Supplementary Material to the Article

„Effects of hydraulic engineering restoration measures on invasive gobies in a large river (Danube, Austria)"

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Online Resource 1:

To assess the sediment composition, the choriotope structure was estimated following Moog et al. (1999). In order to determine whether this structure corresponds to the mesohabitat types, we performed a principal component analysis (Fig. S1; PCA Choriotope type). A similar PCA was conducted with the environmental variables w*ater depth*, *relative water temperature*, *flow velocity*, *grain size*, and *substrate dominance* for the post-surveys (Fig. S1; PCA other environmental variables). *Relative water temperature* is the difference of the water temperature measured in a mesohabitat from the daily mean water temperature of the Danube (measured at a hydrological station). *Grain size* and *substrate dominance* are calculated variables ranging from 0 to 1, and are both based on choriotope composition. *Grain size* is the mean of weighted proportions of the choriotope classes ranked by substrate size. A high *grain size* value corresponds to a high amount of larger stones and rocks, a low value to a high amount of fine substrate (e.g. sand, mud). *Substrate dominance* gives the proportion of a mesohabitat that is composed of substrate (of different grain sizes) vs. living and dead plant material, being 1 if no plants or deadwood are present. For the PCAs all variables were standardized by z-transformation.

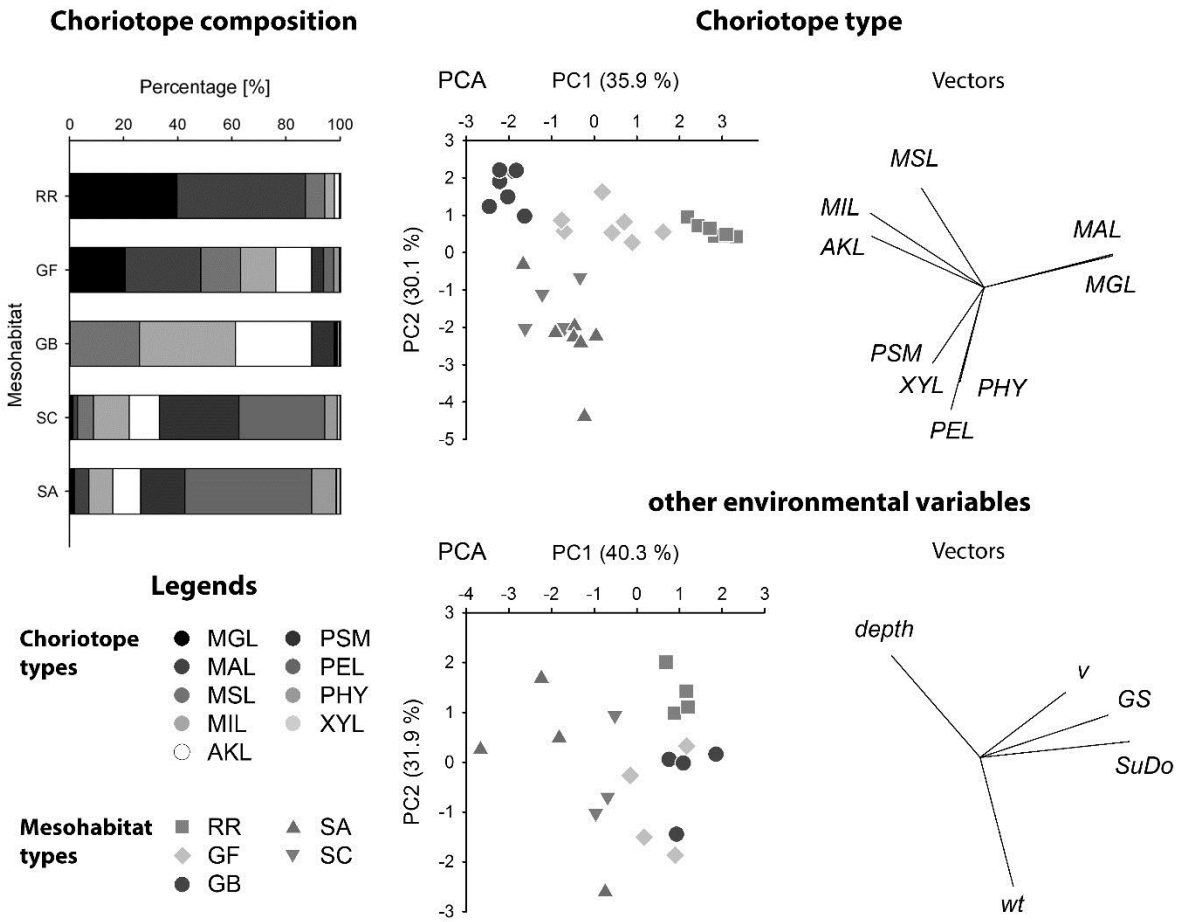

Fig. S1: Choriotope composition and PCAs of abiotic factors of mesohabitat types. The PCAs are based on normalized values of choriotope types (above) and other environmental variables (below) in the mesohabitats, using the variables indicated at the correlation vectors. MGL – megalithal, MAL – macrolithal, MSL – mesolithal, MIL – microlithal, AKL – akal, PSM – psammal, PEL – pelal, PHY – macrophytes, XYL – xylal (see Moog et al., 1999 for details on choriotope types); GS – grain size, SuDo – substrate dominance, depth – mean measured water depth, v – mean measured flow velocity, wt – relative water temperature . RR – riprap, GF – groynefield, GB – gravel bar, SA – side arm, SC – side channel.

Online Resource 2:

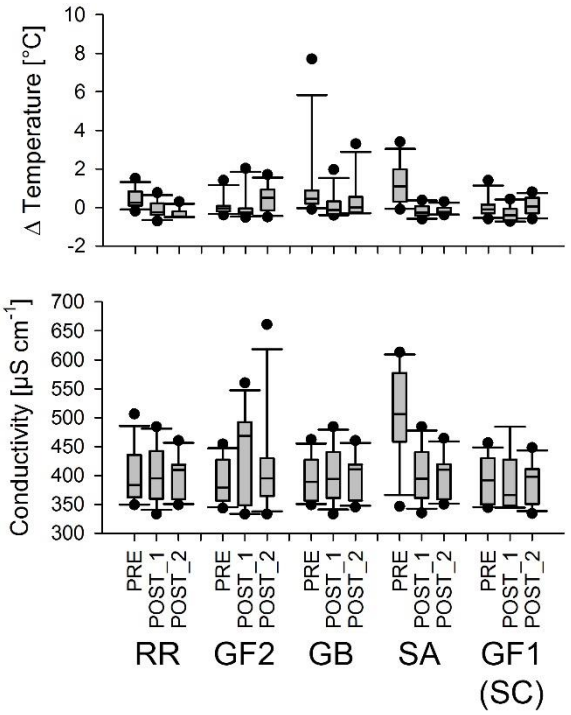

Fig. S2: Changes in mean relative water temperature (above) and conductivity (below) in the five mesohabitats in the project section, which were affected by river engineering measures. Black line – median; whiskers – 25/75 quartiles; dots – 5/95 percentiles. PRE – pre-survey in 2006/07; POST1 – post-survey 1 in 2014/15; POST2 – post-survey 2 in 2017. RR – riprap (measure 3; unmodified part during post-surveys), GF2 – modified groyne field (measure 2), GB – gravel bar (measure 3; unmodified part during pre-survey), SA – reconnected side arm (measure 4), GF1 – groyne field converted to side channel (SC; measure 1). See text for details on measures.

Online Resource 3:

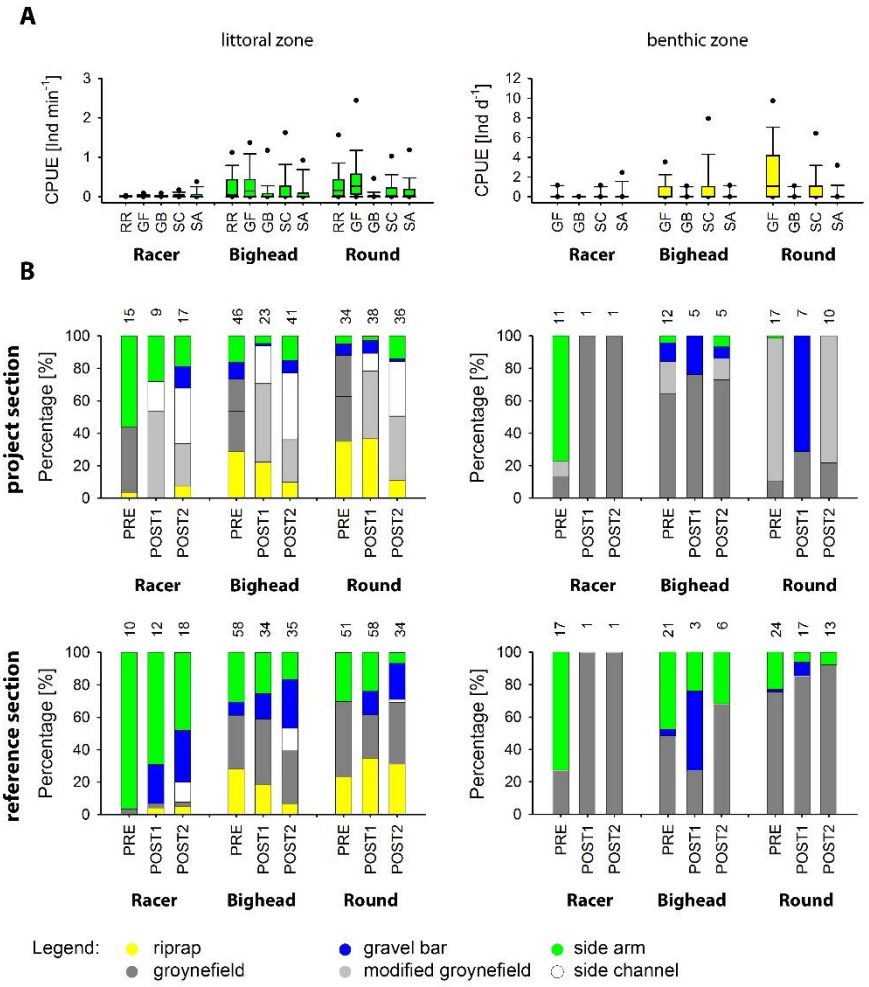

Fig. S3: Mesohabitat usage of the three invasive goby species in the littoral (green, left column) and benthic zone (yellow, right column). [A] Total abundance of the goby species in the mesohabitat types averaged over all surveys and sections, showing long-term habitat preferences. RR – riprap, GF – groynefield, GB – gravel bar, SA – side arm, SC – side channel. [B] Proportional usage of mesohabitat types during the surveys. The side channel in the project section was a groyne field before the measures were conducted in the pre-survey. The side channel in the reference section was only sampled during post-survey 2. Numbers above the bars indicate number of samples (day/mesohabitat combinations) in which at least one of the respective species was caught. Note that ripraps were not sampled with longlines. PRE – pre-survey in 2006; POST1 – post-survey 1 in 2014; POST2 – post-survey 2 in 2017.

Online Resource 4:

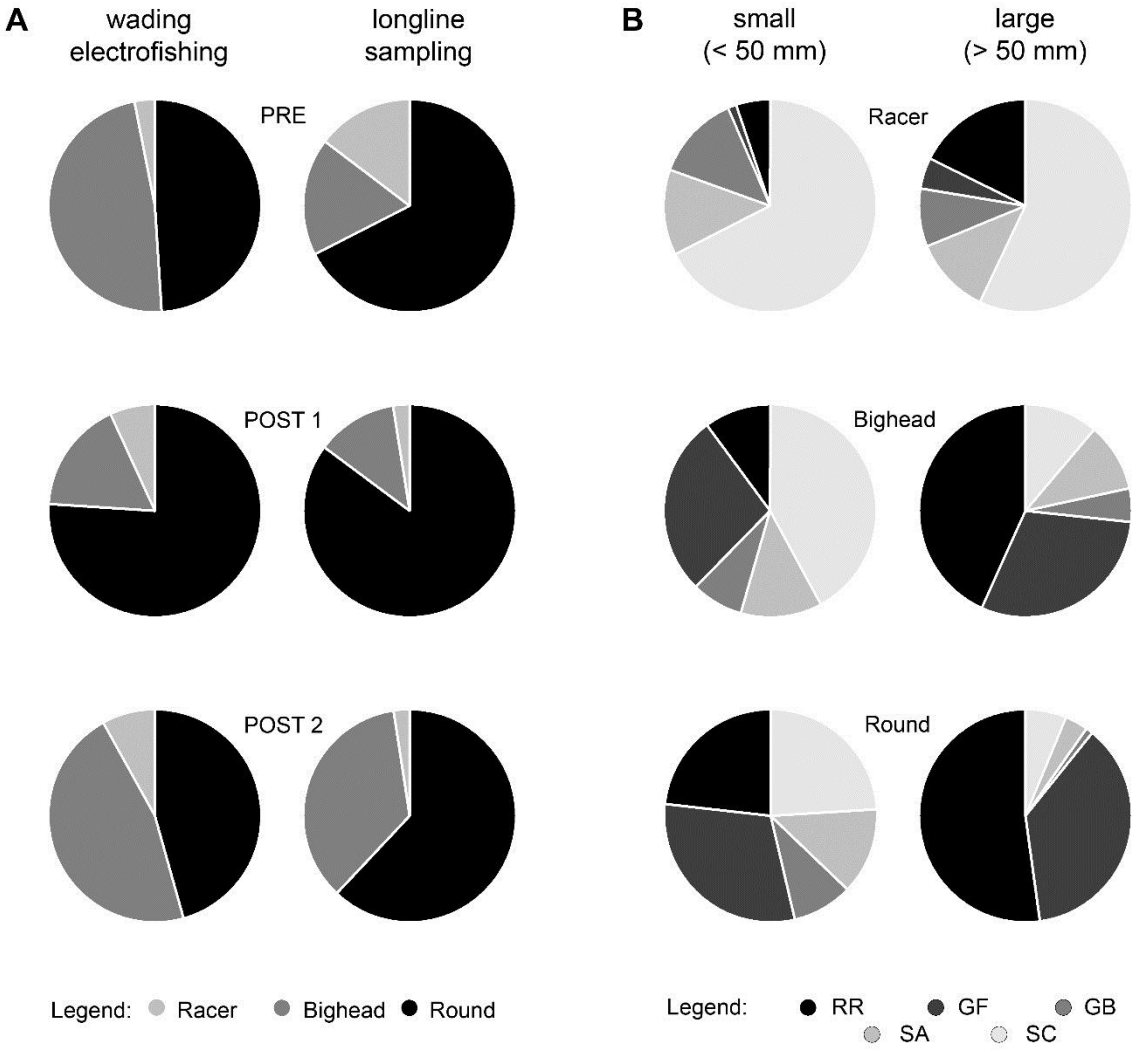

Fig. S4: [A] Composition of total catch of gobies for the littoral (left; wading electrofishing) and benthic zone (right; longline sampling). PRE – pre-survey in 2006/07; POST1 – post-survey 1 in 2014/15; POST2 – post-survey 2 in 2017. [B] Composition of total catch of small (left column) and large (right column) gobies in the mesohabitat types. RR – riprap, GF – groynefield, GB – gravel bar, SA – side arm, SC – side channel.

Online Resource 5:

Table S1: Results of the general linear model for the effect of the measures on goby size in the littoral zone (wading electrofishing), using square root-transformed total length as response variable and section and survey as factors. The degrees of freedom (df) in brackets in the first row of the model are the df for the Error. Asterisks indicate level of significance: *** *P*<0.001; ** *P*<0.01; * *P*<0.05.

Method	Regression coefficient	Bighead goby				Round goby			
		F	df	*P*		*F*	df	*P*	
Measure 1 – Groyne adaptations	corr. Model	17.190	5 (684)	< 0.001	***	29.353	5 (959)	< 0.001	***
	Intercept	12597.991	1	< 0.001	***	10533.287	1	< 0.001	***
	Survey	30.453	2	< 0.001	***	9.527	2	< 0.001	***
	Section	10.308	1	0.001	***	61.766	1	< 0.001	***
	Survey x Section	6.183	2	0.002	**	3.773	2	0.023	*
Measure 2 = Groyne adaptations	corr. Model	17.265	5 (738)	< 0.001	***	14.422	5 (1175)	< 0.001	***
	Intercept	19636.187	1	< 0.001	***	28639.213	1	< 0.001	***
	Survey	25.431	2	< 0.001	***	31.648	2	< 0.001	***
	Section	18.926	1	< 0.001	***	12.651	1	< 0.001	***
	Survey x Section	0.431	2	0.650		1.289	2	0.276	
Measure 3 bank restoration	corr. Model	7.550	5 (440)	< 0.001	***	9.365	5 (632)	< 0.001	***
	Intercept	1548.589	1	< 0.001	***	2912.386	1	< 0.001	***
	Survey	1.680	2	0.188		9.372	2	< 0.001	***
	Section	1.089	1	0.297		19.424	1	< 0.001	***
	Survey x Section	2.913	2	0.055		12.485	2	< 0.001	***
Measure 4 sidearm reconnection	corr. Model	26.136	5 (255)	< 0.001	***	29.458	4 (334)	< 0.001	***
	Intercept	1518.708	1	< 0.001	***	1822.188	1	< 0.001	***
	Survey	7.553	2	0.001	***	26.194	2	< 0.001	***
	Section	1.275	1	0.260		4.470	1	0.035	*
	Survey x Section	3.080	2	0.048	*	0.266	1	0.606	