA values are much higher thus indicating generally good conditions; in both cases conditions improve with increasing flow rate. (3) Observed WUA values for Barbel for the range of flow rate Q=1.5-6.0 m^3/s are very similar to the values found in the Guadalkivir River. More detailed calculations are in progress to verify and/or extend these preliminary results.

Keywords: hydraulic habitat model, Sperchios River, ecological status, PHABSIM, water abstraction.

1. Introduction

Water abstractions for irrigation purposes represent the highest freshwater consumption in many countries today; significant amounts of water are usually taken out from rivers and aquifers during the dry period of the year causing very often detrimental effects to the aquatic ecosystems. One of the methods to estimate these effects in rivers is via the use of Hydraulic Habitat Models (HHM); HHM relate the physical characteristics of the river with habitat suitability criteria for the aquatic organisms of interest to calculate the amount of in-stream habitat for these organisms (Stamou,

2015) for various flow rates (Q). The physical characteristics of the river, which commonly include water depth (D), flow velocity (U), depth averaged water temperature (T), and substrate quality (S), can be determined via modelling (hydraulic, sediment, thermal etc.), while the habitat suitability criteria are usually expressed via indexes for the frequency or abundance with which the aquatic organisms are found in the particular habitats, such as the Habitat Suitability Curves (HSC); the correspong indexes are SI_D for water depth, SI_U for flow velocity, SI_T for water temperature, and SI_S for substrate quality.The amount of in-stream habitat is usually calculated as 'area of usable habitat' or Weighted Usable Area (WUA); then, it can be normalized by the length of the river under investigation and expressed as m^2/km or m^2/m.

In the present work we perform preliminary calculations using the PHABSIM model (Milhous and Waddle, 2012) in Spercheios River to estimate the effect of local abstraction for irrigation purposes or simply the effect of Q on the WUA that is habitat for the prevailing fish in the river.

2. The area of study

The Spercheios River, which is shown in Figure 1, is located in Central Greece; it originates from the Tymfristos Mountain, then it flows to the east through the village Agios Georgios, enters a wide plain (along the towns Makrakomi and Leianokladi and south of the Phthiotidan capital Lamia) and finally discharges into the Maliakos Gulf at 13 km southeast of Lamia. The area of Spercheios river catchment is 1,660.9 km^2 while the average and highest altitudes are 641 and 2285 m, respectively. Approximately 32% of the entire catchment is covered by agricultural land, 2% from built-up areas and 66% from natural vegetation and bare land. The available field data include geometrical characteristics (i.e. EGSA coordinates that are transformed to local coordinates x and y), water depths (or equivalently water levels, WL), flow velocities and flow rates in 4 main cross sections of the river, that are named as KP1, KP2 (close to the village Kastri and immediately downstream of Inahos tributary), KP3 (close to village Lianokladi) and KP14 (downstream of the junction with the German Canal); these are also shown in Table 1. The river flows through an area of former wetlands, which have been reclaimed for agriculture; subsequently, its water is used primarily for irrigation purposes via local water abstractions, which are more intense downstream of KP2 (for approximately 2.5 km by the Local Organization for Land Reclamation) and immediately upstream of KP14 (for approximately 0.5 km). It is noted that the numbering of these cross sections in PHABSIM starts from the most downstream one and follows the upstream direction; see values of x's in Table 1.The fish of interest are Chub and Barbell. Currently, there is a field campaign regarding the in-situ determination of their HSC (through ECOFLOW project; see www.ecoflow.gr); in the present preliminary assessment we obtained the HSC from Marsili-Libelli *et al.* (2009); these are shown in Figure 2. Calculations are performed for 7 values of flow rates that are named Q_1 to Q_7, which cover the expected range of flow rates in the river; Q_3, Q_5 and Q_6 are used as 'calibration' (noted as 'cal' in Table 1) and Q_1, Q_2, Q_4 and Q_7 as 'simulation' flow rates (noted as 'sim' in Table 1).

Assuming that the relationship Q-WL is logarithmic; see equation (1), we performed an initial calibration of the model using the field data to determine the values of the coefficients A and B of equation (1)

$$\log(\text{WL-SZF}) = \log(A) + B^* \log(Q) \quad (1)$$

where SZF is the zero stage flow, and then the values of the water elevations for the calibration flow rates; these are indicated in Table 1. Moreover, we collected information on the bed characteristics, from which we have chosen proper values for the Manning coefficient (N) and the type of substrate (channel index, CI) in the cross sections; more specifically, in the region x=0-0.5 km the type of bed is fine sand, while in the rest of the river it is mainly gravel.

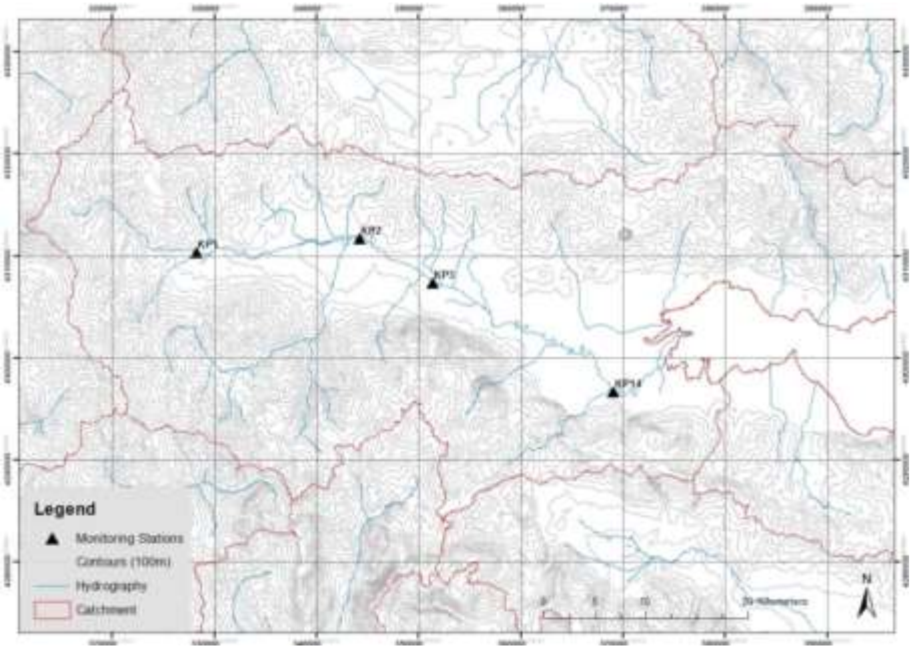

Figure 1: The area of study.

Table 1: Flow rates and water levels at the main cross sections of the river.

		Q	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7
		m^3/s	0.05	0.5	1.6	3.0	6.3	9.0	15.0
		Type	sim	sim	cal	sim	cal	sim	sim
KP	ID	x (m)	WL_1	WL_2	WL_3	WL_4	WL_5	WL_6	WL_7
KP_{14} SZF	ID_1 6.07	0	6.15	6.26	sim=6.36 cal=6.44	6.45	sim=6.60 cal=6.63	6.70 cal=6.70	6.87
KP_3 SZF	ID_2 34.98	20.6	35.06	35.20	sim=35.32 cal=35.29	35.40	sim=35.54 cal=35.54	35.63 cal=35.63	35.79
KP_2 SZF	ID_3 76.75	28.4	76.86	77.00	sim=77.15 cal=77.13	77.27	sim=77.46 cal=77.44	77.58 cal=77.58	77.79
KP_1 SZF	ID_4 225.20	44.8	225.31	225.43	sim=225.53 cal=225.54	225.61	sim=225.72 cal=225.73	225.79 cal=225.79	225.90

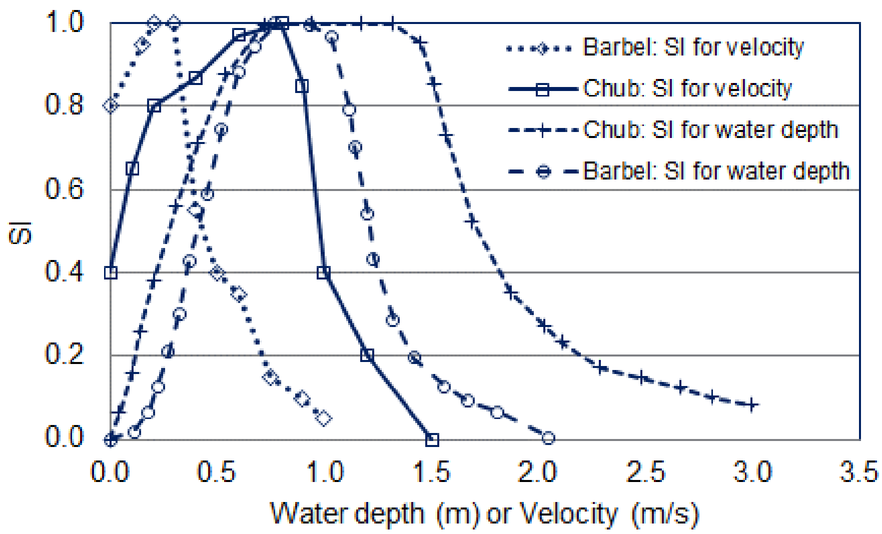

Figure 2: Habitat Suitability Curves(HSC) for the fish of interest.

3. Calculations, discussion and conclusions

We performed the calculations following the 5-step procedure that is described in Stamou (2015). In the 1st step, we provided to the program for each cross section (i) the geometry (i.e. the coordinates x and y), (ii) the values of Q and WL for the calibration flow rates, and (iii) the values of N and CI. In the 2nd step we calculated the water elevations; from the available 3 modeling options, we selected the MANSQ model that employs Manning's equation (i.e. uniform flow is assumed), which is expressed in the form of conveyance factor (i.e. it does not involve the energy slope) with an unknown coefficient (b) that is determined via the a trial and error procedure minimizing the error between observed and simulated water surface elevations at all measured flow rates, at each cross section, independently. Then, we checked the calculated water elevations for consistency and proceeded in the 3rd step, in which we calculated the distributions of water velocities in each cross section. Table 2 shows that the agreement of simulated values of D and U for various values of Q with measurements at the 4 cross section is generally satisfactory.

Table 2: Simulated (sim.) vs. measured (meas.) flow velocities and water levels.

Crosssection	Q	Dmeas.	Dsim.	Error	Umeas.	U sim.	Error
-	m^3/s	m	M	%	m/s	m/s	%
KP1	2.07	0.40	0.36	-10	1.40	1.06	-24
KP1	3.90	0.44	0.44	0	1.50	1.21	-20
KP2	0.17	0.14	0.16	14	0.38	0.33	-14
KP2	4.06	0.50	0.58	16	0.84	0.74	-11
KP3	1.81	0.40	0.40	0	0.81	0.81	0
KP3	6.29	0.54	0.55	2	1.40	1.10	-21
KP14	0.63	0.220	0.21	-5	0.62	0.73	18
KP14	0.19	0.150	0.13	-13	0.57	0.55	-4

In the 4th step we applied the habitat model and calculated the values of WUA (m^2/m) in the whole river and in the regions of interest, which are shown in Figure 3 and Table 3, respectively.

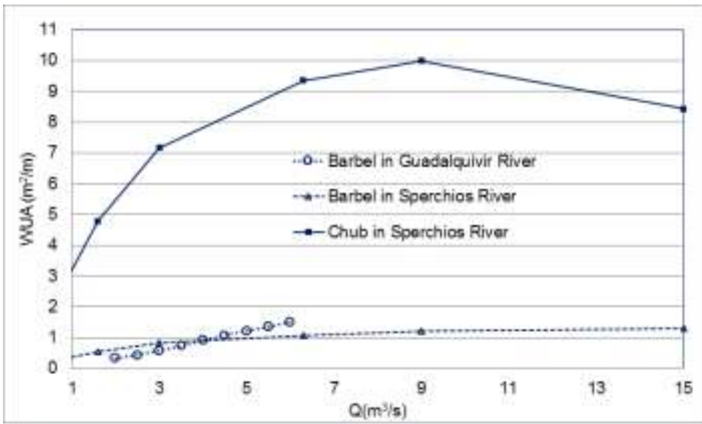

Figure 3: Calculated values WUA for the whole river for various values of flow rate.

Table 3: Calculated WUA for Chub (C) and Barbel (B) at the 4 reaches of the river.

$Q (m^3/s)$	0.05	0.5	1.6	3.0	6.3	9.0	15	0.05	0.5	1.6	3.0	6.3	9.0	15
Fish	C	C	C	C	C	C	C	B	B	B	B	B	B	B
x=0-0.5 km	0.03	0.1	0.2	0.3	0.4	0.5	0.7	0.2	1.2	3.0	3.2	2.1	1.4	0.9
x=0.5-20.6	0.04	0.2	0.5	0.7	0.9	1.1	1.1	0.3	1.8	4.8	7.7	10.0	9.7	6.1
x=20.6-28.4	0.05	0.5	1.3	2.1	2.5	2.5	2.2	0.3	2.4	5.6	8.8	13.9	15.5	13.6
x=28.4-44.8	0.04	0.1	0.3	0.4	0.6	0.8	1.1	0.2	1.7	4.4	5.9	6.6	8.0	9.1

The required overall habitat suitability index HSI_i was calculated as the geometric mean of the values of the three physical chacteristics D, U and S, while the effect of T was not taken into consideration. The 5th step is devoted to the interpretation and discussion of the results, which is summarised as follows: (1) River conditions in the whole river are more appropriate for Chub than for Barbel. (2) In the abstraction region x=0-0.5 km WUA values are very low (due mainly to the low CI values), while in the region x=20.6-28.4 km WUA values are much higher and generally indicate good conditions; in both cases conditions improve with increasing Q. (3) Observed WUA values for Barbel for the range of flow rate Q=1.5-6.0 m^3/s are very similar to the values found in the Guadalkivir River (Martínez-Capel and García de Jalón, 2004), which are also shown in Figure 3. More detailed calculations are in progress to extend these preliminary results.

ACKNOWLEDGEMENT

The present work is a part of the Study Project of the first author that was performed under the supervision of the third author, while he was Visiting Professor at the TUM; the authors would like to thank the GSRT funded project named KRIPIS-ITHAVIPEY (ESPA 2007-2013, www.spercheios.com) for the provision of the field data.

REFERENCES

1. Marsili-Libelli S., Giusti E. and Nocita A. (2013), A new instream flow assessment method based on fuzzy habitat suitability and large scale river modelling, Environmental Modelling & Software, **41**, 27-38.
2. Martínez-Capel F. and García de Jalón D., Testing a new approach to discuss weighted usable area in the Guadalquivir River Basin (South Spain). Congress Proceedings of the 5th International Symposium on Eco-Hydraulics. Madrid, 2004.
3. Milhous R.T. and Waddle T.J. (2012), Physical Habitat Simulation (PHABSIM) Software for Windows (v.1.5.1). Fort Collins, CO: USGS Fort Collins Science Center.
4. Stamou A., Ecological modeling of surface waters, Notes, Technical University of Munich, Munich, 2015.
5. www.ecoflow.gr