

Supplementary Data

Predicting the Impact of Climate Change on Freshwater Fish Distribution by Incorporating Water Flow Rate and Quality Variables

Zhonghyun Kim ¹, Taeyong Shim ¹, Young Min Koo ², Dongil Seo ², Young-Oh Kim ³, Soon-
Jin Hwang ⁴ and Jinho Jung ^{1,*}

¹ Division of Environmental Science & Ecological Engineering, Korea University, Seoul 02841, Korea;
kimzh@korea.ac.kr (Z.K.); xizor@korea.ac.kr (T.S.)

² Department of Environmental Engineering, Chungnam National University, Daejeon, 34134, Korea;
crownkoo@daum.net (Y.M.K.); seodi@cnu.ac.kr (D.S.)

³ Department Civil and Environmental Engineering, Seoul National University, Seoul 08826, Korea;
yokim05@snu.ac.kr

⁴ Department of Environmental Health Science, Konkuk University, Seoul 05029, Korea;
sjhwang@konkuk.ac.kr

* Correspondence: jjung@korea.ac.kr; Tel.: +82-2-3290-3066; Fax: +82-2-3290-3509

17 Table S1. List of freshwater fish species included in this study and their presence records
 18 (2012–2014) used in the training and testing of species distribution modeling. The
 19 tolerance guild of fish is also indicated as tolerant species (TS), intermediate species (IS),
 20 and sensitive species (SS).

Species	Number of presence records		Tolerance guild
	Training	Testing	
<i>Abbottina rivularis</i>	27	11	TS
<i>Abbottina springeri</i>	16	6	TS
<i>Acanthorhodeus gracilis</i>	43	18	IS
<i>Acanthorhodeus macropterus</i>	36	15	IS
<i>Acheilognathus koreensis</i>	63	26	IS
<i>Acheilognathus lanceolatus</i>	111	47	IS
<i>Acheilognathus majusculus</i>	21	8	IS
<i>Acheilognathus rhombeus</i>	54	22	IS
<i>Acheilognathus signifier</i>	25	10	SS
<i>Acheilognathus yamatsutae</i>	74	31	IS
<i>Carassius auratus</i>	254	108	TS
<i>Carassius cuvieri</i>	21	8	TS
<i>Chaenogobius urotaenia</i>	13	5	IS
<i>Cobitis hankugensis</i>	50	21	IS
<i>Cobitis lutheri</i>	25	10	IS
<i>Cobitis tetralineata</i>	29	12	IS
<i>Coreoleuciscus splendidus</i>	165	70	SS
<i>Coreoperca herzi</i>	189	80	SS
<i>Cottus koreanus</i>	12	5	SS
<i>Cyprinus carpio</i>	116	49	TS
<i>Erythroculter erythropterus</i>	37	15	TS
<i>Gnathopogon strigatus</i>	52	21	IS
<i>Gobiobotia brevibarba</i>	29	12	SS
<i>Hemibarbus labeo</i>	203	87	TS
<i>Hemibarbus longirostris</i>	215	92	IS

21

22 Table S1. Continued.

Species	Number of presence records		Tolerance guild
	Training	Testing	
<i>Hemibarbus mylodon</i>	31	12	SS
<i>Hemiculter eigenmanni</i>	63	27	TS
<i>Iksookimia koreensis</i>	148	63	IS
<i>Iksookimia longicorpa</i>	39	16	IS
<i>Koreocobitis naktongensis</i>	10	4	SS
<i>Koreocobitis rotundicaudata</i>	93	39	SS
<i>Leiocassis ussuriensis</i>	13	5	IS
<i>Lepomis macrochirus</i>	87	37	TS
<i>Liobagrus andersoni</i>	66	27	SS
<i>Liobagrus mediadiposalis</i>	47	20	SS
<i>Liobagrus somjinensis</i>	24	9	SS
<i>Microphysogobio jeoni</i>	11	4	IS
<i>Microphysogobio longidorsalis</i>	65	27	SS
<i>Microphysogobio yaluensis</i>	196	84	IS
<i>Micropterus salmoides</i>	171	72	TS
<i>Misgurnus anguillicaudatus</i>	166	71	TS
<i>Misgurnus mizolepis</i>	40	17	TS
<i>Niwaella multifasciata</i>	40	16	SS
<i>Odontobutis interrupta</i>	137	58	IS
<i>Odontobutis platycephala</i>	203	87	SS
<i>Opsarichthys uncirostris amurensis</i>	164	70	TS
<i>Orthrias nudus</i>	59	24	SS
<i>Oryzias sinensis</i>	15	6	TS
<i>Plecoglossus altivelis altivelis</i>	18	7	IS
<i>Pseudobagrus fulvidraco</i>	28	12	TS
<i>Pseudobagrus koreanus</i>	78	33	IS
<i>Pseudogobio esocinus</i>	330	141	IS
<i>Pseudopungtungia nigra</i>	10	4	SS
<i>Pseudopungtungia tenuicorpa</i>	33	13	SS
<i>Pseudorasbora parva</i>	126	53	TS

<i>Pungtungia herzi</i>	305	130	IS
-------------------------	-----	-----	----

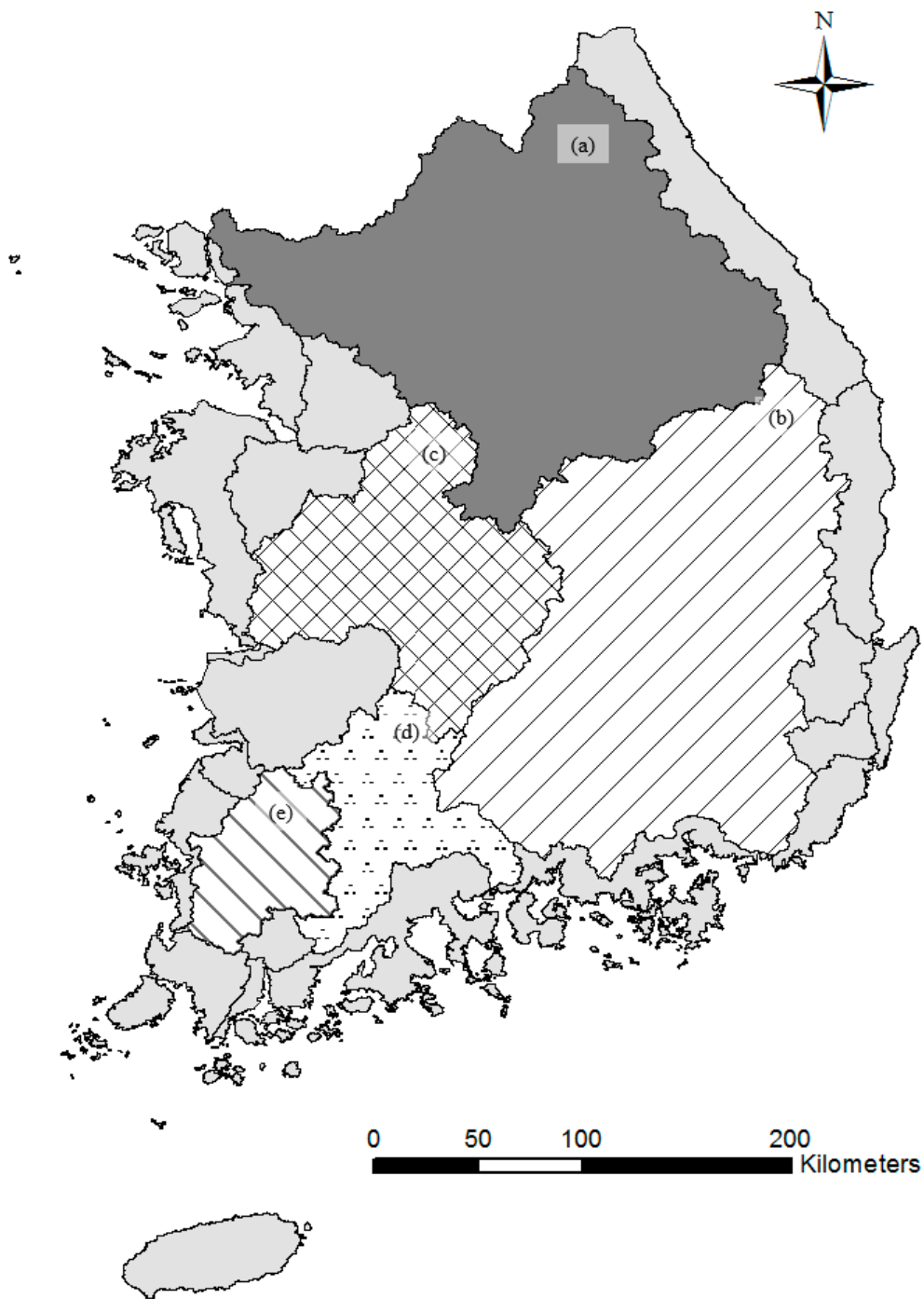
23 Table S1. Continued.

Species	Number of presence records		Tolerance guild
	Training	Testing	
<i>Rhinogobius brunneus</i>	266	113	IS
<i>Rhinogobius giurinus</i>	21	9	TS
<i>Rhodeus notatus</i>	28	12	IS
<i>Rhodeus ocellatus</i>	11	4	IS
<i>Rhodeus uyekii</i>	61	25	IS
<i>Rhynchocypris kumgangensis</i>	28	12	SS
<i>Rhynchocypris oxycephalus</i>	138	59	SS
<i>Sarcocheilichthys nigripinnis morii</i>	33	13	IS
<i>Sarcocheilichthys variegatus wakiyae</i>	55	23	IS
<i>Silurus asotus</i>	48	20	TS
<i>Silurus microdorsalis</i>	17	7	SS
<i>Siniperca scherzeri</i>	42	17	IS
<i>Squalidus chankaensis tsuchigae</i>	134	57	IS
<i>Squalidus gracilis majimae</i>	159	67	IS
<i>Squalidus japonicus coreanus</i>	54	23	TS
<i>Squaliobarbus curriculus</i>	18	7	IS
<i>Tridentiger brevispinis</i>	91	39	IS
<i>Zacco koreanus</i>	262	112	SS
<i>Zacco platypus</i>	396	169	IS
<i>Zacco temminckii</i>	31	12	SS

24

25 Table S2. Prediction of species richness index (SRI), tolerance guild index (TGI), and number of sensitive species (SS) of freshwater fish
 26 in five river basins in South Korea in the present (2012–2014) and future (2030 and 2050) changes compared with present under RCP 4.5
 27 and 8.5 climate change scenarios. Data of present variables are average \pm standard deviation.

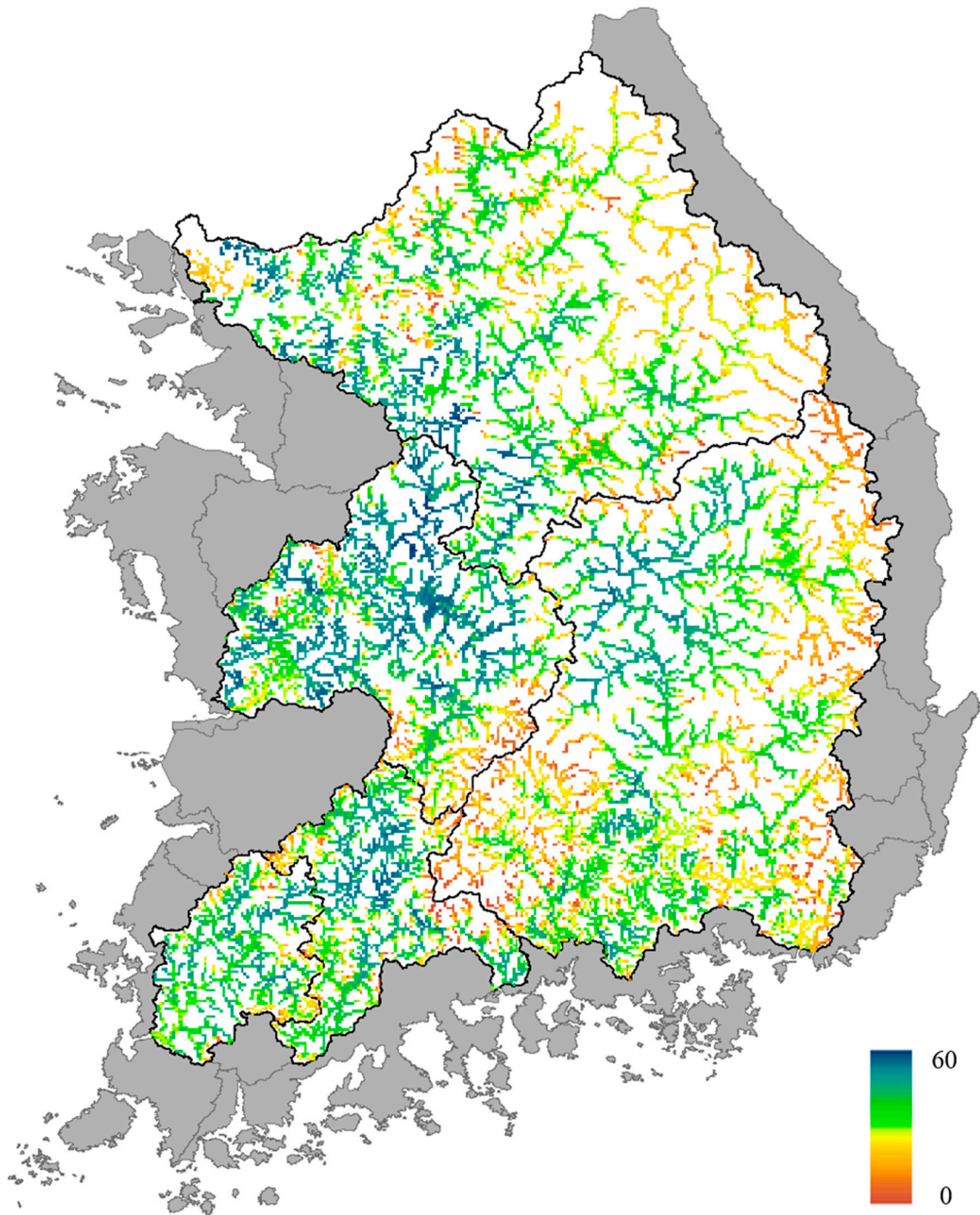
		Han	Nakdong	Geum	Seomjin	Yeongsan
SRI	Present	32.53 \pm 11.16	29.54 \pm 11.27	40.18 \pm 12.43	36.31 \pm 12.31	37.05 \pm 9.05
	RCP 4.5—2030	+3.91	−3.21	−14.02	−10.84	−11.19
	RCP 4.5—2050	−0.70	−7.68	−22.42	−14.53	−14.80
	RCP 8.5—2030	+0.94	−3.46	−17.08	−8.15	−5.44
	RCP 8.5—2050	−9.50	−11.09	−21.13	−17.78	−13.37
TGI	Present	0.595 \pm 0.256	0.488 \pm 0.265	0.347 \pm 0.211	0.528 \pm 0.192	0.341 \pm 0.199
	RCP 4.5—2030	+0.088	+0.110	+0.268	+0.239	+0.156
	RCP 4.5—2050	−0.052	+0.098	+0.111	+0.185	+0.082
	RCP 8.5—2030	−0.030	+0.074	+0.208	+0.111	+0.098
	RCP 8.5—2050	−0.058	+0.066	+0.188	+0.127	+0.026
SS	Present	10.09 \pm 4.02	6.87 \pm 2.56	6.04 \pm 2.92	7.34 \pm 1.44	5.73 \pm 2.64
	RCP 4.5—2030	+3.44	+1.38	+2.69	+1.11	+1.16
	RCP 4.5—2050	−1.25	−0.71	−2.33	−1.53	−1.46
	RCP 8.5—2030	−0.28	+0.55	+0.54	−0.60	+0.97
	RCP 8.5—2050	−3.20	−0.85	−0.36	−1.47	−1.00



29

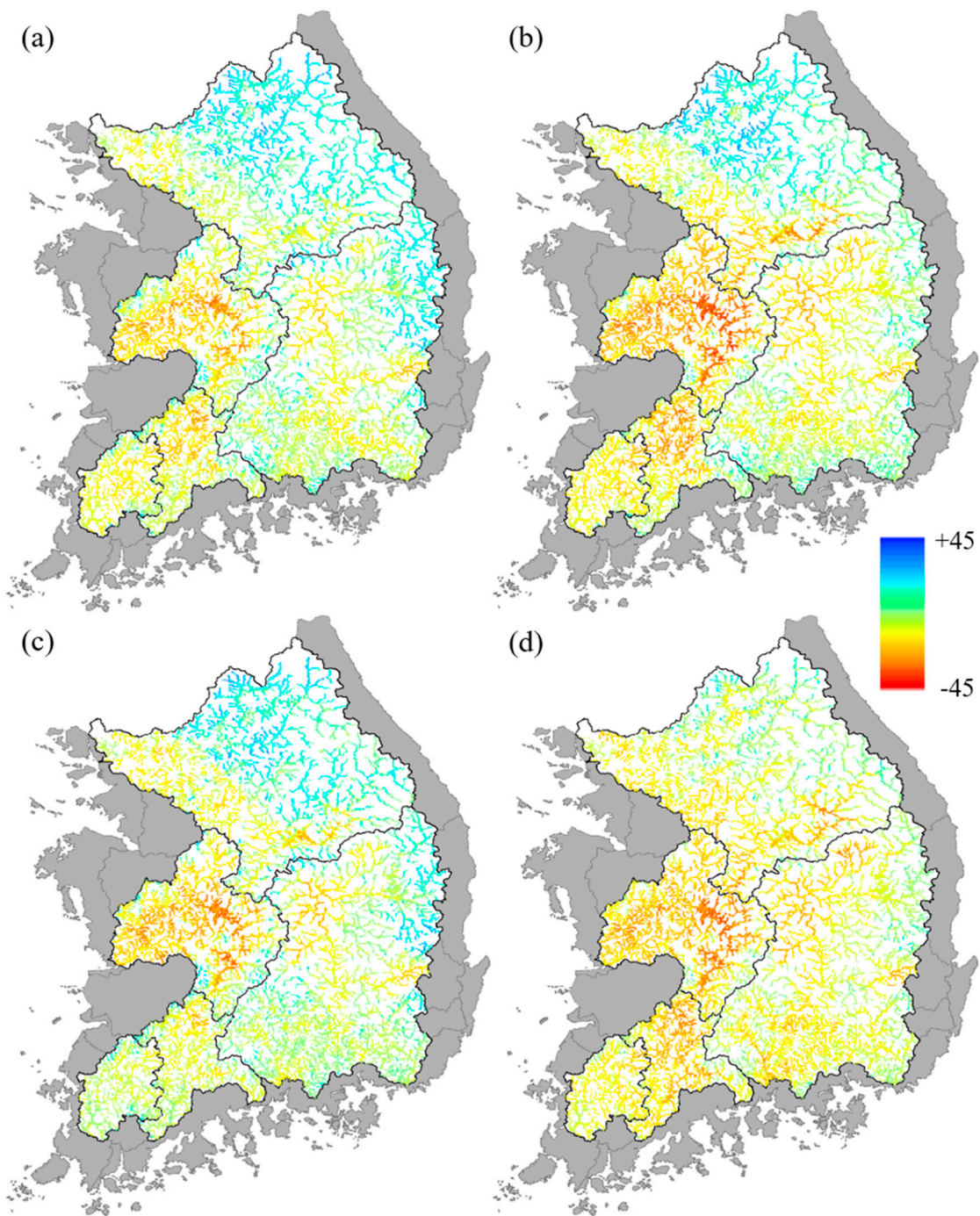
30 Figure S1. Study area of the (a) Han, (b) Nakdong, (c) Geum, (d) Seomjin, and (e)
31 Yeongsan river basins in South Korea.

32



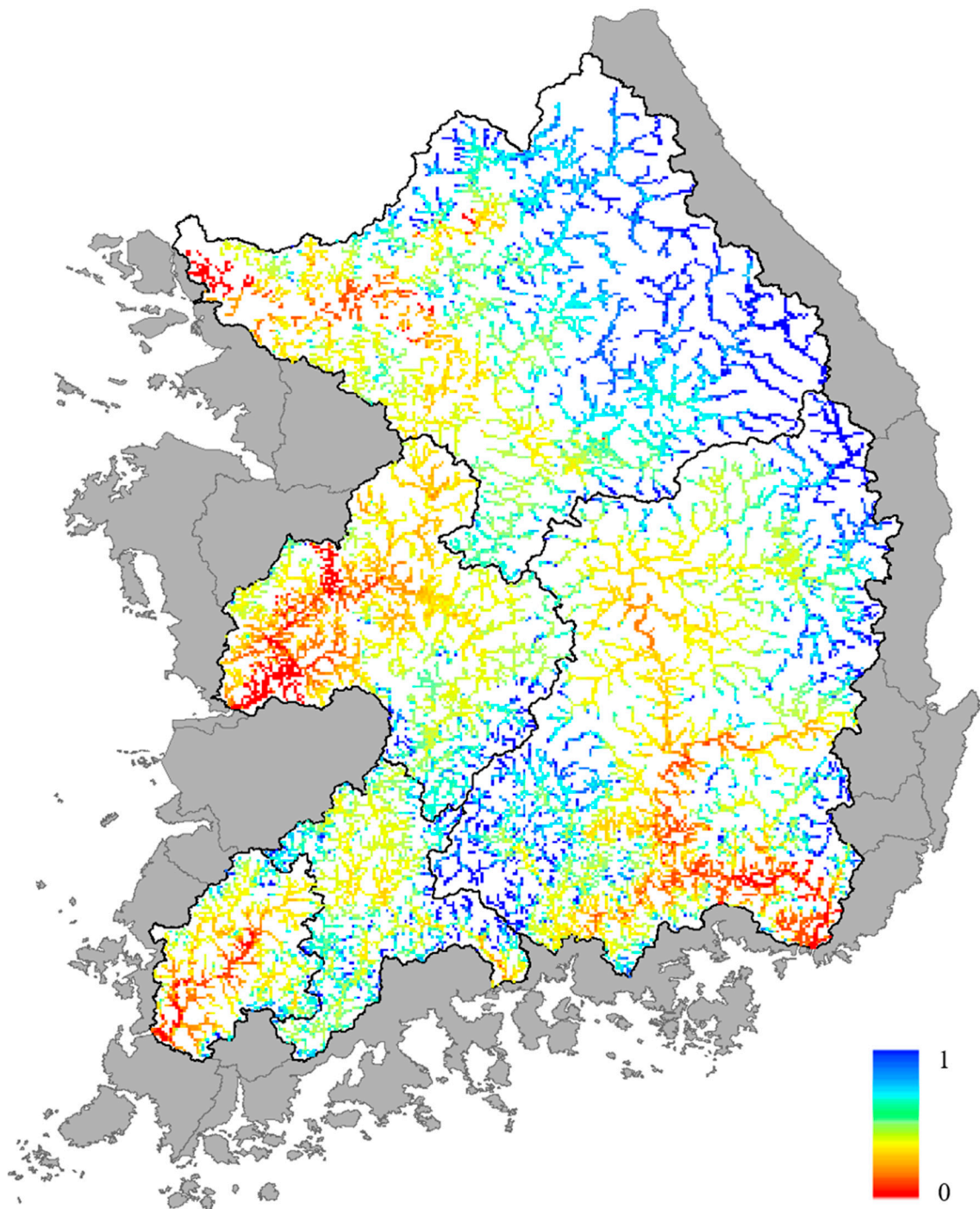
33

34 Figure S2. Species richness index of freshwater fish in South Korea in the present (2012–
35 2014).



36

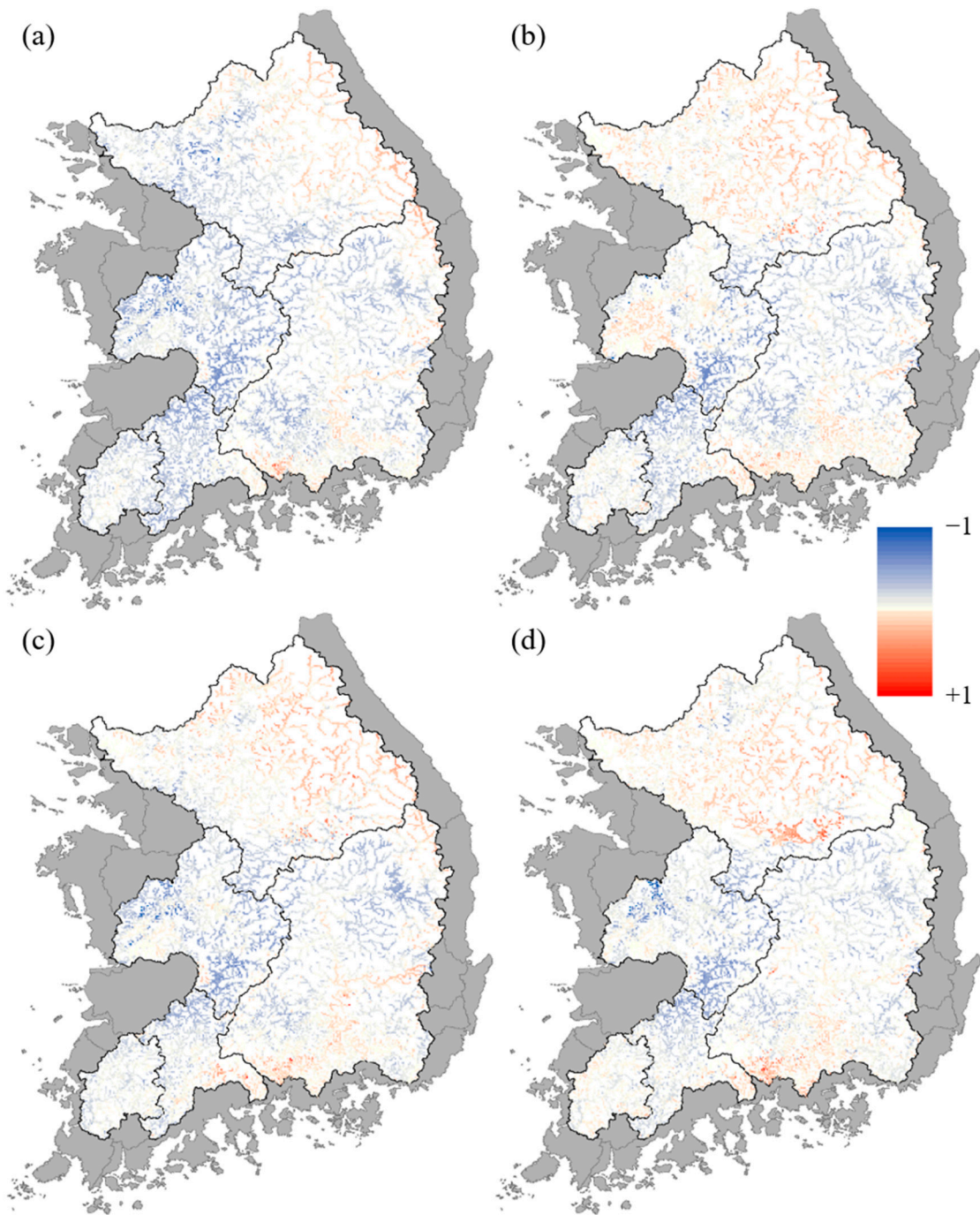
37 Figure S3. Predicted future changes in the species richness index of freshwater fish in
 38 South Korea based on the climate change scenarios of (a) RCP 4.5—2030, (b) RCP 4.5—
 39 2050, (c) RCP 8.5—2030, and (d) RCP 8.5—2050.



40

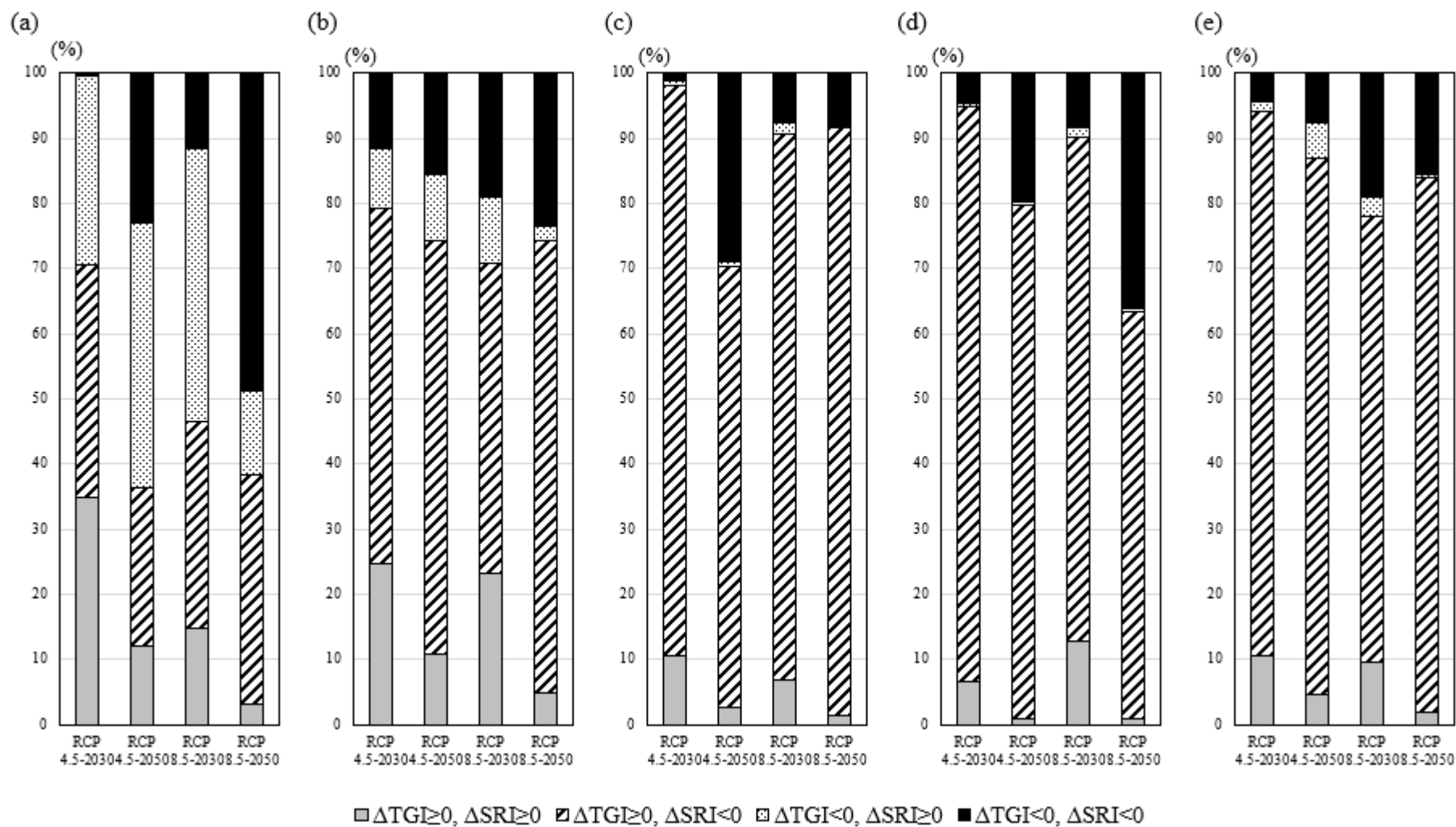
41 Figure S4. Tolerance guild index of freshwater fish in South Korea in the present (2012–
42 2014).

43



44

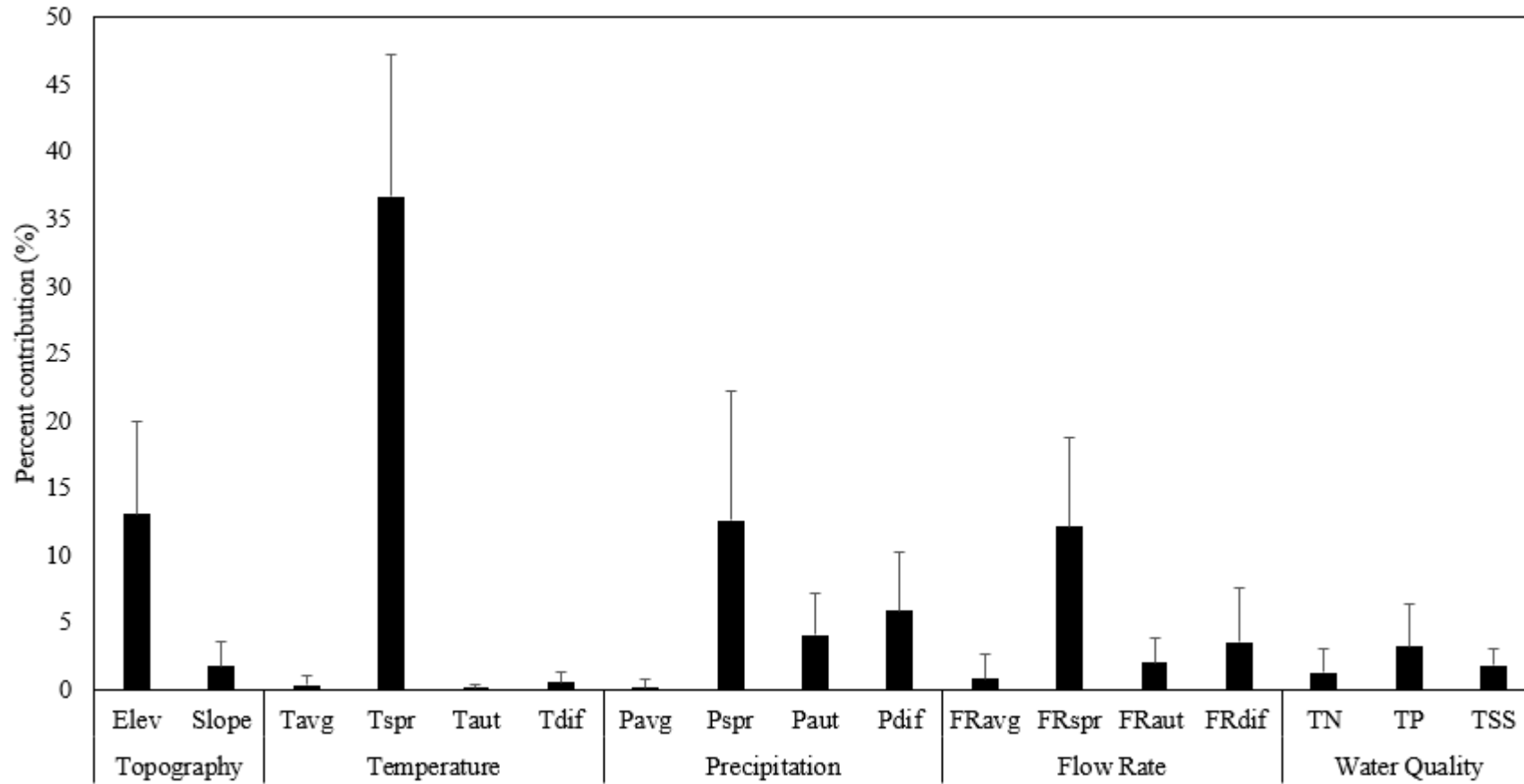
45 Figure S5. Predicted future changes in the tolerance guild index of freshwater fish in
 46 South Korea based on the climate change scenarios of (a) RCP 4.5—2030, (b) RCP 4.5—
 47 2050, (c) RCP 8.5—2030, and (d) RCP 8.5—2050.



48

49 Figure S6. Future changes in the species richness index (SRI) and tolerance guild index (TGI) of freshwater fish in the (a) Han, (b) Nakdong,

50 (c) Geum, (d) Seomjin, and (e) Yeongsan river basin in South Korea (2030 and 2050) under climate change scenarios RCP 4.5 and 8.5.



51

52 Figure S7. Percent contribution of environmental variables to distribution modeling of the Korean spotted barbel. Descriptions of variable are

53 given in Table 1. The standard deviation of variables is represented by the error bars.