

SUPPLEMENTARY INFORMATION

Biodiversity-centric habitat networks for Green Infrastructure planning: A case study in Northern Italy

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Table S1. List of the 23 municipalities included in the study area. All municipalities are either crossed by the rivers or placed in neighboring areas.

Municipality	Crossed by Isonzo-Vipacco
Campolongo Tapogliano	No
Doberdò del Lago	No
Farra d'Isonzo	Yes
Fiumicello Villavicentina	Yes
Fogliano Redipuglia	No
Gorizia	Yes
Gradisca d'Isonzo	Yes
Grado*	Yes
Mariano del Friuli	No
Moraro	No
Mossa	No
Romans d'Isonzo	No
Ronchi dei Legionari	No
Ruda	No
Sagrado	Yes
San Canzian d'Isonzo	Yes
San Floriano del Collio	No
San Lorenzo Isontino	No
San Pier d'Isonzo	Yes
Savogna d'Isonzo	Yes
Staranzano	No
Turriaco	Yes
Villesse	Yes

*A large portion of the Grado municipality is far from the river and we therefore did not consider it as part of its system. Only the section of this municipality that was directly influenced by the river – i.e. the hydraulic/flood risk area surrounding the Isonzo river, as defined in the “Piano stralcio per l’assetto idrogeologico dei bacini dei fiumi Isonzo, Tagliamento, Piave, Brenta-Bacchiglione” (http://pai.adbve.it/PAI_4B_2012/idro_isonzo.html) was included.

Table S2. Criteria adopted for the selection of target animal and plant species.

Plant species	Animal species
<ul style="list-style-type: none">a) Included in the list of vascular flora species in Appendix to the Habitat Directive;b) Included in national or regional Red Lists;c) Rare or endemic species;d) Ecological importance;e) Specialized for specific habitat types.	<ul style="list-style-type: none">a) Included in the list of species in Appendix to the Habitat Directive;b) Included in national or regional Red Lists;c) Rarity, endemism, vulnerability;d) Knowledge about autoecology and synecology;e) Data availability;f) Specialized for specific habitat types;g) Low mobility and dispersal ability;h) Sensitive to habitat fragmentation and at risk of genetic isolation.

Table S3. List of the 17 selected target animal species, with basic information about their biology and conservation status

Species	Group	Linked with wetlands	Habitats Directive	Fauna of Regional Interest
<i>Bombina variegata</i>	Vertebrates	Yes	Ann. II, IV	Yes
<i>Carabus italicus</i>	Invertebrates	No	No	No
<i>Coenonympha oedippus</i>	Invertebrates	Yes	Ann. II, IV	No
<i>Cordulegaster heros</i>	Invertebrates	Yes	Ann. II, IV	No
<i>Emys orbicularis</i>	Vertebrates	Yes	Ann. II, IV	Yes
<i>Lacerta viridis</i>	Vertebrates	No	Ann. IV	Yes
<i>Lucanus cervus</i>	Invertebrates	No	Ann. II	Yes
<i>Lycaena dispar</i>	Invertebrates	Yes	Ann. II, IV	No
<i>Maculinea teleius</i>	Invertebrates	Yes	Ann. II, IV	No
<i>Muscardinus avellanarius</i>	Vertebrates	No	Ann. IV	No
<i>Natrix tessellata</i>	Vertebrates	Yes	Ann. IV	Yes
<i>Rana dalmatina</i>	Vertebrates	Yes	Ann. IV	Yes
<i>Rana latastei</i>	Vertebrates	Yes	Ann. II, IV	Yes
<i>Triturus carnifex</i>	Vertebrates	Yes	Ann. II, IV	Yes
<i>Zamenis longissimus</i>	Vertebrates	No	Ann. IV	Yes
<i>Zerynthia polyxena</i>	Invertebrates	Yes	Ann. IV	No
<i>Zeuneriana marmorata</i>	Invertebrates	Yes	No	Yes

Table S4. List of the 13 selected focus habitats for plant species. Some focus habitats include more than one CORINE 2017 habitat category, as detailed in the description.

Target habitat code	CORINE 2017 code	CORINE 2017 description
AC	22.432	Rooted communities of shallow waters with depth variations
AC	22.42	Rooted submerged vegetation
AC	24.4	Submerged river vegetation
AC	24.13	Grayling zone
AC	24.42	Lime-rich oligotrophic river vegetation
BL13	41.2A2	Sub-hygrophilous oak-hornbeam forests of illyrian plains
BU10	44.911	Meso-eutrophic swamp alder woods
BU5	44.614	Italian poplar riparian galleries
BU5	44.13	White willow gallery forests
BU	44.431	Illyrian ash-oak-alder flooded forests
BU	44.44	Oak-ash-alder forests of Po fluvial terraces
CA	15.21	Flooded codgrass swards
CA	15.113	Mediterranean glasswort swards
CA	15.51	Mediterranean tall rush saltmarshes
CA	15.55	Mediterranean saltmarsh grass swards
CA	15.57	Saltmarsh couch-wormwood stands
CA	15.612	Shrubby glasswort thickets
CP5	16.22	Grey dunes
PC pio	34.11	Middle European rock debris swards
PC pio	62.311	Limestone pavements
PC10	34.753b	Xero-mesophilous sub-mediterranean dry grasslands of lowland and pre-alpine areas
PC4	34.752a	Karstic xerophilous sub-mediterranean dry grasslands
PC9	34.753a	Karstic xero-mesophilous sub-mediterranean dry grasslands
PM1	38.2	Lowland hay meadows
PU	37.1	Meadowsweet stands and related communities
PU	37.31	Purple moorgrass meadows and related communities

Table S5. Soil sealing of nodes, corridors and stepping stones of the ecological network, expressed as total area (ha), % of occupied area in each municipality and % of the total sealed surface in the entire study area.

Municipality	Nodes			Corridors			Stepping stones		
	Area (ha)	%	% of the total	Area (ha)	%	% of the total	Area (ha)	%	% of the total
CAMPOLONGO	10.0	10.7	1.7	8.5	14.0	1.1	0.5	6.5	0.5
TAOGLIANO									
DOBERDO' DEL LAGO	127.2	5.3	21.6	0.3	16.6	0.0	2.9	12.9	2.9
FARRA D'ISONZO	5.5	3.9	0.9	16.2	13.8	2.0	2.3	9.4	2.3
FIUMICELLO VILLA VICENTINA	12.3	9.1	2.1	77.8	17.7	9.7	1.1	11.2	1.1
FOGLIANO REDIPUGLIA	16.9	5.7	2.9	13.1	22.3	1.6	3.7	16.8	3.7
GORIZIA	55.9	5.5	9.5	155.8	26.4	19.5	19.5	7.8	19.7
GRADISCA D'ISONZO	10.4	6.1	1.8	76.6	29.1	9.6	1.5	10.8	1.5
GRADO	10.2	3.2	1.7	19.3	7.6	2.4	0.6	3.1	0.6
MARIANO DEL FRIULI	7.0	8.7	1.2	32.0	19.8	4.0	0.2	7.2	0.2
MORARO	1.1	5.5	0.2	23.0	14.2	2.9	1.0	6.6	1.0
MOSSA	5.1	5.2	0.9	23.0	13.1	2.9	3.0	6.8	3.1
ROMANS D'ISONZO	26.1	12.0	4.4	41.4	22.1	5.2	8.6	8.3	8.6
RONCHI DEI LEGIONARI	60.2	7.8	10.2	66.9	33.6	8.4	17.2	29.0	17.3
RUDA	10.1	5.5	1.7	41.8	14.8	5.2	2.9	6.8	2.9
SAGRADO	56.1	5.8	9.5	2.2	13.6	0.3	0.8	4.8	0.8
SAN CANZIAN D'ISONZO	20.3	5.5	3.5	42.0	10.0	5.3	9.2	7.5	9.3
SAN FLORIANO DEL COLLIO	9.6	7.3	1.6	11.3	9.6	1.4	4.9	4.3	5.0
SAN LORENZO ISONTINO	3.7	15.2	0.6	26.8	16.8	3.4	1.3	5.7	1.3
SAN PIER D'ISONZO	16.6	8.5	2.8	10.4	12.0	1.3	2.3	10.1	2.3
SAVOGNA D'ISONZO	66.3	6.0	11.3	6.0	14.5	0.7	0.2	10.6	0.2
STARANZANO	6.1	1.7	1.0	63.9	23.4	8.0	4.2	3.4	4.2
TURRIACO	13.3	7.9	2.3	4.4	20.8	0.5	1.7	6.5	1.7
VILLESSE	38.1	10.6	6.5	36.5	40.3	4.6	10.0	19.2	10.1
ENTIRE STUDY AREA	588.2	6.1	100.0	799.0	19.1	100.0	99.4	8.7	100.0

Table S6. Anthropic impacts of intensive agriculture, intensive agriculture with seminatural residuals, perennial crops and alien vegetation on corridors of the ecological network, expressed as total area (ha), % of occupied area in each municipality and % of the total impact in the entire study area.

Municipality	Intensive agriculture			Intensive agriculture with seminatural residuals			Perennial crops			Alien vegetation		
	Area (ha)	%	% of the total	Area (ha)	%	% of the total	Area (ha)	%	% of the total	Area (ha)	%	% of the total
CAMPOLONGO	43.9	72.7	3.3	0.0	0.0	0.0	4.6	7.6	0.7	1.1	1.7	0.4
TAPOGLIANO												
DOBERDO' DEL LAGO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	83.9	0.5
FARRA D'ISONZO	14.1	12.1	1.0	17.7	15.2	3.8	47.0	40.2	7.5	16.4	14.1	5.9
FIUMICELLO												
VILLA VICENTINA	236.8	53.9	17.5	16.2	3.7	3.5	71.2	16.2	11.4	0.9	0.2	0.3
FOGLIANO												
REDIPUGLIA	18.8	32.0	1.4	0.9	1.5	0.2	9.9	16.8	1.6	6.7	11.3	2.4
GORIZIA	8.0	1.4	0.6	124.8	21.2	27.0	92.3	15.6	14.7	93.7	15.9	33.4
GRADISCA												
D'ISONZO	90.7	34.4	6.7	6.5	2.5	1.4	22.3	8.5	3.6	10.3	3.9	3.7
GRADO	175.7	69.1	13.0	0.0	0.0	0.0	26.6	10.5	4.2	4.3	1.7	1.5
MARIANO DEL FRIULI	41.0	25.4	3.0	20.7	12.8	4.5	46.4	28.7	7.4	9.5	5.9	3.4
MORARO	25.4	15.7	1.9	48.3	29.9	10.5	47.7	29.4	7.6	5.6	3.5	2.0
MOSSA	21.7	12.3	1.6	34.1	19.4	7.4	31.5	17.9	5.0	12.7	7.2	4.5
ROMANS												
D'ISONZO	67.1	35.9	5.0	33.5	17.9	7.3	18.2	9.7	2.9	8.7	4.7	3.1
RONCHI DEI LEGIONARI	27.2	13.7	2.0	33.3	16.7	7.2	12.0	6.0	1.9	14.1	7.1	5.0
RUDA	173.9	61.7	12.9	7.2	2.5	1.6	38.5	13.6	6.1	4.4	1.6	1.6
SAGRADO	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.1	0.0	0.4	2.6	0.2
S. CANZIAN												
D'ISONZO	235.9	56.2	17.5	33.8	8.0	7.3	40.0	9.5	6.4	9.3	2.2	3.3
S. FLORIANO DEL COLLIO	3.8	3.3	0.3	11.2	9.5	2.4	56.4	48.1	9.0	16.2	13.8	5.8
S. LORENZO												
ISONTINO	3.7	2.3	0.3	35.2	22.0	7.6	14.5	9.1	2.3	41.9	26.2	15.0
S. PIER D'ISONZO	19.6	22.8	1.5	15.3	17.8	3.3	27.0	31.4	4.3	3.5	4.0	1.2
SAVOGNA												
D'ISONZO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	30.0	4.4
STARANZANO	106.5	38.9	7.9	8.8	3.2	1.9	18.7	6.8	3.0	4.3	1.6	1.5
TURRIACO	8.2	39.3	0.6	2.1	10.1	0.5	0.0	0.0	0.0	0.8	3.8	0.3
VILLESSE	28.7	31.6	2.1	11.9	13.1	2.6	2.0	2.2	0.3	1.9	2.0	0.7
ENTIRE STUDY AREA	1350.9	32.3	100.0	461.5	11.0	100.0	626.6	15.0	100.0	280.2	6.7	100.0

Table S7. Roads, highways and railways in the nodes, corridors and stepping stones of the ecological network, expressed as total length (m), density (m/ha) and % of the total length in the entire study area.

Municipality	Nodes			Corridors			Stepping stones		
	Length (m)	Density (m/ha)	% of the total	Length (m)	Density (m/ha)	% of the total	Length (m)	Density (m/ha)	% of the total
CAMPOLONGO	567.2	6.0	1.3	204.3	3.4	0.3	0.0	0.0	0.0
TAPOGLIANO									
DOBERDO' DEL LAGO	14420.6	6.0	33.6	89.3	51.0	0.1	40.4	1.8	0.7
FARRA D'ISONZO	173.1	1.2	0.4	1477.6	12.7	2.4	25.1	1.0	0.4
FIUMICELLO VILLA	2501.8	18.4	5.8	7700.0	17.5	12.8	160.2	16.8	2.6
VICENTINA									
FOGLIANO	1172.2	3.9	2.7	600.0	10.2	1.0	292.4	13.4	4.8
REDIPUGLIA									
GORIZIA	5289.0	5.2	12.3	7268.8	12.3	12.0	557.5	2.2	9.2
GRADISCA D'ISONZO	281.1	1.6	0.7	6217.1	23.6	10.3	156.7	11.3	2.6
GRADO	42.2	0.1	0.1	496.4	2.0	0.8	128.0	6.5	2.1
MARIANO DEL FRIULI	188.3	2.3	0.4	1397.5	8.7	2.3	0.0	0.0	0.0
MORARO	0.0	0.0	0.0	2832.1	17.5	4.7	201.3	13.5	3.3
MOSSA	312.5	3.1	0.7	1693.3	9.6	2.8	0.0	0.0	0.0
ROMANS D'ISONZO	624.5	2.9	1.5	2454.6	13.1	4.1	833.3	8.1	13.7
RONCHI DEI	3546.9	4.6	8.3	7806.7	39.2	12.9	919.1	15.5	15.1
LEGIONARI									
RUDA	115.4	0.6	0.3	2808.9	10.0	4.7	0.0	0.0	0.0
SAGRADO	6344.3	6.6	14.8	0.0	0.0	0.0	0.0	0.0	0.0
S. CANZIAN D'ISONZO	918.8	2.5	2.1	4798.0	11.4	7.9	1432.0	11.7	23.5
S. FLORIANO DEL	260.5	2.0	0.6	0.0	0.0	0.0	126.5	1.1	2.1
COLLIO									
S. LORENZO ISONTINO	0.0	0.0	0.0	2152.4	13.5	3.6	478.1	20.5	7.9
S. PIER D'ISONZO	194.7	1.0	0.5	1202.1	14.0	2.0	0.0	0.0	0.0
SAVOGNA D'ISONZO	3849.7	3.5	9.0	1684.9	41.1	2.8	0.0	0.0	0.0
STARANZANO	0.0	0.0	0.0	4125.4	15.1	6.8	204.4	1.6	3.4
TURRIACO	697.2	4.1	1.6	124.2	5.9	0.2	307.0	11.6	5.0
VILLESSE	1435.7	4.0	3.3	3255.5	35.9	5.4	218.7	4.2	3.6
ENTIRE STUDY AREA	42935.3	4.5	100.0	60389.1	14.5	100.0	6080.8	5.3	100.0

Table S8. Linear barriers linked with aquatic habitats (i.e. dams and weirs) in the nodes of the ecological network, expressed as total length (m), density (m/ha) and % of the total length in the entire study area.

Municipality	Length (m)	Density (m/ha)	% of the total
CAMPOLONGO TAPOGLIANO	0.0	0.0	0.0
DOBERDO' DEL LAGO	0.0	0.0	0.0
FARRA D'ISONZO	216.0	1.5	11.4
FIUMICELLO VILLA VICENTINA	0.0	0.0	0.0
FOGLIANO REDIPUGLIA	0.0	0.0	0.0
GORIZIA	615.4	0.6	32.4
GRADISCA D'ISONZO	285.9	1.7	15.1
GRADO	0.0	0.0	0.0
MARIANO DEL FRIULI	63.2	0.8	3.3
MORARO	51.9	2.5	2.7
MOSSA	17.6	0.2	0.9
ROMANS D'ISONZO	28.1	0.1	1.5
RONCHI DEI LEGIONARI	0.0	0.0	0.0
RUDA	0.0	0.0	0.0
SAGRADO	322.9	0.3	17.0
SAN CANZIAN D'ISONZO	0.0	0.0	0.0
SAN FLORIANO DEL COLLIO	41.1	0.3	2.2
SAN LORENZO ISONTINO	0.0	0.0	0.0
SAN PIER D'ISONZO	0.0	0.0	0.0
SAVOGNA D'ISONZO	0.0	0.0	0.0
STARANZANO	0.0	0.0	0.0
TURRIACO	0.0	0.0	0.0
VILLESSE	256.9	0.7	13.5
ENTIRE STUDY AREA	1898.9	0.2	100.0

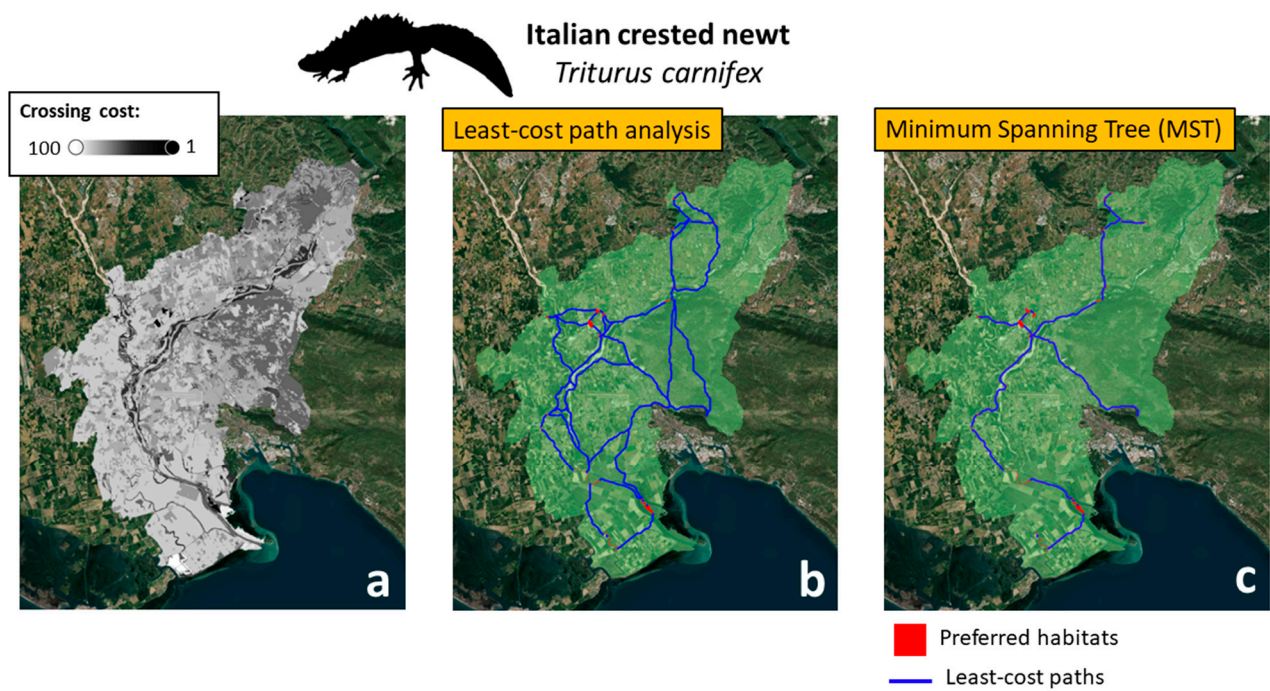


Figure S1. Generation of the Minimum Spanning Tree (MST) for one of the focus animal species, the Italian crested newt: a) Assignment of crossing costs to the mapped habitat types; b) Graph resulting from least-cost path analysis; c) MST connecting all nodes while minimizing crossing cost.

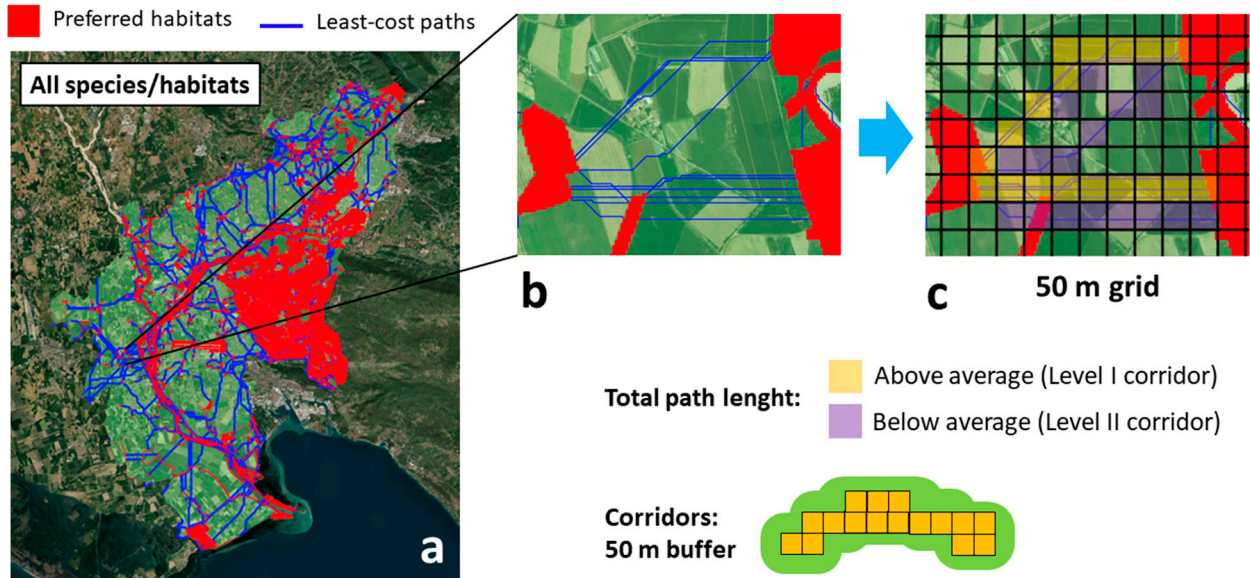


Figure S2. Mapping of corridors for the ecological network: a) The MST of all focal animal species and plant habitats are merged; b) Detail of the resulting graph; c) A 50 x 50 m grid was overlapped to the MST links, and only cells crossed by at least one link were selected. The link length index (TLL), as sum of all the length of links in each cell, was calculated. Cells showing TLL above the average value of the study area were deemed part of Level I corridors, while cells encompassing a below-average total link length were considered as Level II corridors. A buffer of 50 m was then applied to the cells, generating corridors with a minimum width of 150 m.