Supplementary Material

# Meso-scale data collection in the Argentina Creek

In 2015 a field campaign was carried out in the Argentina Creek (UTM 32N E: 406391.00 m; UTM 32N N:4865963.25 m, NW Italy) to assess the environmental impact of a run-of-river hydropower plant through the MesoHABSIM methodology. From this data collection campaign two geomorphic unit (GU or mesohabitat) surveys were used in this study to show the output of the conditional habitat suitability models developed for adult and juvenile *Telestes muticellus*. These river surveys were performed at 0.25 m3/s and 2.2 m3/s, which correspond to typically low (90-percentile of flow duration curve) and medium (25-percentile of flow duration curve) discharge conditions of the Argentina Creek. Together with the river survey at the lowest flow condition (0.25 m3/s), a quantitative fish data collection was performed at the mesohabitat scale to describe fish species distribution (presence/absence).

GUs and fish data collection was carried out following the MesoHABSIM protocols and standards (Vezza et al., 2014b; 2017). In particular, by using the multi-scale characterization procedure proposed by Gurnell et al. (2014) and Belletti et al. (2017), it was possible to identify a morphologically homogeneous reach downstream the hydropower plant. A study site (sub-reach) was then selected and the GUs description was based on a mobile mapping technique defined in Vezza et al. (2014b, 2017). This technique is based on the use of a rangefinder (TruPulse360B, Laser Technology, Inc.), a rugged PC (Nomad TDS, Field Environmental Instruments,Inc.) and a geographic information system (GIS) software to properly record the GUs with all their habitat attributes (see Table S2, Vezza et al 2014b). In particular, by walking downstream, the GU areas were delineated and stored in a GIS environment, and the mesohabitat-scale features (GU type, GU longitudinal connectivity, GU gradient, cover, shores characteristics) were recorded. Coming back upstream, depth and velocity values were measured using a flow meter (Marsh McBirney Flo-Mate 2000) and substrate composition were assessed from each of the mapped mesohabitats (Vezza et al., 2014b). Finally, flow measurements were performed at the beginning and the end of each survey. The two river surveys permitted to outlined 46 GUs, 37 GUs at 0.25 m3/s and 19 GUs at 2.2 m3/s.

Fish data were collected by sampling 20 GUs within the study site with backpack electrofishing (i.e., two-pass removal method, Meador et al., 2003) at the lowest flow condition (0.25 m3/s). To ensure the direct association between sampled GUs and the captured fish species, each mesohabitat was kept separated by using nets (Vezza et al., 2014a). Collected fish were measured in terms of total length (TL) and successively released within the same sampled mesohabitat. In total, 424 fish were captured, most of which were Italian vairone (*Telestes muticellus*, 317), classified as adult or juvenile according to the length/age relationships reported in Vezza et al. (2012).

It is important to highlight that the application of the MesoHABSIM methodology for the Argentina Creek included the calculation of the spatio-temporal variation in habitat availability at the reach-scale, following the methodology for high gradient streams reported in Vezza et al. (2014b, 2017). For the sake of brevity, the comprehensive explanation of all the methodological steps is not reported in this Supplementary Material.

# Supplementary Tables

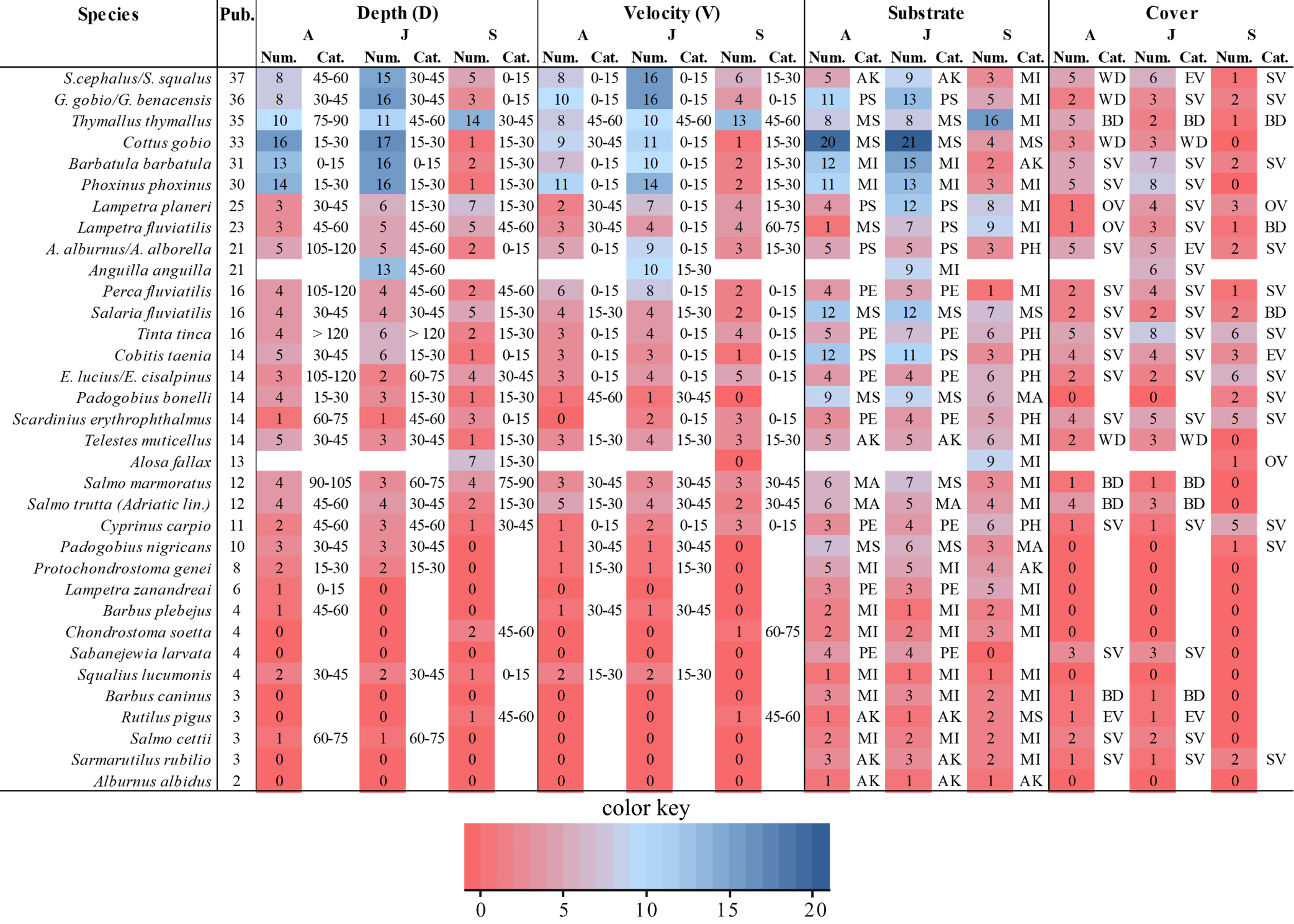
**Table S1.** Search strings used for the database screening. All possible combinations of species’ scientific/common names both in English and Italian language and the following habitat-related statements were used.

|  |  |  |
| --- | --- | --- |
| **Species’ scientific/common names** |  | **Habitat-related statements** |
| species scientific name (e.g., *Anguilla anguilla*) | + | habitat preferences |
| species common name in English (e.g., eel) | + | habitat use |
| species common name in Italian (e.g., anguilla) | + | habitat selection |
|  | + | habitat requirements |
|  | + | habitat |
|  | + | microhabitat |
|  | + | mesohabitat |
|  | + | macrohabitat |
|  | + | habitat suitability curves |
|  | + | biological model |
|  | + | species distribution model |
|  | + | habitat model |
|  | + | biology |
|  | + | life cycle |
|  | + | reproduction |
|  | + | spawning |
|  | + | adult habitat |
|  | + | juvenile habitat |
|  | + | spawning habitat |
|  | + | depth preferences |
|  | + | flow velocity preferences |
|  | + | substrate preferences |
|  | + | cover preferences |

**Table S2.** The physical habitat parameters of the MesoHABSIM model used for the GUs description in the Argentina Creek. For each habitat parameter the corresponding categories (Cat.) are expressed as reported in Vezza et al. (2014b; 2017). Within the review process exclusively Depth, Velocity, Substrate and Cover parameters were taken into account.

|  |  |  |  |
| --- | --- | --- | --- |
| **Habitat parameter** | **Units** | **Number of Categories** | **Categories (Cat.)/Description** |
| Geomorphic units (GUs) | yes/no | 17 | Pothole, Cascade, Rapid, Riffle, Step, Pool, Glide, Dune, Aquatic vegetation, Secondary channel, Flood lake, Wetland, Artificial element, Waterfall, Plunge pool, Backwater, Rock glide |
| GU gradient | % | 1 | bottom mean slope of the GU |
| GU longitudinal gradient | yes/no | 1 | habitat binary attribute describing mesohabitats longitudinal river connectivity |
| Depth | percentage of random samples | 9 | categories in 15 cm increments (range 0-120 cm and above) |
| Velocity | percentage of random samples | 9 | categories in 15 cm/s increments (range 0-120 cm/s and above) |
| Substrate | percentage of random samples | 12 | Gigalithal (GI), Megalithal (ME), Macrolithal (MA), Mesolithal (MS), Microlithal (MI), Akal (AK), Psammal (PS), Pelal (PE), Detritus (DE), Xylal (XY), Sapropel (SA), Phytal (PH) |
| Cover | yes/no | 11 | Boulder (BD), Canopy shading (CS), Overhanging vegetation (OV), Roots (RO), Submerged vegetation (SV), Floating vegetation (FV), Emerging vegetation (EV), Undercut bank (UB), Woody debris (WD), Riprap (RI), Shallow margins (SM) |
| Froude number | (flow velocity)/(9.81 depth)0.5 | 1 | average over the GU area |
| Flow velocity standard deviation | cm/s | 1 | SD over GU area |

**Table S3.** Number of bibliography sources (Num.) reporting the preferred categories (Cat.) of habitat parameters derived from the review analysis for each species, life stage (A=adult, J=juvenile) and bioperiod (S=spawning). Species are sorted with respect to the total amount of corresponding number of bibliography sources found (Pub.). The color-gradient is picturing high (21, blue) to low (0, red) number of bibliography sources reporting the preferred habitat categories . Water depth (D) and current velocity (V) are represented by 9 categories of 15 cm (from 0 up to > 120 cm) and 15 cm/s (from 0 up to > 120 cm/s) respectively. The codes used for substrate and cover categories are reported in Table S2. The Table shows, in numerical terms, the results depicted in Figure 1.



**Table S4.** List of bibliography sources considered in the study.

|  |  |  |  |
| --- | --- | --- | --- |
| **Author(s)** | **Year** | **Type** | **Citation** |
| Acou et al. | 2011 | paper | Acou, A., Rivot, E., Van Gils, J. A., Legault, A., Ysnel, F., and Feunteun, E. (2011). Habitat carrying capacity is reached for the European eel in a small coastal catchment: Evidence and implications for managing eel stocks. *Freshw. Biol.* 56, 952–968. doi:10.1111/j.1365-2427.2010.02540.x. |
| Allouche et al. | 1999 | paper | Allouche, S., Thévenet, A., and Gaudin, P. (1999). Habitat use by chub (Leuciscus cephalus L. 1766) in a large river, the French Upper Rhone, as determined by radiotelemetry. *Arch. fur Hydrobiol.* 145, 219–236. doi:10.1127/archiv-hydrobiol/145/1999/219. |
| Almeida et al. | 2011 | report | Almeida, P. R., Quintella, B. R., Mateus, C. S., Alexandre, C. M., Pereira, T., Ferreira, A. F., et al. (2011). Monitorização da migração reprodutora da lampreia-de-rio na sub-bacia hidrográfica do Rio Sorraia. Lisboa (PT). |
| Almeida et al. | 2017 | paper | Almeida, D., Fletcher, D. H., Rangel, C., García-Berthou, E., and da Silva, E. (2017). Dietary traits of invasive bleak Alburnus alburnus (Actinopterygii, Cyprinidae) between contrasting habitats in Iberian fresh waters. *Hydrobiologia* 795, 23–33. doi:10.1007/s10750-016-3052-8. |
| Aprahamian | 1982 | PhD thesis | Aprahamian, M. W. (1982). Aspects of the biology of the twaite shad, Alosa fallax fallax (Lacépéde) in the Rivers Severn and Wye. |
| Aprahamian et al. | 2003 | report | Aprahamian, M.W., Aprahamian, C. D., Bagliniere, J. L., Sabatie, R., and Alexandrino, P. (2003). Alosa alosa and Alosa fallax spp. Literature Review and Bibliography. Bristol (UK). |
| Arlinghaus and Wolter | 2003 | paper | Arlinghaus, R., and Wolter, C. (2003). Amplitude of ecological potential: Chub Leuciscus cephalus (L.) spawning in an artificial lowland canal. *J. Appl. Ichthyol.* 19, 52–54. doi:10.1046/j.1439-0426.2003.00343.x. |
| Armitage and Ladle | 1989 | report | Armitage, P. D., and Ladle, M. (1989). Habitat preferences of target species for application of PHABSIM testing. Wareham (UK): NERC Institute of Freshwater Ecology. |
| Aronsuu and Tertsunen | 2015 | paper | Aronsuu, K., and Tertsunen, J. (2015). Selection of spawning substratum by European river lampreys (Lampetra fluviatilis) in experimental tanks. *Mar. Freshw. Behav. Physiol.* 48, 41–50. doi:10.1080/10236244.2014.987453. |
| Aronsuu et al. | 2015 | paper | Aronsuu, K., Marjomäki, T. J., Tuohino, J., Wennman, K., Vikström, R., and Ojutkangas, E. (2015). Migratory behaviour and holding habitats of adult river lampreys (Lampetra fluviatilis) in two Finnish rivers. *Boreal Environ. Res.* 20, 120–144. |
| Ayllón et al. | 2009 | paper | Ayllón, D., Almodóvar, A., Nicola, G. G., and Elvira, B. (2009). Interactive effects of cover and hydraulics on brown trout habitat selection patterns. *River Res. Appl.* 25, 1051–1065. doi:10.1002/rra.1215. |
| Baars et al. | 2001 | book | Baars, M., Mathes, E., Stein, H., and Steinhörster, U. (2001). Die Äsche Thymallus thymallus. Hohenwarsleben (DE): Westarp Wissenschaften. |
| Banaduc | 2005 | paper | Banaduc, D. (2005). Fish associations-habitats quality relation in the Târnave rivers (Transylvania, Romania) ecological assessment. *Transylvanian Rev. Syst. Ecol. Res.*, 123. |
| Baras and Nindaba | 1999 | paper | Baras, E., and Nindaba, J. (1999). Seasonal and diel utilisation of inshore microhabitats by larvae and juveniles of Leuciscus cephalus and Leuciscus leuciscus. *Environ. Biol. Fishes* 56, 183–197. doi:10.1023/a:1007594932734. |
| Baras et al. | 1998 | paper | Baras, E., Jeandrain, D., Serouge, B., and Philippart, J. C. (1998). Seasonal variations in time and space utilization by radio-tagged yellow eels Anguilla anguilla (L.) in a small stream. *Hydrobiologia* 371–372, 187–198. doi:10.1007/978-94-011-5090-3\_22. |
| Bardonnet et al. | 1991 | paper | Bardonnet, A., Gaudin, P., and Persat, H. (1991). Microhabitats and diel downstream migration of young grayling (Thymallus thymallm L.). *Freshw. Biol.* 26, 365–376. doi:10.1111/j.1365-2427.1991.tb01404.x. |
| Beyer et al. | 2007 | paper | Beyer, K., Copp, G. H., and Gozlan, R. E. (2007). Microhabitat use and interspecific associations of introduced topmouth gudgeon Pseudorasbora parva and native fishes in a small stream. *J. Fish Biol.* 71, 224–238. doi:10.1111/j.1095-8649.2007.01677.x. |
| Białokoz et al. | 2009 | paper | Białokoz, W., Chybowski, Ł., Krzywosz, T., and Traczuk, P. (2009). Ichthyofauna of the rivers in the Romincka Forest (Pregola River basin, northeastern Poland). *Arch. Polish Fish.* 17, 77–84. doi:10.2478/v10086-009-0005-0. |
| Bianco | 1995 | paper | Bianco, P. G. (1995). Mediterranean endemic freshwater fishes of Italy. *Biol. Conserv.* 72, 159–170. doi:10.1016/0006-3207(94)00078-5. |
| Bianco | 2003 | book section | Bianco, P. G. (2003). “Barbus caninus Bonaparte, 1839,” in *The freshwater fishes of Europe, Volume 5/II, Cyprinidae 2, Part II: Barbus*, eds. P. Banarescu and N. G. Bogutskaya (Wiesbaden (DE): Aula-Verlag). |
| Bicchi et al. | 2006 | paper | Bicchi, A., Angeli, V., Carosi, A., La Porta, G., Mearelli, M., Pedicillo, G., et al. (2006). Curve di preferenza delle principali specie ittiche del bacino del fiume Tevere (Umbria, Italia). in *XVI Congresso della Società Italiana di Ecologia, Viterbo/Civitavecchia* (Viterbo/Civitavecchia (IT)). |
| Blanco-Garrido et al. | 2009 | paper | Blanco-Garrido, F., Clavero, M., and Prenda, J. (2009). Jarabugo (Anaecypris hispanica) and freshwater blenny (Salaria fluviatilis): habitat preferences and relationship with exotic fish species in the middle Guadiana basin. *Limnetica* 28, 139–148. |
| Bless | 1982 | paper | Bless, R. (1982). Untersuchungen zur substratpraferenz der Groppe, Cottus gobio Linnaeus 1758 (Pisces: Cottidae). *Senckenb. Biol.* 63, 161–165. |
| Bless | 1992 | book | Bless, R. (1992). *Einsichten in die Ökologie der Elritze Phoxinus phoxinus (L.): praktische Grundlagen zum Schutz einer gefährdeten Fischart*. , ed. Bundesforschungsanstalt für Naturschutz und Landschaftsökologie Bundesforschungsanstalt für Naturschutz und Landschaftsökologie. |
| Bless | 1996 | book section | Bless, R. (1996). “Reproduction and habitat preference of the threatened spirlin (Alburnoides bipunctatus Bloch) and soufie (Leuciscus souffia Risso) under laboratory conditions (Teleostei: Cyprinidae),” in *Conservation of Endangered Freshwater Fish in Europe*, eds. A. Kirchhofer and D. Hefti (Basel (CH): Birkhäuser), 249–258. doi:10.1007/978-3-0348-9014-4\_24. |
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| Bohl | 1995 | paper | Bohl, E. (1995). Habitatansprüche und Gefährdungspotential von Neunaugen. *Fischökologie* 8, 81–92. |
| Bohl et al. | 2004 | paper | Bohl, E., Herrmann, M., Ott, B., Seitz, B., and Heise, J. (2004). Untersuchungen zur Fortpflanzungsbiologie, Entwicklung und zu den Lebensräumen von Schneider (Alburnoides bipunctatus BLOCH 1782) und Strömer (Leuciscus souffia agassizi VALENCIENNES 1844)-Abschlussbericht über die Untersuchungen 2002-2004. *Bayer. Landesamt für Wasserwirtschaft, Abteilung Gewässerökologische Forschung, Ref. Fischökologie*, 96. |
| Bohlen | 2003 | paper | Bohlen, J. (2003). Spawning habitat in the spined loach, Cobitis taenia (Cypriniformes: Cobitidae). *Ichthyol. Res.* 50, 98–101. doi:10.1007/s102280300016. |
| Bohlen and Mlynek | 2003 | PhD thesis | Bohlen, J., and Mlynek, J. (2003). Untersuchungen zur Autökologie des Steinbeißers, Cobitis taenia. |
| Bohlen et al. | 2003 | paper | Bohlen, J., Šlechtová, V., Šanda, R., Kalous, L., Freyhof, J., Vukic, J., et al. (2003). Cobitis ohridana and Barbatula zetensis in the River Morača Basin, Montenegro: Distribution, Habitat, Population Structure and Conservation Needs. *Folia Biol. (Praha).* 51, 147–153. |
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| Bry | 1996 | book section | Bry, C. (1996). “Role of vegetation in the life cycle of pike,” in *Pike*, ed. J. F. Craig (Dordrecht (NL): Springer), 45–67. doi:10.1007/978-94-015-8775-4\_3. |
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| Carter et al. | 2004 | paper | Carter, M. G., Copp, G. H., and Szomlai, V. (2004). Seasonal abundance and microhabitat use of bullhead Cottus gobio and accompanying fish species in the River Avon (Hampshire), and implications for conservation. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 14, 395–412. doi:10.1002/aqc.617. |
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| Caswell and Aprahamian | 2001 | paper | Caswell, P. A., and Aprahamian, M. W. (2001). Use of river habitat survey to determine the spawning habitat characteristics of twaite shad (alosa fallax fallax). *BFPP - Bull. Fr. la Pech. la Prot. des Milieux Aquat.*, 919–929. doi:10.1051/kmae:2001027. |
| Consorzio Parco Lombardo della Valle del Ticino. | 2007 | report | Consorzio Parco Lombardo della Valle del Ticino. (2007). Il pigo (Rutilus Pigus). Studio dell’autoecologia della specie nel fiume Ticino. Pontevecchio di Magenta (IT). |
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| Copp | 1997 | paper | Copp, G. H. (1997). Microhabitat use of fish larvae and 0+ juveniles in a highly regulated section of the River Great Ouse. *Regul. Rivers Res. Manag.* 13, 267–276. doi:10.1002/(SICI)1099-1646(199705)13:3<267::AID-RRR454>3.0.CO;2-B. |
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| Copp and Mann | 1993 | paper | Copp, G. H., and Mann, R. H. K. (1993). Comparative growth and diet of tench Tinca tinca (L.) larvae and juveniles from river floodplain biotopes in France and England. *Ecol. Freshw. Fish* 2, 58–66. doi:10.1111/j.1600-0633.1993.tb00084.x. |
| Copp and Vilizzi | 2004 | paper | Copp, G. H., and Vilizzi, L. (2004). Spatial and ontogenetic variability in the microhabitat use of stream-dwelling spined loach (Cobitis taenia) and stone loach (Barbatula barbatula). *J. Appl. Ichthyol.* 20, 440–451. doi:10.1111/j.1439-0426.2004.00605.x. |
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| Copp et al. | 1994 | paper | Copp, G. H., Warrington, S., and de Bruine, Q. (1994). Comparison of diet in bullhead, Cottus gobio and stone loach, Barbatula barbatula in a small English lowland river. *Folia Zool.* 43, 171–176. |
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| Cowx et al. | 2001 | report | Cowx, I. G., Pitts, C. S., and Smith, K. L. (2001). Factors influencing coarse fish populations in rivers. Bristol (UK): Environment Agency. |
| Cowx et al. | 2004 | report | Cowx, I. G., Noble, R. A., Nunn, A. D., Harvey, J. P., Welcomme, R. L., and Halls, A. S. (2004). Flow and Level Criteria for Coarse Fish and Conservation Species. Bristol (UK): Environment Agency. |
| Crivelli | 1981 | paper | Crivelli, A. J. (1981). The biology of the common carp, Cyprinus carpio L. in the Camargue, southern France. *J. Fish Biol.* 18, 271–290. doi:10.1111/j.1095-8649.1981.tb03769.x. |
| Curtean-Bănăduc et al. | 2019 | paper | Curtean-Bănăduc, A., Cismaş, I.-C., and Bănăduc, D. (2019). Management Elements for Two Alburninae Species, Alburnus alburnus (Linnaeus, 1758) and Alburnoides bipunctatus (Bloch, 1782) Based on a Decision-Support System Study Case. *Transylvanian Rev. Syst. Ecol. Res.* 21, 81–92. |
| D’Amen et al. | 2017 | paper | D’Amen, M., Bombi, P., Traversetti, L., and Scalici, M. (2017). Relazione fra la presenza di Telestes muticellus (Bonaparte, 1837) e Rutilus rubilio (Bonaparte, 1837) e alcune caratteristiche ambientali. *Ital. J. Freshw. Ichthyol.*, 227–233. |
| Darchambeau and Poncin | 1997 | paper | Darchambeau, F., and Poncin, P. (1997). Field observations of the spawning behaviour of European grayling. *J. Fish Biol.* 51, 1066–1068. |
| Davey et al. | 2005 | paper | Davey, A. J. H., Hawkins, S. J., Turner, G. F., and Doncaster, C. P. (2005). Size-dependent microhabitat use and intraspecific competition in Cottus gobio. *J. Fish Biol.* 67, 428–443. doi:10.1111/j.0022-1112.2005.00736.x. |
| Degerman et al. | 2019 | paper | Degerman, E., Tamario, C., Watz, J., Nilsson, P. A., and Calles, O. (2019). Occurrence and habitat use of European eel (Anguilla anguilla) in running waters: lessons for improved monitoring, habitat restoration and stocking. *Aquat. Ecol.* 53, 639–650. doi:10.1007/s10452-019-09714-3. |
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| Domingos et al. | 2006 | paper | Domingos, I., Costa, J. L., and Costa, M. J. (2006). Factors determining length distribution and abundance of the European eel, Anguilla anguilla, in the River Mondego (Portugal). *Freshw. Biol.* 51, 2265–2281. doi:10.1111/j.1365-2427.2006.01656.x. |
| Duchi | 2011 | paper | Duchi, A. (2011). Fecundity, egg and alevin size in the River Irminio population of the threatened Salmo cettii Rafinesque-Schmaltz, 1810 (Sicily, Italy). *J. Appl. Ichthyol.* 27, 868–872. doi:10.1111/j.1439-0426.2010.01617.x. |
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