List of Supplementary Materials

S1: Overview of the distribution of specific survey sites along river Bregalnica profile including site-specific stream integrity rating and land use/cover in the corresponding basins

S2: Detailed overview of WHEBIP rating criteria, calculation specifics and applied alterations in regard to the original protocol first elaborated by Goforth and Bain (2010)

S3: Overview of the contribution of individual WHEBIP category metrics in the final WHEBIP stream integrity score for the 35 stream segments used in comparison with the site-specific sites

S4: Supplementary Material References

Figure S1: Overview of the distribution of specific survey sites along river Bregalnica profile including site-specific stream integrity rating and land use/cover in the corresponding basins

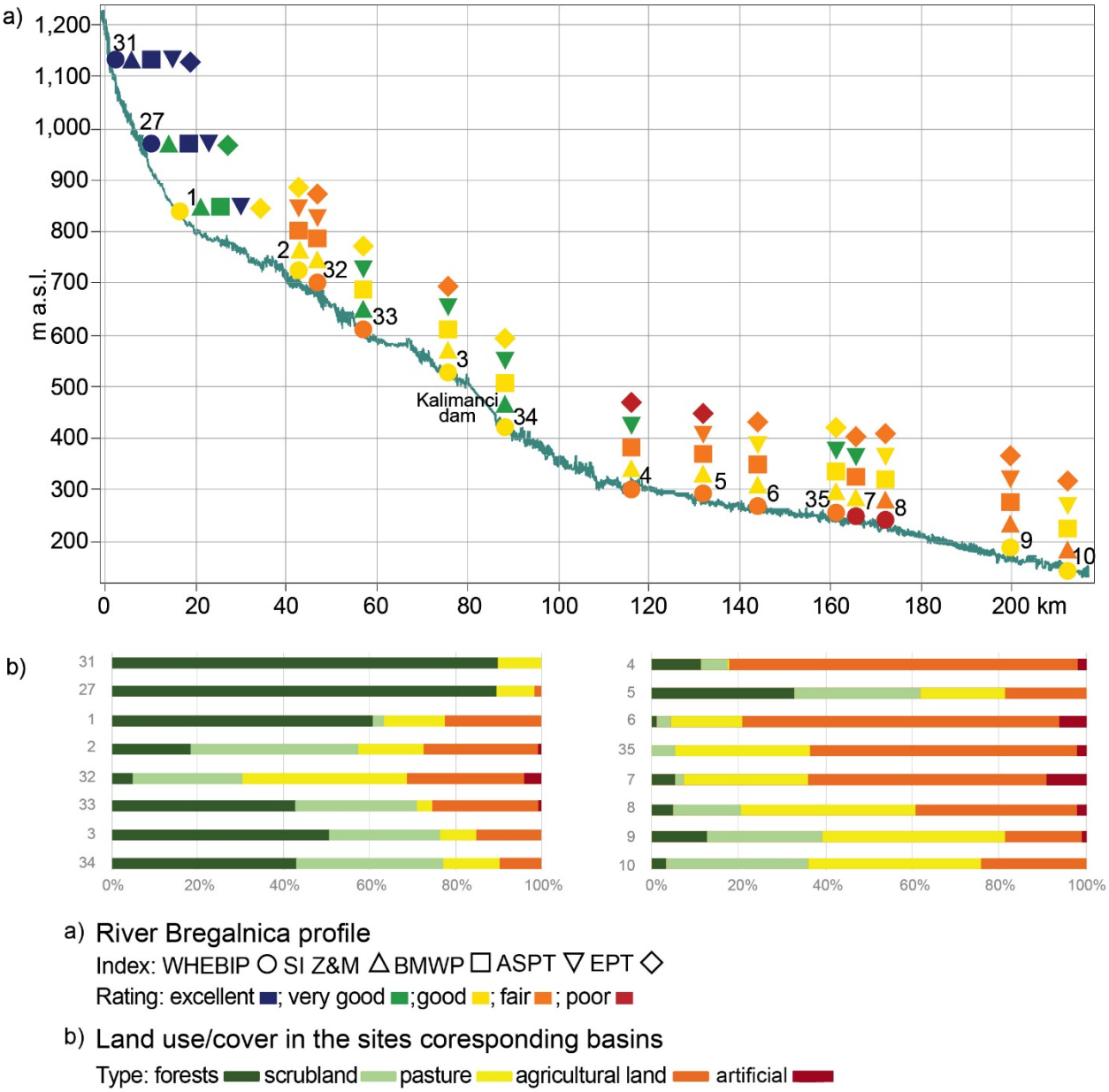

Table S2: Detailed overview of WHEBIP rating criteria, calculation specifics and applied alterations in regard to the original protocol first elaborated by Goforth and Bain (2010)

Category metric*	Metric descriptive characteristics (as originally provided by Goforth and Bain (2010)	Score	Upper French Creek watershed, USA Goforth and Bain (2010)** calculation specifics	Bregalnica watershed calculation specifics	Supporting literature***
1. Dominant riparian land cover	Forested; wooded wetland	35	Assessed with use of land-cover maps and aerial photographs. Assessment specifics and assessment references are not provided.	Determined by the dominant land use/cover group inside the 30, 50 and 100 m stream segment(s) buffer(s) area (30 m fixed buffer in Jovanovska *et al.* (2013)). Assessed with CLC 212: ***Forests:*** [311] Broad-leaved forest ; [312] Coniferous forest and [313] Mixed forest were rated highest; ***Brush/tall grass; wetland:*** [243] Land principally occupied by agriculture, with significant areas of natural vegetation; [321] Natural grasslands; [323] Sclerophyllous vegetation and [324] Transitional woodland-shrub; ***Meadows and pastures:*** [231] Pastures [331] Beaches, dunes, sands; [333] Sparsely vegetated areas; ***Altered/Anthropogenic habitats:*** all other CLC categories (in the case of Bregalnica [112, 121, 131, 132, 211, 213, 221, 222 and 242 Not assessed: [512] Water bodies Calculated by applying only the particular streams' (30, 50, 100 m) segment buffer.	Many authors have examined the complex interaction between the stream and its adjacency and have confirmed the causal effects (Burcher *et al.* 2007) that the adjacent land use/cover has on the instream physical habitat and the stream communities (Roth *et al.* 1996, Naiman and Décamps 1997, Lammert and Allan 1999, Allan 2004, Miserendino *et al.* 2011, Gieswein *et al.* 2017) with Ferńandez *et al.* (2011) listing the adjacent land use amongst the most recorded river habitat characteristics. The selected buffer widths has been supported by Hawes and Smith (2005) and Valle *et al.* (2013) with consideration of the background theories of the river continuum (Vannote *et al.* 1980, Ward *et al.* 2002) and accounting for the dynamics of the river floodplain (Ward and Stanford 1995).
	Brush/tall grasses; wetland	25			
	Grazed grasses	5			
	Row crop, construction, residential/commercial or no vegetation (bare soil)	1			
2. Estimated width of riparian area	>30m	35	Estimates the width of forest or wetland in the riparian area. Scores all other land covers as 1. Assessment specifics and assessment references are not provided.	Calculated as the area of riparian land cover inside a 50 m buffer of the stream segment divided with twice the stream segment length, thus representing the average width of the riparian belt. Assessed with combined use (intersection) of CLC 12 and Google Earth Imagery (specifically digitized layer of riparian vegetation used to assess the attributes of the immediate stream surroundings of river Bregalnica (given its significance as a carrying watercourse))	Wider and disrupted riparian forests, with larger trees and values of vertical canopy structure support higher macroinvertebrate community richness (Seger *et al.* 2012, Tanaka *et al.* 2016, Vimos-Lojano *et al.* 2017) and are
	5-30m	25			
	<5m	1			

3. Riparian canopy continuity along stream reach	No breaks in riparian canopy 35	35	Estimates riparian canopy continuity using aerial photographs. Assessment specifics and assessment references are not provided.	Calculated as the percentage of the stream segment length that is intersected with the 15 m buffer (5 m buffer in Jovanovska *et al.* (2013)) of the riparian land cover, thus representing the riparian canopy continuity. Assessed as WHEBIP 2	crucial for preservation of biodiversity (Bennett 1990, Roy *et al.* 2007, Valle Junior *et al.* 2015) and serve as a filter of the watershed nutrient input (Naiman and Décamps 1997, Tabacchi *et al.* 1998, Rios and Bailey 2006). Riparian habitat is also positively related to river habitat heterogeneity (Barquín *et al.* 2011). The ratings provided by Goforth and Bain (2010) are supported by the Riparian, Channel, and Environmental (RCE) protocol (Petersen 1992) and similar width and continuity rating is presented in the Riparian Quality Index (del Tánago and de Jalón Lastra 2011).
	Breaks compose up to 10% of canopy 25	25			
	Breaks compose 10–50% of canopy 10	10			
	Breaks compose more than 50% of canopy	1			
4. Presence of wetlands	Wetlands dominate riparian area	20	Assessment specifics and assessment references are not provided.	Calculated as the area of wetland land cover categories inside a 30, 50, 100 m buffer of the stream segment (30 m fixed buffer in Jovanovska *et al.* (2013)). Assessed using a digitized vector of wetland habitats, complemented by the land use data files and CLC 12	Lateral connection between the river and the floodplain has a great importance for river ecosystems (Ward and Stanford 1995). When the communication between the wetlands and the river courses is not impeded wetlands are a source of biodiversity and have a significant role in improving stream-water quality (Verhoeven *et al.* 2006, Richardson *et al.* 2011)
	Wetlands compose up to 50% of riparian area	10			
	No wetlands present	5			
5. Estimated percentage of land cover beyond riparian zone as cropland or pasture	<25%	25	Calculated as a % of land cover beyond riparian area as cropland or pasture. Assessed using land-cover maps and aerial photographs. Assessment specifics and assessment references are not provided.	Calculated as the percentage of agricultural land in the basin of the analysed stream segment. Area under pasture was not considered because of the extensive management of both hilly and mountain pastures in Bregalnica basin, and following the findings of Miserendino *et al.* (2011) that if the functions of the riparian belt are preserved, areas under pasture still supported rich communities of invertebrates, increasing overall biodiversity. The following CLC 12 categories were considered in the assessment: [211] Non-irrigated arable land [213] Permanently irrigated land [221] Vineyards [222] Fruit trees and berry plantations [242] Complex cultivation patterns and	The amount and the intensity of agricultural land use in the basin and the decrease in natural cover (e.g. Forests) have a negative effect on river integrity. The decrease in naturalness in the basin (mostly associated to intense agriculture) is often related to hydromorphological alterations, changes in physical habitat quality, nutrient enrichment and deprivation of stream
	25-49%	15			
	50-75%	5			
	≥75%	1			

				[243] Land principally occupied by agriculture, with significant areas of natural vegetation	communities richness (Roth *et al.* 1996, Allan *et al.* 1997, Blanco *et al.* 2007, Clapcott *et al.* 2012, Kail and Wolter 2013, Valle *et al.* 2013, Bruno *et al.* 2014, dos Santos and Esteves 2015, Feld *et al.* 2016, Tanaka *et al.* 2016, Segurado *et al.* 2018) etc.
6. Estimated percentage of land cover beyond riparian area as forest or brush	>75% 50-75% 25-49% <25%	35 20 10 1	Assessed as a % of land cover beyond riparian area as forest or brush. Assessed using land-cover maps and aerial photographs. Assessment specifics and assessment references are not provided.	Calculated as the percentage of forests in the basin of the analysed stream segment. The following CLC 12 categories were considered in the assessment: [311] Broad-leaved forest [312] Coniferous forest [313] Mixed forest [323] Sclerophyllous vegetation [324] Transitional woodland-shrub	
7. Riparian land cover for upstream stream segments	Forested Brush/tall grasses Grazed grasses Row crops or bare soil	50 40 10 1	Assessed using land-cover maps and aerial photographs. Includes riparian land cover of tributaries converging to form segment. Assessment specifics and assessment references are not provided.	Same as WHEBIP 1, calculated for upstream segment (incl. tributaries). Lowest score is assigned if the upstream stream segment riverbed has been hydromorphologicaly altered by dam construction or has a hydro accumulation reservoir.	Aside from the land use pressures acting at the reach and catchment scale, the river integrity is also significantly affected by the attributes of its upstream and those of its tributaries (Kail and Hering 2009, Kail and Wolter 2013, Feld *et al.* 2016) with upstream river habitat degradation seen as a dominant stressor (Lorenz and Feld 2013, Gieswein *et al.* 2017)
8. Subbasin land cover for stream segments immediately upstream	>75% intact 50–75% intact 25–49% intact <25% intact	3 20 10 1	Assessed using land-cover maps and aerial photographs. Includes subbasin areas of tributaries converging to form stream segment. Assessment specifics and assessment references are not provided.	Same as WHEBIP 6, calculated for upstream segment (incl. tributaries) Lowest score is assigned if the upstream stream segment riverbed has been hydromorphologicaly altered by dam construction or has a hydro accumulation reservoir.	
9. Stream segment subbasin land gradient	Low gradient Moderate gradient High gradient	20 15 10	Assessed using topographic map. Assessment specifics are not provided	Calculated as the most common of the three terrain slope range categories in stream segments' subbasin (1. [0-4]; 2. [4-8]; 3. [>8] degrees slope). Assessed using the Digital Elevation Model (ASTER GDEM).	Land gradient in this case serves as a "weight" of the upstream-downstream turnoff in the final score. Slope together with distance from source is also used by Gieswein *et al.* (2017) to account for natural biological response patterns.
	No point sources likely	25			

10. Point source pollution	Point source likely within drainage area	10	Assessed using land-cover maps and aerial photographs. Sewage treatment plants, mines, construction, barnyards, cow trails and roads are considered. Assessment specifics and assessment references are not provided.	Calculated as the presence or absence of intersection between the union of populated places/settlements vector and point sources pollution vector (digitized polygon-vectors) with a) stream segments (for differentiation between the low and middle score) and b) stream segments' subbasin (for differentiation between middle and high score). The buffer width on populated places/settlements varied from 30 m, 50 m to 100 m (fixed 50m buffer in Jovanovska *et al.* (2013)) depending on the settlement type (tourist settlements, scattered/ clumped village type) and the degree of impact that the settlements have on the specific stream segment (low, medium and high). The buffer width of other single identifiable source of pollution ranged from 250 m for industrial centres, factories, disposal sites and dumps going up to 500 m for mines depending on the character and the degree of impact of the pollution source (only wastewater discharge points were considered in Jovanovska *et al.* (2013)). Assessed using a digitized vectors, complemented by the land use data files and CLC 12		Various studies have confirmed that settlements (Paul and Meyer 2001, Roy *et al.* 2001, Wang and Kanehl 2003, Miltner *et al.* 2004), mines (Alderton *et al.* 2005, Ramani *et al.* 2014) and industrial centres (Imoobe and Koye 2011, Walakira and Okot-Okumu 2011) impact the stream biotic integrity.
	Point source likely adjacent to stream	1				
10a. Point source pollution upstream	No point source upstream (incl. tributaries)	-20	Not considered	Same as WHEBIP 10, calculated for upstream segment(s) (incl. tributaries)		Included considering the important role of upstream river habitat quality and that of its tributaries referred to previously (WBP 7 and 8)
	Point source likely within the drainage area upstream (incl. tributaries)	-10				
	No point sources upstream (incl. tributaries)	0				
11. Presence of roads	No roads present	25	Assessed using maps and aerial photographs. Considered due to the causal effects of increased availability to resources: e.g. logging, farm, gravel. Crossings with bridges or culverts are considered. Assessment specifics and assessment references are not provided.	No significant hydromorphological alterations	***All major hydromorphological alterations are considered.*** Calculated as the presence or absence of intersection between a) the stream and the buffer of a vector comprising hydromorphological disturbances and alterations (determining the lowest score) and b) intersection between 30m buffer of the stream segment and the vector comprising hydromorphological disturbances and alterations (for differentiation between the middle and high score). Buffer width (5m, 10m and 50m) depends of the character and the degree of impact of the hydromorphological disturbance.	A number of studies have confirmed the rivers are affected by hydromorphological alterations, especially dams (Vinson 2001, Bredenhand and Samways 2009, Belmar *et al.* 2013, Kail and Wolter 2013, Aguiar *et al.* 2016). Aside from the well-studied fragmentation effect of roads, they also play a role in increasing the runoff pollution (Krein and Schorer 2000, Helmreich *et al.* 2010).
	Roads present, within 30 m of stream or crossing with bridges or culvert	10		Alterations within 30 m of the stream segment		
	Roads present: crossings through streambed or active construction	1		Alterations directly intersect with the stream segment		

					Roads, bridges, sand quarries, canals, river barrages, reservoirs and accumulations have been taken as relevant input data on hydromorphological disturbances. Assessed using a digitized vectors, complemented by the land use data files and CLC 12 In Jovanovska *et al.* (2013) a fixed 30 m buffer is applied and only roads and bridges have been considered (same as Goforth and Bain. 2010)	
12. Existence of conservation activity	Conservation actions for >10 years	25	Assessed using land cover maps, aerial photographs and input from county land planners, county extension and conservation organizations. Riparian fencing, soil conservation, set-asides are considered. Forest and wetland dominated areas receive the highest score. Other assessment specifics and assessment references are not provided.	Calculated by the time length of a conservation activity in a stream segments' vicinity (the presence of a protected area in a 50 m buffer (depends of the type and effect of the conservational activity the buffer can be changed) of a stream segment). If a stream segment's WHEBIP category 6 score has been high - 35 (76-100 % forest or brush in the subbasin), then the score of WHEBIP category 12 becomes high (25). Assessed using the national Representative network of protected areas		Existing conservational activities in the basin (especially along the stream) are a reference to high naturalness. Protected areas are generally considered to support high naturalness and high valued free flowing rivers (Mancini *et al.* 2005, Nel *et al.* 2007).
	Conservation actions within 5–10 years	15				
	Conservation actions within <5 years	10				
	No conservation action	1				

*Category metrics presented in the table follow on those originally provided by Goforth and Bain (2010). In the case of Bregalnica watershed few category metrics have been rephrased (following on Jovanovska *et al.* (2013). See Figure 1 and Table S3.

**Criteria by Goforth and Bain (2010) are "developed based on published relationships between stream ecosystems and surrounding landscapes, the authors' field experiences, and on-site stream assessments" [e.g., fish Index of Biotic Integrity (IBI)] (Karr, 1981) and Riparian, Channel, and Environmental (RCE) protocol developed by Petersen (1992). Assessment specifics and assessment references are not provided.

***Considering that land use pressures do not act in isolation, much of the papers used as a supporting literature focus on both catchment and local scale, some dealing with the multiscale effects and interactive pathways of stressors and examined species specific responses.

Table S3: Overview of the contribution of individual WHEBIP category metrics in the final WHEBIP stream integrity score for the 35 stream segments used in comparison with the site-specific sites

Site survey locality code	*WBP1*	*WBP2*	*WBP3*	*WBP4*	*WBP5*	*WBP6*	*WBP7*	*WBP8*	*WBP9*	*WBP10*	*WBP10a*	*WBP11*	*WBP12*	*WHEBIP score*	*WHEBIP rating*
1	25	35	10	1	15	20	50	20	10	1	0	1	1	189	good
2	25	35	35	1	15	10	50	1	10	1	-20	10	1	174	Good
3	25	25	1	1	1	1	1	1	10	10	-10	1	1	68	Poor
4	25	35	10	1	1	1	40	10	15	10	-20	1	1	130	Fair
5	25	35	10	1	25	20	1	10	10	1	-20	1	1	120	Fair
6	25	35	25	1	1	1	1	10	15	1	-20	1	1	97	Fair
7	1	25	1	1	1	1	1	1	15	1	-20	1	1	30	Poor
8	25	35	10	1	5	1	1	1	15	1	-20	1	1	77	Poor
9	25	35	25	1	15	10	40	1	10	1	-20	25	1	169	Good
10	35	35	25	1	15	1	40	20	15	25	-20	25	1	218	Good
27	35	35	35	1	25	35	50	30	10	25	0	25	25	331	Excellent
31	35	35	35	1	25	35	50	30	10	25	0	25	25	331	Excellent
32	5	25	10	1	25	10	40	10	10	1	-20	1	1	119	Fair
33	1	25	1	1	15	20	1	1	10	1	-10	25	1	92	Fair
34	35	35	25	1	25	20	1	10	10	1	0	1	1	165	Good
35	1	25	10	1	1	1	40	1	15	1	-20	10	1	87	Fair

Watershed Habitat Evaluation and Biotic Integrity Protocol (WHEBIP) metric descriptions and rating criteria for each metric according to Goforth & Bain (2010), rephrased: *Dominant riparian land cover (WBP1):* forest (35); riparian scrubland, grassland and wetland (25); meadows and pastures (5); altered, anthropogenic habitats (1); *Width of Riparian Belt (WBP2):* > 30 m (35); 5–30 m (25); < 5 m (1); *Riparian canopy continuity (WBP3):* No breaks in the riparian canopy (35); Breaks up to 10% of canopy (25); Breaks of 10-50% of canopy (10); Breaks compose >50% of canopy (1); *Presence of Wetlands (WBP4):* Wetlands dominate riparian area (20); Wetlands compose up to 50% of riparian area (10); No wetlands (1); *Agriculture in the drainage area (WBP5):* 0-25% (25); 26-50% (15); 51-75% (5); 76-100% (1); *Forest or scrubland in the drainage area (WBP6):* 76-100% (35); 51-75% (20); 26-50% (10); 0-25% (1); *Upstream riparian land cover (WBP7):* forest (50); riparian scrubland, grassland and wetland (40); meadows and pastures (10); altered, anthropogenic habitats (1); *Upstream forest or scrubland (WBP8):* 76-100% (30); 51-75% (20); 26-50% (10); 0-25% (1); *Land Gradient (WBP9):* Low or flat (20); Moderate (15); High (10); *Point Source Pollution (WBP10):* No point source(s) likely (25); Point source(s) likely within watershed (10); Point source(s) likely along stream (1); *Point source pollution upstream* (WBP10a) No point sources upstream (0); Point sources within the drainage area upstream (-10); Point sources adjacent upstream (-20); *Hydromorphological alterations (WBP11):* No significant hydromorphological alterations (25); Alterations within 30 m of the stream segment (10); Alterations directly intersect with the stream segment (1); *Conservation Activity (WBP12):* Conservation actions for > 10 yrs (25); Conservation actions 5-10 yrs (15); Conservation actions within <5 yrs (10); No conservation actions (1); *WHEBIP rating:* p - poor, f - fair; g - good; vg - very good; e – excellent. For site survey codes position see Figure 2.

S4: Supplementary Material References

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