ACTA ZOOLOGICA BULGARICA

Aquatic Ecology
Research Article

Acta Zool. Bulg., 72 (2), June 2020: 289-296

Published online 30 June 2020
http://www.acta-zoologica-bulgarica.eu/002322

Dynamics of 24-hour Upstream Fish Migration in the Lower Course of Tundzha River, Southern Bulgaria, Based on a Fish-pass Video Monitoring

***Mladen V. Angelov*[1]*, Zhivko M. Zhelev*[2*]*, Georgi S. Popgeorgiev*[3] *& Apostolos I. Apostolou*[4]**

[1] East Aegean River Basin Directorate, 35 Yanko Sakazov Street, 4000 Plovdiv, Bulgaria
[2] Department of Human Anatomy and Physiology, Faculty of Biology, University of Plovdiv "Paisii Hilendarski", 24 Tsar Assen Street, 4000 Plovdiv, Bulgaria
[3] National Museum of Natural History, Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Blvd., 1000 Sofia, Bulgaria
[4] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Blvd., 1000 Sofia, Bulgaria

Abstract: We tested a method for studying the species composition and dynamics of 24-hour upstream fish migration. We analysed a complete footage of 24-hour video recorded in the period April–May 2014–2016 in a fish-pass of a small hydroelectric power station constructed on the Tundzha River. Water flow, temperature and water levels were also registered, in order to establish the dependence of the main physical water parameters on the migration rate. Recordings from the fish-pass showed that migration occurred mainly during the daytime. For the whole period of the study, we registered 9745 fish migrating upstream (2380 individuals were identified at the species level). Seven fish species of the family Cyprinidae were recorded during the study at the pass. Dominant species were *Chondrostoma vardarense* (relative abundance 46.93%), *Barbus cyclolepis* (23.31%), *Squalius orpheus* (16.59%) and *Vimba melanops* (10.76%). The migration activity of *V. melanops* was positively affected by water level and water temperature and negatively correlated with water flow. For *B. cyclolepis*, water flow affected the fish numbers. For *C. vardarense*, the role of water temperature was more significant than that of water flow.

Key words: potamodromous fishes, upstream migration, Tundzha River, fish-pass monitoring

Introduction

Most fish species are characterised by certain movement and migration behaviours important for various stages of their annual life cycles and within their natural distribution range (Heape 1931, Northcote 1978, Benitez et al. 2015). Freshwater fish migrate for three main reasons: spawning (Lucas & Baras 2001), avoidance of predators (Hulthén et al. 2015) and to escape the harmful effects of their physical environment (Gallagher et al. 1999). Generally, migrations of potamodromous fish species cover short distances. This behaviour is typical for certain cyprinid species (Lelek 1987, Baras 1992). Abiotic factors as temperature, light, water flow and water level influence the fish reproductive migrations (Lilja et al. 2003, Brodersen et al. 2008, Taylor & Cooke 2012, Amaral et al. 2016). In addition, hydro-constructions such as dams and weirs lead to habitat fragmentation as well as to migration disorders (Hladik et al. 2008, Meixler et al. 2009, Lönnerholm 2011, Benitez et al. 2015). Restoration of longitudinal connectivity in an upstream direction through using different fish-pass models is

[*]Corresponding author: zhivko-m@uni-plovdiv.bg; zhivko-m@mail.bg

the most frequent remediation measure owing to the fact that the re-establishment of upstream reproductive migration is considered a priority (Stuart et al. 2008, Roscoe & Hinch 2010, Favrot & Kwak 2016). Fish-passes and other devices (fish ladders, fish elevators and channel bypasses) are built in order to facilitate fish migration (Ovidio & Philippart 2002, Meixler et al. 2009). At the same time, they allow for observing such migrations in large rivers (Kotusz et al. 2006, Aparicio et al. 2012, Benitez et al. 2015, Mader & Kratzert 2016).

The Tundzha River is the largest tributary of the Maritsa (Evros) River and belongs to the Aegean Sea catchment area. Most of the fish species in the lower course of the Tundzha River are typical for the wider water basin of the Maritsa River and include potamodromous cyprinids (Stefanov 2007). Recently, 19 species of eight families were recorded in the lower Tundzha River (Kolev 2014). In this area, dominant rheophilic species are *Barbus cyclolepis* (Heckel, 1840) and *Squalius orpheus* (Kottelat & Economidis 2006, (Cheshmedjiev et al. 2010, Apostolou 2017).

There is a plethora of fish-pass case studies worldwide, European territory included (Roscoe & Hinch 2010). Previously, such scientific surveys have not been performed in Bulgaria.

The aim of the present study is to test a method for studying the composition and dynamics of 24-hour fish migration and its dependence of the main physical water parameters in the lower course of the Tundzha River on the basis video monitoring of a fish-pass.

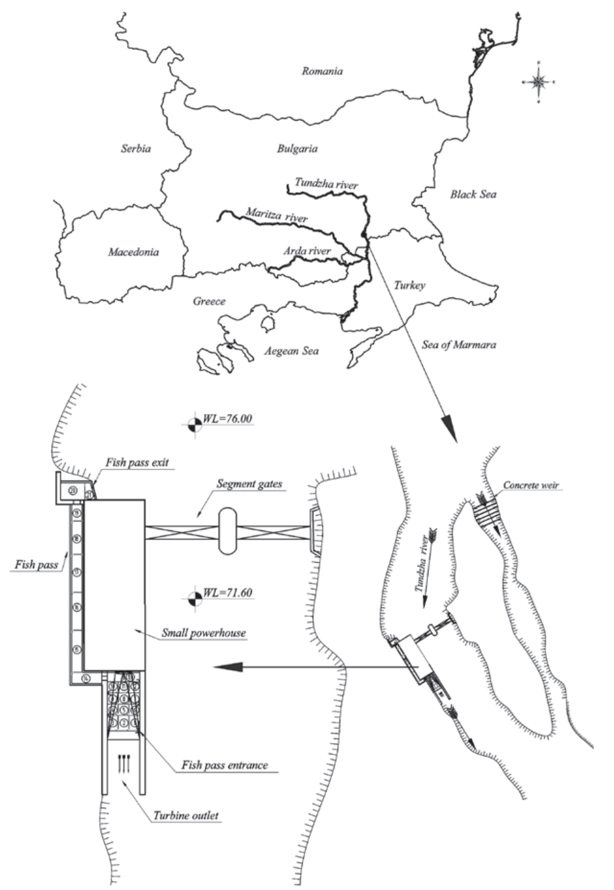

Fig. 1. Location of the small HPS Ustrem on the Tundzha River and the scheme of the fish-pass.

Materials and Methods

The study was conducted in the lower course of the Tundzha River, the second longest inner river in Bulgaria, national river type R12. Its length is 390 km, of which 349.5 km are within the Bulgarian borders. Its total catchment area is 8429 km^2 (7884 km^2 in Bulgaria). The mean annual water flow of the Tundzha River in this section is 18.5 $m^3.s^{-1}$ (1961–2004). Low water levels ordinarily occur between July and October, while high water levels – between November and June, with average annual turbidity of 1140 g/m^3 (Christova 2012).

The observed fish-pass was built in 2013 at a small hydro-power station (HPS) on the Tundzha River (520 kWh power) named *Ustrem* (42.012411 N, 26.487527 E, 76 m a.s.l.). The power station is provided with a vertical slot fish-pass with 21 individual cascade-linked chambers with 2 m width, 1.7 m depth, delta h = 0.2 m, 0.3 m slot width, water flow Q = 0.8 m^3/s^{-1}, with combined length of 114.0 m. At the operational water level of the small HPS, the water pass is the only viable way for the fish to migrate upstream (Fig. 1).

Data for fish migration were collected through video recording using a specially installed camera 270 x 300 pixels (Fig. 2) at the 21st basin of the fish-pass, where a vertical obstacle was placed without a "plunging jet" (Baudoin et al. 2014). Counting of upstream migrating fish was conducted and the results were grouped in one-hour intervals, considering the water level (H), water flow (Q) and temperature (T), with data obtained from the Institute of Meteorology and Water Management in Plovdiv. Full 24-hour records were done in April as follows: 4 days in 2014; 6 days in 2015 and 3 days in 2016. Species identification was according to Kottelat & Freyhof (2007). Unidentified species were recorded as "unidentified" and were included in the analysis. The results were tested by one-way ANOVA, followed by post-hoc LSD test at the significance level of $\alpha = 0.05$. The dependence between physical factors and the migration intensity was analysed for the most abundant species, using standard models of multiple regression (Kotusz et al. 2006). The num-

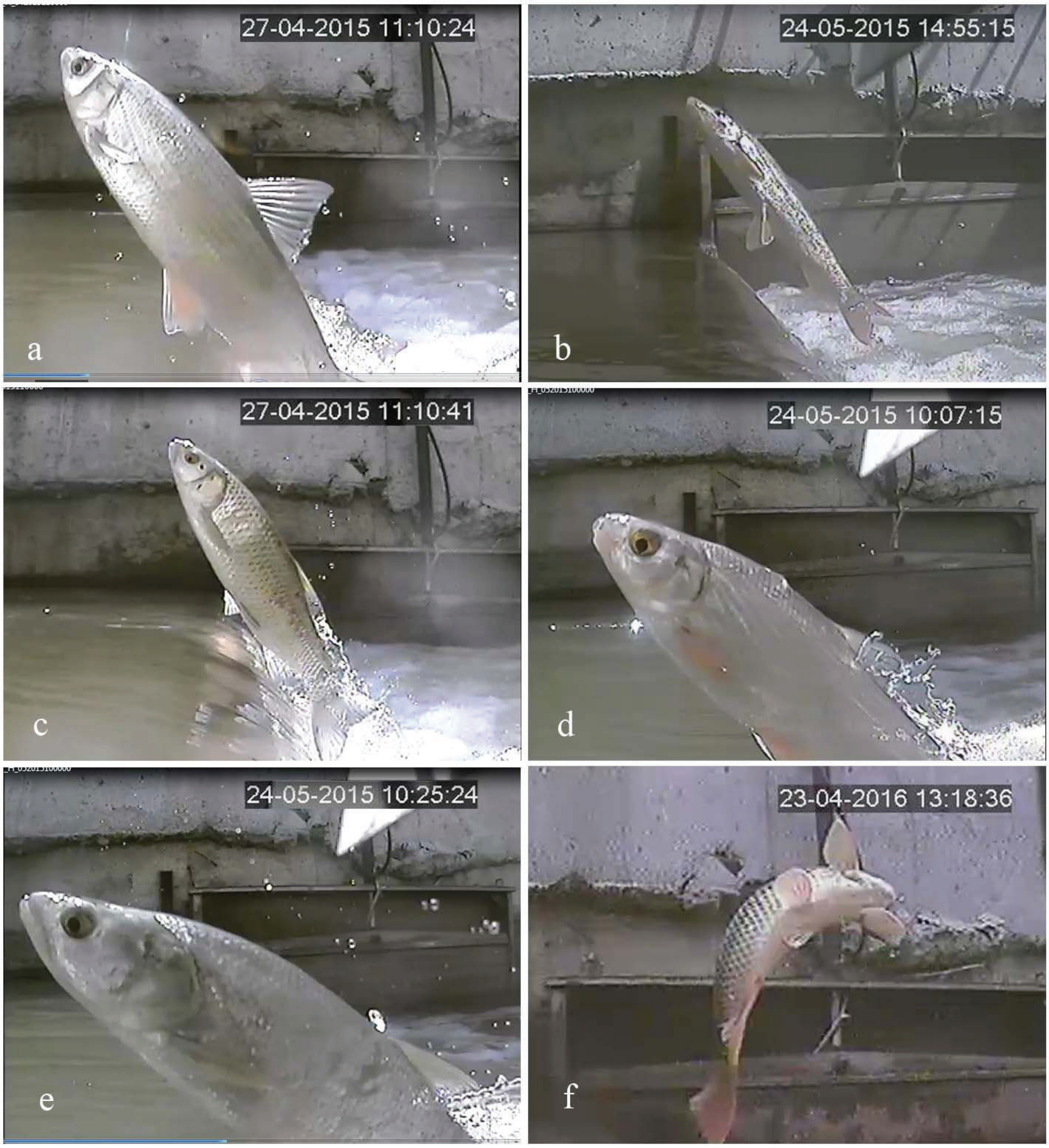

Fig. 2. Record of the passage of carp fishes through the fish-pass. Legend: a. *Chondrostoma vardarense*; b. *Barbus cyclolepis*; c. *Squalius orpheus*; d. *Vimba melanops*; e. *Aspius aspius*; f. *Cyprinus carpio.*

ber of specimens per species passed via the fish-pass was the dependent variable, with independent variables being the water physical parameters. Statistical analyses were performed with Statistica (version 7.0) statistical package program (Statsoft 2004).

Results

For the whole study period, we registered 12,125 fish specimens passing upstream through the fish-pass. Of them, 19.7 % could be identified at the species level. Nine species of the family Cyprinidae have been identified, with relative abundance as shown in Table 1. Single specimens of *Cyprinus carpio* L., 1758 and *Rutilus rutilus* L., 1758 recorded in the fish-pass in 2016 were not included in the statistical model. The maximum counted specimens (including unidentified) crossing the fish-pass per hour were 931.

All recorded cyprinid fishes (excluding *Carassius gibelio* Bloch, 1782) crossed the fish-pass more intensively between 10:00 and 18:00, with a peak

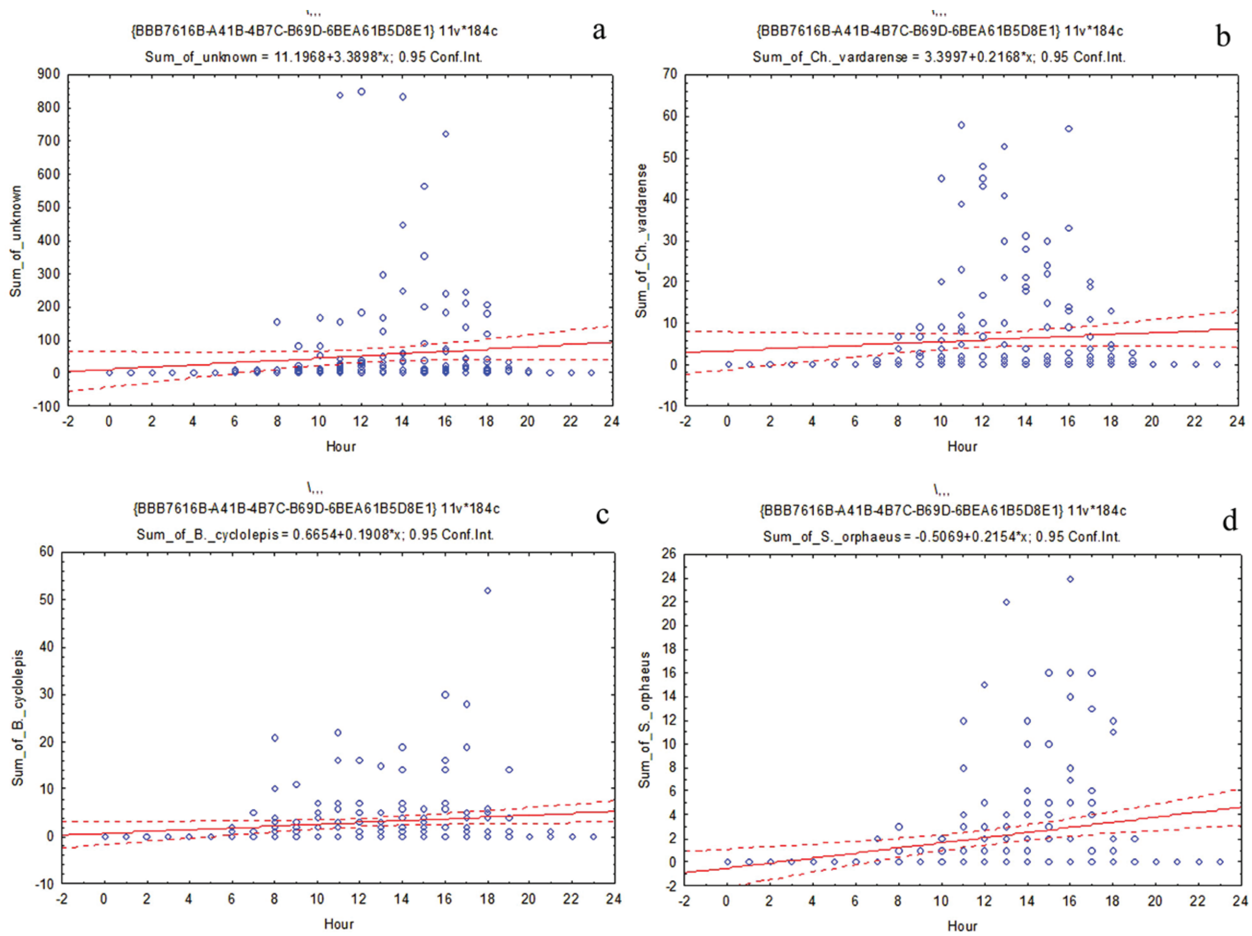

Fig. 3. 24-hour intensity of potamodromous fish migration via the fish-pass on the Tundzha River during the whole study period (April–May 2014–2016) registered by video monitoring. Legend: a. Unidentified; b. *Chondrostoma vardarense*; c. *Barbus cyclolepis*; d. *Squalius orpheus.*

Table 1. Analysis of variance of the migration intensity of potamodromous fish migration via the fish-pass on the Tundzha River during the whole study period (April–May 2014–2016), registered by video monitoring (SS – sum of squares, Df – Degree of freedom).

One-way ANOVA									
Species	**N**	**Relative abundance %**	**SS effect**	**Df effect**	**MS effect**	**SS error**	**Df error**	**MS error**	**F value**
Unidentified	9745	N.A.	354021.9	23	15392.26	3155887	160	19724.29	0.780
C. vardarense	1117	46.93	4798.0	23	208.61	21196	160	132.48	1.574
B. cyclolepis	555	23.32	771.2	23	33.53	6442	160	40.26	0.832
S. orpheus	395	16.60	734.4	23	31.93	2677	160	16.73	1.908^{v}
V. melanops	256	10.76	287.9	23	12.52	1098	160	6.86	1.824^{v}
A. aspius	42	1.76	10.3	23	0.45	58	160	0.36	1.234
A. alburnus	9	0.38	0.7	23	33.53	6442	160	40.26	0.646
C. gibelio	6	0.25	5.5	23	0.24	14	160	0.09	0.832^{v}

number of crossings as follows (Table 1, Figs. 3, 4): *Squalius orpheus* and *Vimba melanops* Heckel, 1840 without identified significant clusters of crossings – between 16:00 and 18:00 ($p < 0.001$), *Chondrostoma vardarense* Karaman, 1928 with a migration peak at 12:00 ($p < 0.001$), *Alburnus alburnus* L., 1758 at 14:00 ($p < 0.01$), *Aspius aspius* L., 1758 at 16:00 ($p < 0.001$). *Barbus cyclolepis* was spread relatively even but primarily during the daylight hours without the detection of concentrated crossings during a particular hour ($p > 0.05$). Concerning the small number of *C. gibelio* specimens crossing

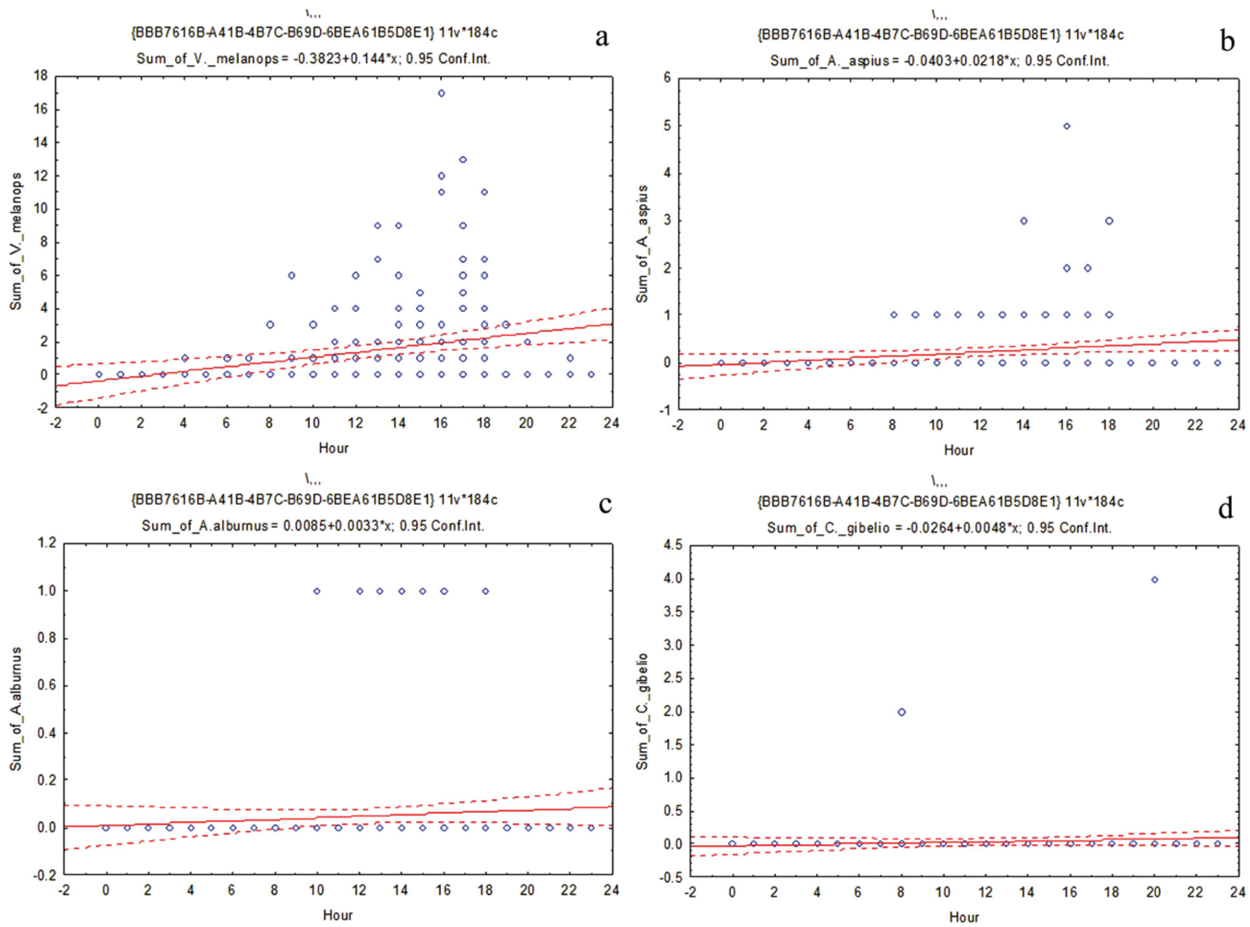

Fig. 4. 24-hour intensity of potamodromous fish migration via the fish-pass on the Tundzha River during the whole study period (April–May 2014–2016) registered using video monitoring. Legend: a. *Vimba melanops*; b. *Aspius aspius*; c. *Alburnus alburnus*; d. *Carassius gibelio.*

the fish-pass primarily around 20:00, no specific migration peak could be identified. The same applied for the registered in 2016 single specimens of *C. carpio* and *R. rutilus*.

Migration of 9745 unidentified specimens occurred between 11:00 и 16:00, with a peak at 14:00.

For the studied period (April-May 2014–2016), mean water flow was 17.3 $m^3.s^{-1}$ (10.6–32.4 $m^3.s^{-1}$), mean water level was 139 cm (92–215 cm) and mean water temperature was 14.5 C° (11.2–20.1 C°). The results of the multiple regression analysis for the period of this study indicated low values of the coefficient of determination (Table 2). For three species (*C. vardarense*, *B. cyclolepis* and *V. melanops*) from the primary migrants potamodromous species, the values of R^2 were in the range of 0.16–0.29. Concerning the other two species, *A. aspius* and *S. orpheus*, the values of R^2 (0.03–0.04) were minimal and, in practice, indicated that the intensity of the migration was not affected by the physical factors that have been included in the model. Regardless of the low values of R^2, however, in *C. vardarense, B. cyclolepis* and *V. melanops,* statistically significant standardised correlation coefficients (beta*) was found.

The results showed a statistically reliable connection between the number of fishes crossing the fish-pass for *C. vardarense*, *B. cyclolepis* and *V. melanops*. For *V. melanops*, the three physical parameters (H, Q and T) affected the intensity of the migration (F = 125.02, p = 0.000); however, water flow (t = -10.93, p = 0.000) and temperature (t = 18.97, p = 0.000) played a bigger role than water level (t = 2.51, p = 0.001). For *B. cyclolepis*, water flow affected the fish numbers (t = 10.39, p = 0.000). For *C. vardarense*, the role of water temperature (t = -10.12, p = 0.000) was more significant than that of water flow (t = 3.07, p = 0.002).

Discussion

Juxtaposing the data regarding the numbers of the registered passing species with those recorded in the region by a recent survey (Cheshmedjiev et al. 2010), there is a coincidence of dominating species,

Table 2. Multiple regression analysis of the effect of water level H (cm), water flow Q (m^3/s^{-1}) and temperature T (C°) on the intensity of potamodromous fish migration via the fish-pass on the Tundzha River during the whole study period (April-May 2014-2016), registered by video monitoring. Legend: R^2 – coefficient of the multiple determination, F – Fisher's test, beta* – Standardised coefficients, SE beta* – Standard errors of beta*, b – Unstandardized coefficients, SE b – Standard errors of beta, t – Student's test.

Species/ physical water parameters		R^2	F	p	beta*	SE beta*	b	SE b	t	p
C. vardarense	Intercept	0.16	34.95	2.761			0.05	0.80	13.49	0.000
	H				0.06	0.04	0.00	0.00	1.29	0.194
	Q				0.16	0.05	0.00	0.00	3.07	0.002
	T				-0.27	0.02	0.00	-0.06	-10.12	0.000
B. cyclolepis	Intercept	0.21	61.57	6.816			0.03	-0.12	-3.24	0.001
	H				-0.42	0.04	0.00	0.02	-8.83	0.000
	Q				0.55	0.05	0.00	0.00	10.39	0.000
	T				0.00	0.02	0.00	0.00	0.38	0.727
S. orpheus	Intercept	0.04	2.95	0.031			0.03	0.05	1.73	0.082
	H				0.11	0.04	0.00	-0.00	2.32	0.021
	Q				-0.13	0.05	0.00	0.00	-2.48	0.012
	T				0.04	0.02	0.00	0.00	1.75	0.079
V. melanops	Intercept	0.29	125.02	0.000			0.02	-0.26	-11.07	0.000
	H				0.11	0.04	0.00	-0.00	2.51	0.001
	Q				-0.57	0.05	0.00	-0.00	-10.93	0.000
	T				0.50*	0.02	0.00	0.04	18.97	0.000
A. aspius	Intercept	0.03	1.65	0.178			0.00	0.01	1.79	0.071
	H				0.10	0.04	0.00	0.00	2.06	0.039
	Q				-0.11	0.05	-0.00	-0.00	-2.02	0.042
	T				0.00	0.02	0.00	0.00	0.07	0.941

which are the most abundant rheophilic species. The only exception is *C. vardarense*; this could be potentially explained by its migratory behaviour, similar to that of *Chondrostoma nasus* L., 1758, which engages massive migratory aggregations over distances of 100 km and in schools of more than a thousand individuals (Lucas & Baras 2001). Studies targeting a number of rivers in Southern, Eastern and Central Europe show that the majority of potamodromous cyprinid fishes migrate to reproduce mostly during spring and early summer (Lucas & Baras 2001, Santos et al. 2002, Kotusz et al. 2006, Benitez et al. 2015). The present data are consistent with the above-mentioned, indicating that the species identified to cross through fish-pass during April–May are performing upstream spawning migration. Such spawning migration of the endemic *C. vardarense* and *V. melanops* during this period has been established before (Zhelev et al. 2018). In unstable environments with varying temperature, light is important for migration. During spring, the photoperiod becomes longer, representing a key trigger factor for upstream spawning migrations in some cyprinid fish as *R. rutilus* (Vøllestad & L'Abée-Lund 1987, Baade & Fredrich 1998). However, the modalities of migration connected to the variation in the photoperiod in most potamodromous fishes are not sufficiently understood. Potamodromous cyprinid species conduct primarily daily upstream migrations (Kotusz et al. 2006, Brodersen et al. 2008, Benitez et al. 2015, Amaral et al. 2016), as established by this survey; however, there is no reliable data about their hourly intensiveness. At the same time, there is also evidence for upstream migrations during the night (Lucas & Baras 2001).

According to literature, there is a connection between the dynamics of upstream migrations and different abiotic factors. Changes of the migratory rates can occur with fluctuations of the water parameters such as water level, water flow and temperature (Santos et al. 2002, Lilja et al. 2003, Kotusz et al. 2006, Brodersen et al. 2008, Taylor & Cooke 2012, Benitez et al. 2015, Amaral et al. 2016). Water temperature is an important regulator for reproductive migrations, especially for *A. aspius*, *A. alburnus* and *Abramis brama* L., 1758. It also influences the length and intensity of spawning (Hladik & Kubečka 2003). Most data from Central and Western Europe indicate temperature range of 8–12 C° for an "explosive" migration with a subsequently falling intensity (Lelek & Libosvárský 1960, Prignon et al. 1998, Travade et al. 1998, Kotusz et al. 2006, Benitez et al. 2015), regardless the fact that the temperature optimum for each species is different. In the current study, the most intensive migration was recorded for temperatures between 11 and 14 C°. Changes in water levels may also function as an initiating factor for migration, especially during the period of high spring waters, following the ice-melting (Jonsson 1991). High water flow may help the fish to find the entrance to the stream but if flows are very high, they can instead hinder fish migration (Hohausová et al. 2003). Most species of the genera *Chondrostoma* and *Vimba* reproduce in early spring in low water temperatures (Kotusz et al. 2006, Benitez et al. 2015). As a result, it is not surprising that their migration activity through this particular fish-pass is linked to water flow and temperature. Our data demonstrate that the two species migrate intensively when the water level is in the range 158–186 cm and the temperature is between 11 C° and 13 C°.

The proposed method could also be used in other cases of fish-passes. Regardless, in order to establish clearer connections between the impacts of environmental factors on the upstream migration of potamodromous fishes, a more precise study over a longer period of time is needed. However, it must be also kept into consideration that different parts of Europe are characterised by different climate and environmental peculiarities, which could represent obstacles to the inference of generalised correlations.

Acknowledgments: This research was supported by the National program "Young scientists and Postdoctoral candidates" funded by the Bulgarian Ministry of Education and Science.

References

Amaral S.D., Branco P., da Silva A.T., Katopodis C., Viseu T., Ferreira M.T., Pinheiro A.N. & Santos J.M. 2016. Upstream passage of potamodromous cyprinids over small weirs: the influence of key-hydraulic parameters. Journal of Ecohydraulics 1 (1-2): 79–89.

Aparicio E., Pintor C., Dur C. & Carmona-Catot G. 2012. Fish-passage assessment at the most downstream barrier of the Ebro River (NE Iberian Peninsula). Limnetica 31 (1): 37–46.

Apostolou A.I. 2017. Investigation of biological elements for quality (BEQ) fish on the territory of "Ustrem" HPS, Topolovgrad, Ustrem village, Tundja river. Report on performing one-time sampling and reporting for own monitoring under Art. 70, Ordinance No. 1 of 11.04.2011 on water monitoring. Sofia, 09.08.2017. 6 p. (In Bulgarian).

Baade U. & Fredrich F. 1998. Movement and pattern of activity of the roach in the river Spree, Germany. Journal of Fish Biology 52 (6): 1165–1174.

Baras E. 1992. Etude des strategies d'occupation du temps et de l'espace chez le barbeau fluviatile, *Barbus barbus* (L). Cahiers d'Ethologie 12: 125–442.

Baudoin J. M., Burgun V., Chanseau M., Larinier M., Ovidio M., Sremski W., Steinbach P. & Voegtle B. 2014. Assessing the passage of obstacles by fish. Concepts, design and application. France (Onema). 200 p.

Benitez J. P., Matondo B. N., Dierck A. & Ovidio M. 2015. An overview of potamodromous fish upstream movements in medium-sized rivers, by means of fish-passes monitoring. Aquatic Ecology 49 (4): 481–497.

Brodersen J., Ådahl E., Brönmark C. & Hansson L.-A. 2008. Ecosystem effects of partial fish migration in lakes. Oikos 117: 40–48.

Cheshmedjiev S. D., Ivanov P. N., Mladenov R. D., Gecheva G. M., Mihov S. D. & Todorov D. T. 2010. Final Report, Submitted to the Contracting Authority for approval 30.09.2010. Project: Development of a classification system for assessment of ecological status and maximum ecological potential, 153 p. (In Bulgarian).

Christova N. 2012. River waters of Bulgaria. Sofia (Typ-Top press). 830 p. (In Bulgarian).

Favrot S. D. & Kwak T. J. 2016. Efficiency of two-way weirs and prepositioned electrofishing for sampling potamodromous fish migrations. North American Journal of Fisheries Management 36: 167–182.

Gallagher A. S. 1999. Barriers. In: Bain M. B. & Stevenson N. J. (Eds.): Aquatic Habitat Assessment: Common Methods. American Fisheries Society, Bethesda, MD USA, pp. 135–147.

Heape W. 1931. Emigration, Migration and Nomadism. Cambridge: W. Heffer & Sons, 368 p.

Hladik H. & Kubečka J. 2003. Fish migration between a temperate reservoir and its main tributary. Hydrobiologia 504 (1): 251–266.

Hladik M., Kubečka J., Mrkvička T., Čech M., Draštik V., Frouzova J., Hohausova E., Matěna J., Matěnova V., Kratochvil M., Peterka J., Prchalova M. & Vašek M. 2008. Effects of the construction of a reservoir on the fish assemblage in an inflow river. Czech Journal of Animal Science 53 (12): 537–547.

Hohausová E., Copp G. H. & Jankovský P. 2003. Movement of fish between a river and its backwater: diel activity and relation to environmental gradients. Ecology of Freshwater 12 (2): 107–117.

Hulthén K., Chapman B. B., Nilsson P. A., Vinterstare J., Hansson L. A., Skov Ch., Brodersen J., Baktoft H. & Brönmark Ch. 2015. Escaping peril: perceived predation risk affects migratory propensity. Biology Letters 11 (8): 20150466 (4 pp.)

Jonsson N. 1991. Influence of water flow, water temperature and light on fish migration. Nordic Journal of Freshwater Research 66: 20–35.

Kolev V. 2014. Research on the ichthyofauna in the lower Tundza River in relation to alternative forms of tourism in the region of Yambol and Elhovo. Management and Sustainable Development 6 (49): 94–102. (In Bulgarian).

Kotusz J., Witkowski A., Baran M. & Błachuta J. 2006. Fish migrations in a large lowland river (Odra R., Poland) – based on fish-pass observations. Folia Zoologica 55 (4): 386–398.

Kottelat M. & Freyhof J. 2007. Handbook of European freshwater fishes. Berlin and Cornol: Kottelat & Freyhof. 646 p.

Lelek A. 1987. The Freshwater Fishes of Europe. Vol. 9, Threatened Fishes of Europe. Wiesbaden: Aula-Verlag. 343 p.

Lelek A., Libosvárský J. 1960: The occurrence of fish in a fish ladder in Dyje River near Břeclav. Folia Zoologica 9 (4): 293–308.

Lilja J., Keskinen T., Marjomäki T. J., Valkeajärvi P. & Karjalainen J. 2003. Upstream migration activity of cyprinids and percids in a channel, monitored by a horizontal split-beam echosounder. Aquatic Living Resources 16 (3): 185–190.

Lönnerholm Y. 2011. Upstream fish migration in relation to barriers in Fyrisån. Examensarbete, Avdelningen för Limnologi, Uppsala University. 23 p.

Lucas M. C. & Baras E. 2001. Migration of freshwater fishes. Oxford: Blackwell Science, 420 p.

Mader H. & Kratzert F. 2016. The fishcam migration monitoring system for fish-passes. In: Webb J., Costelloe J., Casas-Mulet R., Lyon J. & Stewardson M. (Eds): Proceedings of the 11th International Symposium on Ecohydraulics. Melbourne: University of Melbourne, Australia, pp. 1–4.

Meixler M. S., Bain M. B. & Walter T. W. 2009. Predicting barrier passage and habitat suitability for migratory fish species. Ecological Modelling 220 (20): 2782–2791.

Northcote T. G. 1978. Migratory strategies and production in freshwater fi shes. In: Gerking S. D. (Ed.): Ecology of Freshwater Production. Oxford: Blackwell, pp. 326–359.

Ovidio M. & Philippart J. C. 2002. The impact of small physical obstacles on upstream movements of six species of fish. Hydrobiologia 483 (1-3): 55–69.

Prignon C., Micha J.C. & Gillet A. 1998: Biological and environmental characteristics of fish-passage at the Tailfer dam on the Meuse River, Belgium. In: Jungwirth M., Schmutz S. & Weiss S. (Eds.): Fish migration and fish bypasses. Fishing News Books. Oxford: Blackwell Science. Ltd, pp. 69–84.

Roscoe D. W. & Hinch S. G. 2010. Effectiveness monitoring of fish-passage facilities: historical trends, geographic patterns and future directions. Fish and Fisheries 11 (1): 12–33.

Santos J. M., Ferreira M. T., Godinho, F. N. & Bochechas J. 2002. Performance of fish lift recently built at the Touvedo Dam on the Lima River, Portugal. Journal of Applied Ichthyology 18 (2): 118–123.

Statistica for Windows (Electronic Version 7.0). Statsoft Inc. (2004) Electronic Statistics Textbook. Tulsa, USA.

Stefanov T. 2007. Fauna and distribution of fishes in Bulgaria. In: Fet V. & Popov A. (Eds.): Biogeography and Ecology of Bulgaria. Dordrecht: Springer, pp. 109–139.

Stuart I. G., Zampatti B. P. & Baumgartner L. J. 2008. Can a low-gradient vertical-slot fishway provide passage for a lowland river fish community? Marine and Freshwater Research 59 (4): 332–346.

Taylor M. K. & Cooke S. J. 2012. Meta-analyses of the effects of river flow on fish movement and activity. Environmental Review 20: 211–219.

Travade F., Larinier M., Boyer-Bernard S. & Dartiguelongue J. 1998. Performance of four fishpass installations recently build on two rivers in south-west France. In: Jungwirth M., Schmutz S. & Weiss S. (Eds.): Fish migration and fish bypasses. Fishing News Books. Oxford: Blackwell Science Ltd, pp. 146–170.

Vøllestad L. A. & L'Abée-Lund J. H. 1987. Reproductive biology of stream-spawning roach *Rutilus rutilus*. Environmental Biology of Fishes 18 (3): 219–227.

Zhelev Z. M., Tsekov A. G., Popgeorgiev G. S., Angelov M. V., Boyadzhiev P. S. & Stefanov T. R. 2018. Ichthyofauna in the lower course of Sazliyka River, Southern Bulgaria: composition, diversity, seasonal dynamics and conservation significance. Acta Zoologica Bulgarica 70 (3): 331–338.

Received: 15.01.2019
Accepted: 31.03.2019