

Interpretation

The indicator provides still a simplified, but more detailed indication (compared to HPI_{simple}) of the importance of the studied floodplain segment for the functional and structural quality of floodplain-typical habitats, biotic communities, and species as a basis for multiple human uses, thus reflecting ES habitat provision.

If the information on the conservation status of the Flora-Fauna-Habitat Directives habitat types or on presence/absence of other value-adding characteristics is available for an investigation area, this can be added to the evaluation on habitat level.

References

- Finck, P., Heinze, S., Rath, U., Riecken, U. & Ssymank, A. (2017). Rote Liste der gefährdeten Biotoptypen Deutschlands. Dritte fortgeschriebene Fassung 2017. Bundesamt für Naturschutz (BfN; Hrsg). Naturschutz und Biologische Vielfalt, Heft 156.
- Fischer, C., Damm, C., Foeckler, F., Gelhaus, M., Gerstner, L., Harris, R., Hoffmann, T.G., Iwanowski, J., Kasperidus, H., Mehl, D., Podschun, S.A., Rumm, A., Stammel, B. & Scholz, M. (2019). The "habitat provision" index for assessing floodplain biodiversity and restoration potential as an ecosystem service—Method and application. *Frontiers in Ecology and Evolution*, 7, 483; <https://www.frontiersin.org/articles/10.3389/fevo.2019.00483/full>
- Riecken U., Finck, P., Rath, U., Schröder, E. & Ssymank, A. (2006). Rote Liste der gefährdeten Biotoptypen Deutschlands. Zweite fortgeschriebene Fassung 2006. Bundesamt für Naturschutz (BfN; Hrsg). Naturschutz und Biologische Vielfalt, Heft 85, Bonn - Finck, P., Heinze, S., Rath, U., Riecken, U. & Ssymank, A. (2017). Rote Liste der gefährdeten Biotoptypen Deutschlands. Dritte fortgeschriebene Fassung 2017. Bundesamt für Naturschutz (BfN; Hrsg). Naturschutz und Biologische Vielfalt, Heft 156.

■ Original approach according to River Ecosystem Service Index (RESI) (Podschun et al., 2018)

Class	Abbr.	Description			Spatial reference
Regulating	HPI_{detail}	"Habitat Provision covers the functional and structural quality of habitats and their communities as a basis for multiple human uses. In this case, habitats provide a diversity of animal and plant communities typical for rivers and floodplains both of natural and cultural landscape." (Fischer et al. 2019)			Floodplain segment or compartment <input checked="" type="checkbox"/> former floodplain <input checked="" type="checkbox"/> active floodplain <input type="checkbox"/> river
Variable	Abbr.	Unit	Variable description	Data basis	Comment
Habitat type value	HTVi	Nominal, evaluation ordinal (1-5)	Habitat types were classified and evaluated for the 6 variables GDi, RLi, FFHi, LPi, REi and FSi following Fischer et al. (2019). The mean of these 6 parameters is the HTVi for a specific habitat type	Habitat mapping	Assign/adapt the occurring habitat types according to Finck et al. (2017)
Groundwater dependence of the specific habitat	GDi	Ordinal (5, 3, 1)	Groundwater dependence of HTVi according to the European Water Framework Directive (WFD)	Finck et al. (2017)	5: dependent; 3: depending on certain characteristics; 1: independent

Red List status of the specific habitat	RLi	Ordinal (5, 3, 1)	Red List Status (Germany) of HTVi	Finck et al. (2017)	5: strongly endangered to destroyed; 3: endangered/affected; 1: not endangered
Fauna Flora Habitat of the specific habitat	FFHi	Ordinal (5, 3, 1)	Classification of HTVi as habitat type of the Habitats Directive	Finck et al. (2017)	5: FFH-type; 3: depending on certain characteristics; 1: not FFH-type
Legal Protection Status of the specific habitat	LPi	Ordinal (5, 3, 1)	Legal Protection Status of the HTVi	Finck et al. (2017)	5: protected by law; 3: depending on certain characteristics; 1: not protected
Regenerability of the specific habitat	REi	Ordinal (5, 3, 1)	Regenerability (recoverability/development time) of HTVi: regeneration by natural succession or restoration	Finck et al. (2017)	5: Minimal or none; 3: very limited; 1: limited
Floodplain specific habitat	FSi	Ordinal (5, 3, 1)	Binding of HTVi to floodplains and its functionality	Expert opinion	5: exclusive floodplain characteristic; 3: Medium floodplain characteristic; 1: Not floodplain characteristic
Conservation status of FFH-habitat	CShab	Ordinal (1; 0; -0,5)	Conservation status of habitat according to the Habitat Directive of HTVi	FFH-mapping	Bonus/Malus at the habitat level A: 1; B: 0; C: -0.5
Additional biological quality feature	Value_added	Bonus	Higher quality of HTVi in terms of nature conservation	Projekt specific data	Bonus at habitat level
Altered flooding regime	FR	Penalty	Anthropogenic changes of flooding frequency or exclusion	lokal Data	Penalty at habitat level
Backwater influence	BI	Penalty	Influence of impoundment/backwater of transverse structures (e.g. barrage)	Data on impoundments	Malus at habitat level
Moisture integrity	MI	Bonus	Completeness of habitats of the whole moisture gradient within the entire floodplain segment	Expert opinion	Bonus at compartment level

Calculation						
Evaluation scheme				Indicator		
<p>1. Step: Habitat type level</p> <p>Assessment unit: Habitat type</p> <p>6 evaluation criteria</p> <div> Groundwater dependency Red List status FFH-Habitat Legal protection Regenerability Floodplain specific habitats </div> <p>Habitat type-unit in 5 classes (Individual area-/polygons per compartment)</p> <p>2. Step: Habitat level</p> <div> <div> Abiotic¹ <div> Altered flooding regime² former floodplain: -1 with flooding: +0.25, +0.5, +0.75 Polder without ecological flooding -0.25 Backwater influence active floodplain: 1, 0.5, 0.25 former floodplain: -0.5, -0.25, 0 </div> </div> <div> Conservation status (bonus/penalty: A: +1; B: 0; C: -0.5) Characteristic species (bonus: +1) </div> </div> <p>3. Step: Aggregation on the Compartment level</p> <p>Σ Habitat value (all areas, 1-5 standardization through area-weighting after km-compartment)</p> <p>Moisture integrity³ (bonus: +0.5)</p> <p>Habitat index in 5 classes (per compartment)</p> <div> 1 Very low 2 Low 3 Medium 4 High 5 Very high </div>				<p>1. Step: Assessment of habitat type value in general by calculating the mean of 6 parameters (Fischer et al. 2019)</p> $HTV_i = \frac{GD_i + RL_i + FFH_i + LP_i + RE_i + FS_i}{n}$ <p>n=number of criteria</p> <p>Mean value from the individual variables of the habitat quality elements. If individual values are missing, the mean value is calculated from the remaining variables.</p> <p>2. Step: Assessment of individual habitats</p> $HV_i = HTV_i FR_i + BI_i$ <p>The assessment is based on the value of the habitat type in general (HTV) and additional abiotic (FR, BI) site specific parameters..</p> <p>3. Step: Area-weighted aggregation of Index for floodplain segment or compartment</p> $HPI_{detail} = \frac{\sum_{i=1}^n (HV_i * A_i)}{\sum_{i=1}^n A_i + MI}$ <p>Area-weighted averaging of all HVi of a compartment (Ai). Bonus for moisture gradient (MI).</p>		
<p>¹ Penalty/Bonus only for floodplain-typical/near-natural habitat types (habitat types with floodplain connection 3 and 5</p> <p>² Summer polders and other floodplain areas protected by dikes, floodplains with inlet sills or controllable inlet structures (e.g. the reed stream on the Danube) and controlled polders (possibly with stages of ecological flooding</p> <p>³ Only for habitat types with floodplain connection 5</p>						
Scaling	<input type="checkbox"/> national <input checked="" type="checkbox"/> local	HPI _{detail}	≥ 4.5	< 4.5 - ≥3.5	< 3.5 - ≥2.5	< 2.5 - ≥1.5
Evaluation Class						
Qualitative Evaluation			5 Very high importance for habitat provision	4 High importance for habitat provision	3 Moderate importance for habitat provision	2 Low importance for habitat provision
						1 Very low importance for habitat provision

■ Adaption for Danube-wide application

Class	Abbr.	Description			Spatial reference
Regulating	HPI _{detail}	“Habitat Provision covers the functional and structural quality of habitats and their communities as a basis for multiple human uses. In this case, habitats provide a diversity of animal and plant communities typical for rivers and floodplains both of natural and cultural landscape.” (Fischer et al. 2019)			Floodplain segment or compartment <input checked="" type="checkbox"/> former floodplain <input checked="" type="checkbox"/> active floodplain <input type="checkbox"/> river
Variable	Abbr.	Unit	Variable description	Data basis	Comment
Habitat type value	HTVi	Nominal, Evaluation ordinal (1-5)	Habitat types were classified and evaluated for the 6 variables GD _i , RL _i , FFH _i , LP _i , RE _i and FS _i following Fischer et al. (2019). The mean of these 6 parameters is the HTVi for a specific habitat type	Habitat mapping. When only selective maps or not available completed or substituted by Copernicus Riparian Zone (MAES_4) and Corine land cover	Assign/adapt the occurring habitat types according to Finck et al. (2017)
Groundwater dependence of the specific habitat	GD _i	Ordinal (5, 3, 1)	Groundwater dependence of HTVi according to the European Water Framework Directive (WFD)	Habitat list (Finck et al. 2017)	5: dependent; 3: depending on certain characteristics; 1: independent
Red List status of the specific habitat	RL _i	Ordinal (5, 3, 1)	Red List Status (Germany) of HTVi	Habitat list (Finck et al. 2017)	5: strongly endangered to destroyed; 3: endangered/affected; 1: not endangered
Fauna Flora Habitat of the specific habitat	FFH _i	Ordinal (5, 3, 1)	Classification of HTVi as habitat type of the Habitats Directive (FFH-Dir)	Habitat list (Finck et al. 2017)	5: FFH-type; 3: depending on certain characteristics; 1: not FFH-type
Legal Protection Status of the specific habitat	LP _i	Ordinal (5, 3, 1)	Legal Protection Status of the HTVi	Habitat list (Finck et al. 2017)	5: protected by law; 3: depending on certain characteristics; 1: not protected
Regenerability of the specific habitat	RE _i	Ordinal (5, 3, 1)	Regenerability (recoverability/development time) of HTVi: regeneration by natural succession or restoration	Habitat list (Finck et al. 2017)	5: Minimal or none; 3: very limited; 1: limited
Floodplain specific habitat	FS _i	Ordinal (5, 3, 1)	Binding of HTVi to floodplains	Fischer et al. (2019)	5: exclusive floodplain characteristic;

			and its functionality		3: Medium floodplain characteristic; 1: Not floodplain characteristic
Altered flooding regime	FR	Penalty	Anthropogenic changes of flooding frequency or exclusion	Active floodplain delineated by Danube Floodplain Project	Optional, penalty for former floodplain for the segments which contain active floodplains from the Danube Floodplain Project only
Backwater influence	BI	Penalty	Influence of impoundment/backwater of transverse structures (e.g. barrage)	Hydrological Alterations – Impoundments, Danube River Basin Management Plan (DRBMP)	Malus at habitat level
Moisture integrity	MI	Bonus	Completeness of habitats of the whole moisture gradient within the entire floodplain segment	Fischer et al. (2019)	Bonus at compartment level

Evaluation scheme			Indicator			
<div>1. Step: Habitat type level</div> <div>Assessment unit: Habitat type</div> <div>6 evaluation criteria</div> <div>Groundwater dependency Red List status FFH-Habitat Legal protection Regenerability Floodplain specific habitats</div> <div>Habitat type-unit in 5 classes (Individual area-/polygons per compartment)</div> <div>2. Step: Habitat level</div> <div>Abiotic¹<div>Altered flooding regime² former floodplain: -1 with flooding: +0.25, +0.5, +0.75 Polder without ecological flooding: -0.25</div><div>Backwater influence active floodplain: 1, 0.5, 0.25 former floodplain: -0.5, -0.25, 0</div></div> <div>Conservation status (bonus/penalty: A: +1; B: 0; C: -0.5)</div> <div>Characteristic species (bonus: +1)</div> <div>Biotic</div> <div>3. Step: Aggregation on the Compartment level</div> <div>Σ Habitat value (all areas, 1-5 standardization through area-weighting after km-compartment)</div> <div>Moisture integrity³ (bonus: +0.5)</div> <div>Habitat index in 5 classes (per compartment)</div> <div>1 Very low 2 Low 3 Medium 4 High 5 Very high</div>			<div>1. Step: Assessment of habitat type value in general by calculating the mean of 6 parameters (Fischer et al. 2019)</div> <div>$HTV_i = \frac{1}{n} \sum_{i=1}^n GD_i + RL_i + FFH_i + LP_i + RE_i + FS_i$</div> <div>n=number of criteria</div> <div>Mean value from the assignment of HTVi values of groundwater dependence according to groundwater dependence (GD), red list status (RL), FFH status (FFH), legal protection (LP) and regenerability (RE) according to Finck et al. (2017). Floodplain specific habitat (Fs) was determined on an expert basis. For the criteria GW and RE, no assessment was made for "no classification meaningful" according to Finck et al. (2017). If these values were missing, the mean value was calculated from the remaining variables.</div> <div>2. Step: Assessment of individual habitats</div> <div>$HV_i = HTV_i + Cshab_i + FR_i + BI_i + Value_{add_i}$</div> <div>The assessment is based on abiotic and biotic site parameters. The first group includes altered flooding regime (FR) and location of the floodplain compartment in the backwater area of a dam. The second group includes FFH conservation status (Cshab) and value-adding features (Value_{add}). Addition of bonus (Cshab, Value_{add}) and malus (FR, Cshab, Value_{add}).</div> <div>3. Step: Area-weighted aggregation of Index for floodplain segment or compartment</div> <div>$HPI_{detail} = \frac{\sum_{i=1}^n (HV_i * A_i)}{\sum_{i=1}^n A_i + MI}$</div> <div>Area-weighted averaging of all HVi of a compartment (Ai). Bonus for moisture gradient (MI).</div>			
Scaling	HPI _{detail}	≥ 4.5	< 4.5 - ≥3.5	< 3.5 - ≥2.5	< 2.5 - ≥1.5	<1.5
<input type="checkbox"/> national <input checked="" type="checkbox"/> local						
Evaluation Class	5	4	3	2	1	
Qualitative Evaluation	Very high importance for habitat provision	High importance for habitat provision	Moderate importance for habitat provision	Low importance for habitat provision	Very low importance for habitat provision	

1. Step: Assessment of habitat type value in general by calculating the mean of 6 parameters (Fischer et al. 2019)

$$HTV_i = \frac{1}{n} \sum_{i=1}^n GD_i + RL_i + FFH_i + LP_i + RE_i + Fs_i$$

n=number of criteria

Mean value from the assignment of HTVi values of groundwater dependence according to groundwater dependence (GD), red list status (RL), FFH status (FFH), legal protection (LP) and regenerability (RE) according to Finck et al. (2017). Floodplain specific habitat (Fs) was determined on an expert basis. For the criteria GW and RE, no assessment was made for "no classification meaningful" according to Finck et al. (2017). If these values were missing, the mean value was calculated from the remaining variables.

2. Step: Assessment of individual habitats

$$HV_i = HTV_i + Cshab_i + FR_i + BI_i + Value_{add_i}$$

The assessment is based on abiotic and biotic site parameters. The first group includes altered flooding regime (FR) and location of the floodplain compartment in the backwater area of a dam. The second group includes FFH conservation status (Cshab) and value-adding features (Value_{add}). Addition of bonus (Cshab, Value_{add}) and malus (FR, Cshab, Value_{add}).

3. Step: Area-weighted aggregation of Index for floodplain segment or compartment

$$HPI_{detail} = \frac{\sum_{i=1}^n (HV_i * A_i)}{\sum_{i=1}^n A_i + MI}$$

Area-weighted averaging of all HVi of a compartment (Ai). Bonus for moisture gradient (MI).

				Scaling ☐ national ☒ local	HPI_{detail}	≥ 4.5	< 4.5 - ≥3.5	< 3.5 - ≥2.5	< 2.5 - ≥1.5	<1.5
Evaluation Class		5	4	3	2	1				
Qualitative Evaluation		Very high importance for habitat provision	High importance for habitat provision	Moderate importance for habitat provision	Low importance for habitat provision	Very low importance for habitat provision				

■ Data sources

Data set	Data type	Spatial reference	Spatial resolution	Source	Creation date	Comments
HTVi Riparian Zone Corine Land Cover	Polygon	international/national, segment		Riparian Zone: https://land.copernicus.eu/local/riparian-zones/land-cover-land-use-lcl-image?tab=download Corine Land Cover: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018?tab=download ; Site-specific habitat mapping		Assignment of the habitat types to those of Fischer et al. (2019) and Finck et al. (2017); intermediate
FSi, MI	Table			Fischer et al. (2019): https://www.frontiersin.org/articles/10.3389/fevo.2019.00483/full		
FR	Polygon	international/FFP		http://www.geo.u-szeged.hu/dfgis/	2020	
BI	Line shape file	international/river		https://www.danubegis.org/	2015	