HyMoCARES Project
WPT3. EFFECTS OF HYDROMORPHOLOGICAL MANAGEMENT AND RESTORATION MEASURES

Report regarding the effects on ES of management/restoration works, applying the overall ES framework

Case studies: Avisio River (Downstream Pezzè reservoir), Avisio River (Downstream Stramentizzo reservoir), Adige River (Ischiello)

Project: HyMoCARES
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1 Case studies

The case studies targeted for the analysis in the HyMoCARES project for the Trentino region are the Avisio River and the Adige River. The Avisio River is divide in 2 case studies, due to the presence of a large reservoir approximately close to the middle of its course.

1.1 Avisio River downstream Pezzè reservoir

The case study starts from the Pezzè reservoir and ends at the river mouth into the Stramentizzo reservoir (Figure 1). The study area is longitudinally divided in sub-units (water bodies) according with the Italian methodology for the assessment of the hydromorphological quality (ISPRA 2011). Laterally, the study area has been delimited using the "Carta del Pericolo" areas. Hence, the study area is divided in 5 segments that have variable width and length.

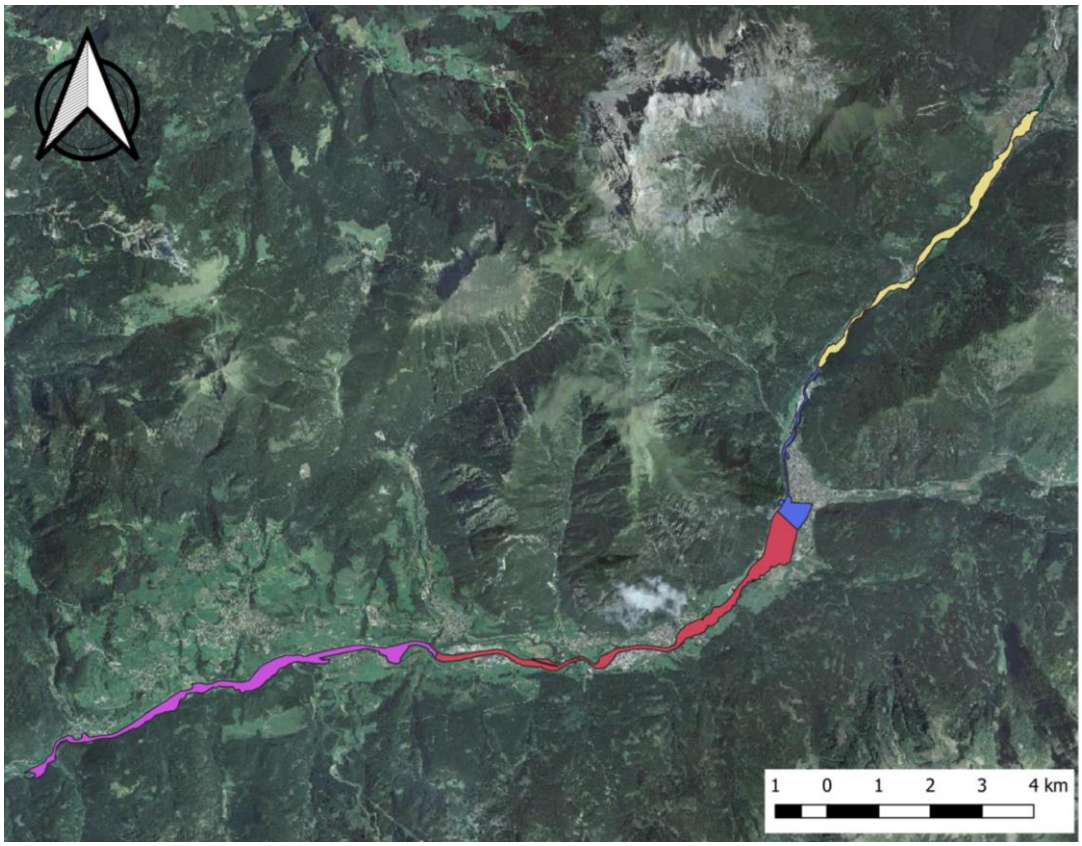


Figure 1 Upstream Stramentizzo reservoir study area, divided in segments (5 segments).

The total length is 28.6 km. The length and the area for each sub-unit are shown in Table 1.

Table 1 Length and area of each sub-unit.

Id	Length (m)	Area (ha)
1	951.456	3.11
2	7053.839	84.84
3	3100.63	36.16
4	8318.208	141.83
5	9234.365	122.24

The restoration actions that are taken into consideration for this area are, according with DT.1.2, ensuring the ecological flows and sediment recharge. Consequently, by applying the HyMoCARES general framework, the hydromorphological processes that are affected by these actions are: sediment continuity, river morphology, hydraulics, vertical connectivity, lateral connectivity, biotic communities, physical habitat, presence and composition of riparian vegetation and instream flow regime (see Figure 2 and Figure 3).

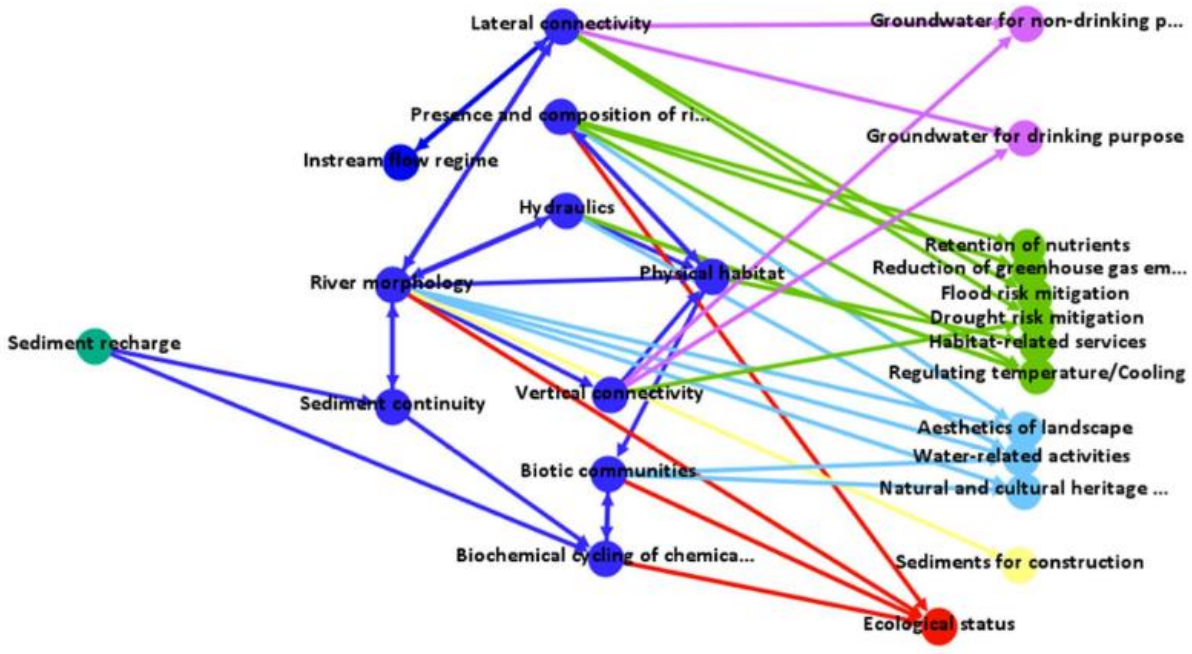


Figure 2 Hydromorphological processes and ES for "Sediment recharge" restoration action.

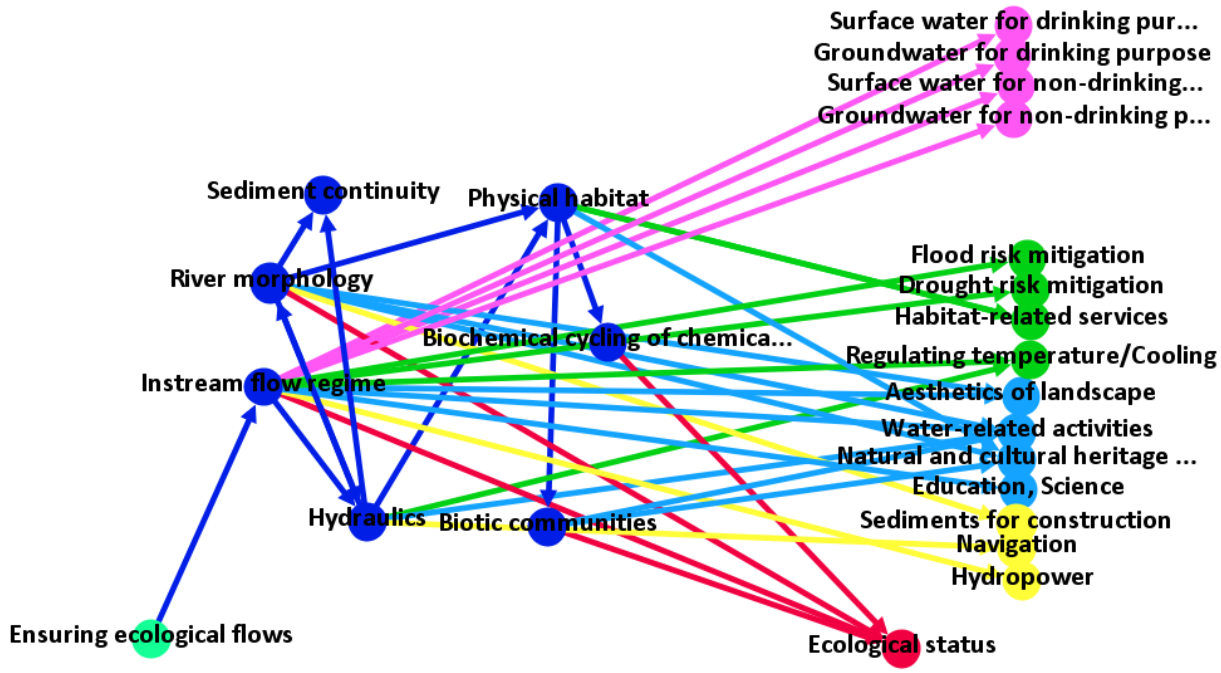


Figure 3 Hydromorphological processes and ES for "Ensuring ecological flows" restoration action.

In this case, “Ensuring ecological flows” should be intended as “ensuring morphological flows” meant to create downstream the reservoir “artificial floods” that are able to at least partially reactivate morphological dynamics.

1.2 Avisio River downstream Stramentizzo reservoir

The case study starts at the Stramentizzo Dam and ends at the confluence between Avisio River and Adige River. The study area is longitudinally divided in sub-units (water bodies) according with the Italian methodology for the assessment of the hydromorphological quality (ISPRA 2011). Laterally, the study area has been delimited using the “Carta del Pericolo” areas. Hence, the study area is divided in 11 segments that have variable width and length. The total length is 34.6 km. The length and the area of each sub-unit are summarized in Table 2.

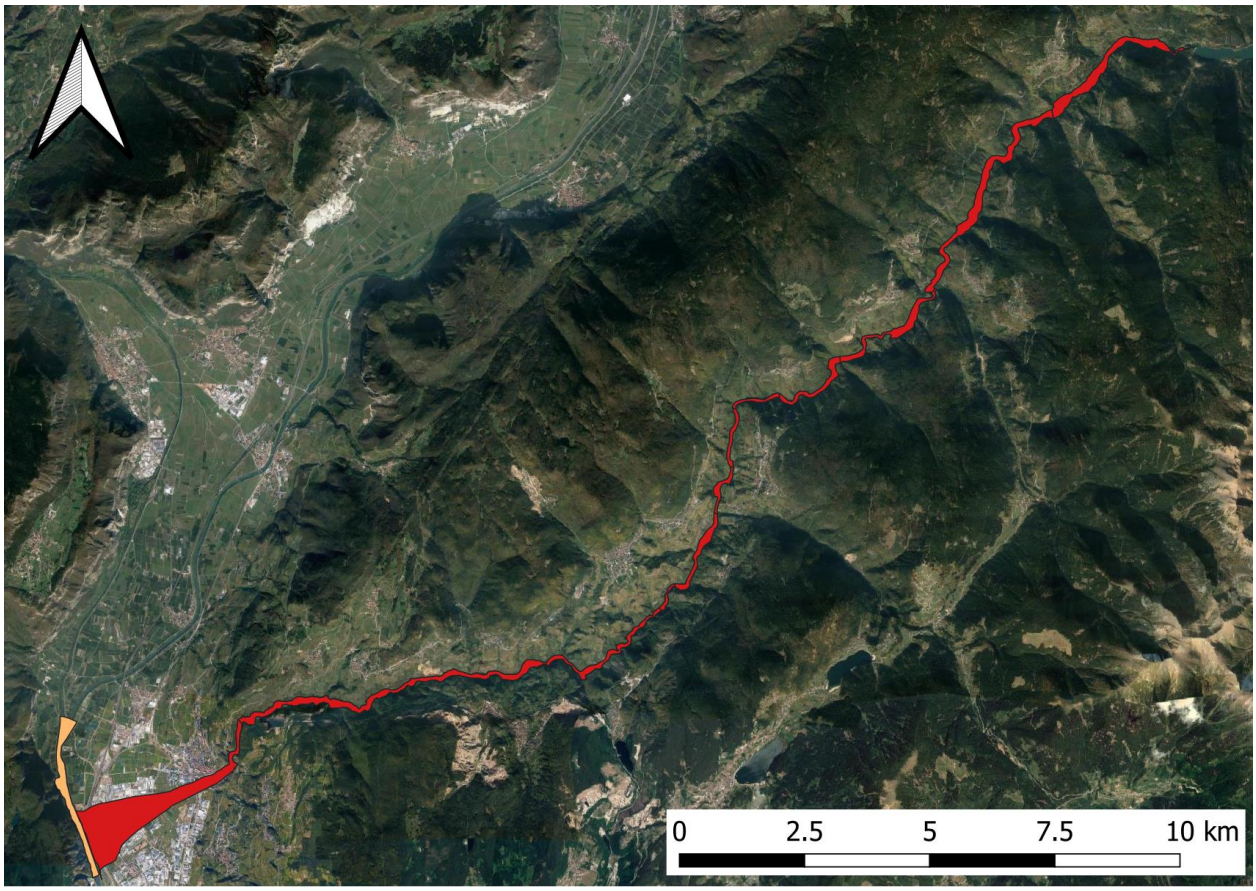


Figure 4 Downstream Stramentizzo dam, divided in 11 segments.

Table 2 Length and area of each sub-unit.

Id	Length (m)	Area (ha)
1	3744.42	48.37
2	5294.93	64.53
3	2888.23	27.51
4	1928.03	17.23
5	1004.41	6.06
6	1263.71	8.34
7	1137.58	8.64
8	1915.49	18.44
9	637.6	3.62
10	10297.14	97.81
11	4522.97	181.17

The restoration actions that are taken into consideration for this area are, according with DT.1.2, ensuring the ecological flows and sediment recharge. Consequently, by applying the HyMoCARES general framework,

the hydromorphological processes that are affected by these actions are: sediment continuity, river morphology, hydraulics, vertical connectivity, lateral connectivity, biotic communities, physical habitat, presence and composition of riparian vegetation and instream flow regime (see Figure 5 and Figure 6)

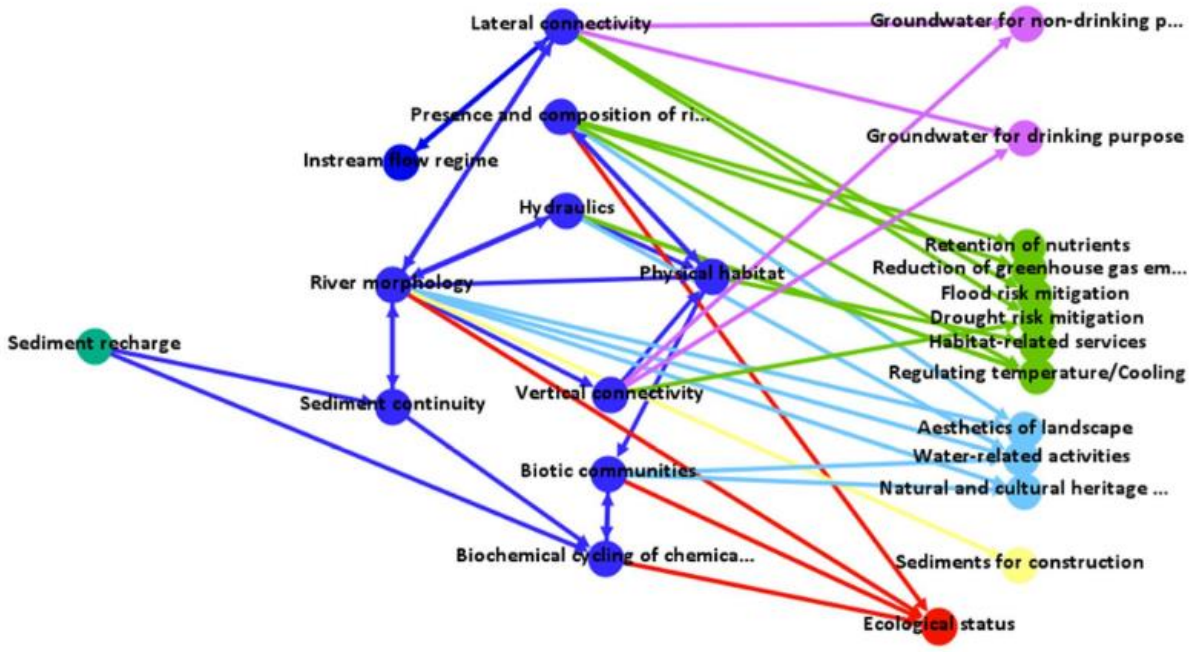


Figure 5 Hydromorphological processes and ES for "Sediment recharge" restoration action.

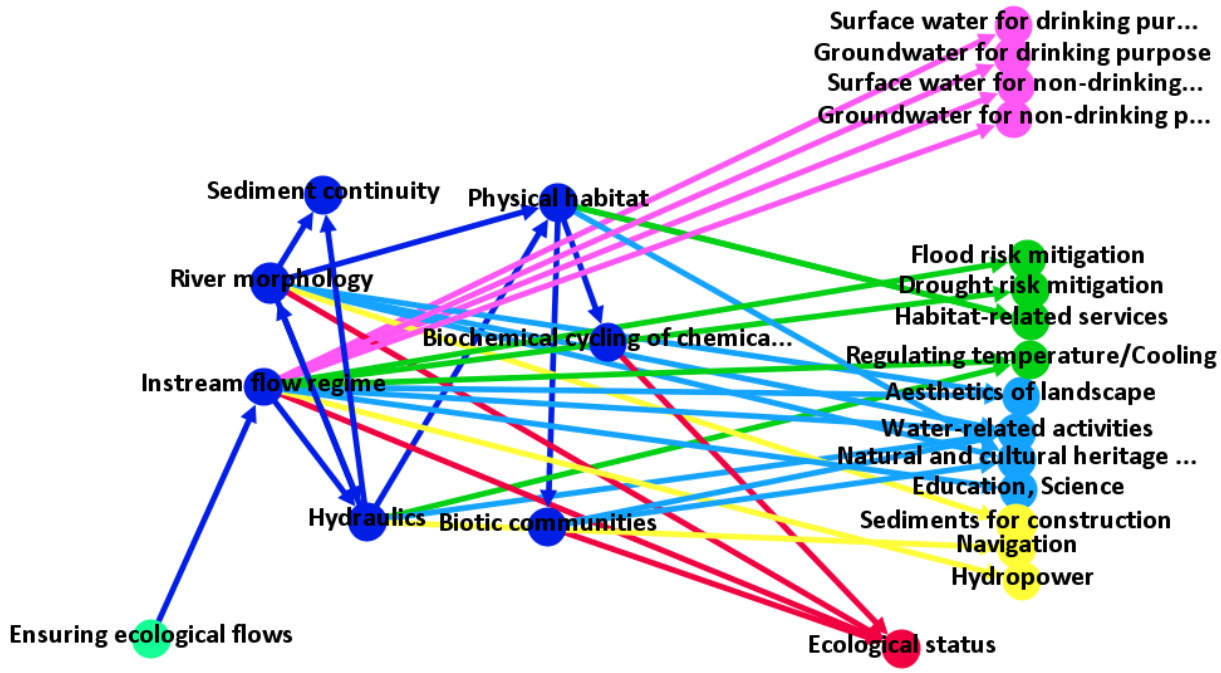


Figure 6 Hydromorphological processes and ES for "Ensuring ecological flows" restoration action.

In this case, “Ensuring ecological flows” should be intended as “ensuring morphological flows” meant to create downstream the reservoir “artificial floods” that are able to at least partially reactivate morphological dynamics.

1.3 Adige River (Ischiello)

The case study starts close to the confluence between Adige River and Noce River, and it ends at the confluence between Adige River and Avisio River. In this area, the Autonomous Province of Trento performed in 2011 a restoration project, which consisted in a river widening using thefloodplain area present in the left river side, characterized by two distincts parts, a riparian area at the beginning of the study area and a secondary channel along the left bank downstream the confluence. See the technical notes for further and additional details. Longitudinally, the study area has been divided according with the Italian methodology for the assessment of the hydromorphological quality (ISPRA 2011). Laterally, the study area has been delimited using the “Carta del Pericolo” areas. Consequently, the study area includes only one segment.

Figure 7 Adige Ischiello study site.

Id	Length (m)	Area (ha)
1	1100	16.48

According with DT.1.2, the restoration actions performed in this area are the removal of bank protection and retreat of the levees.

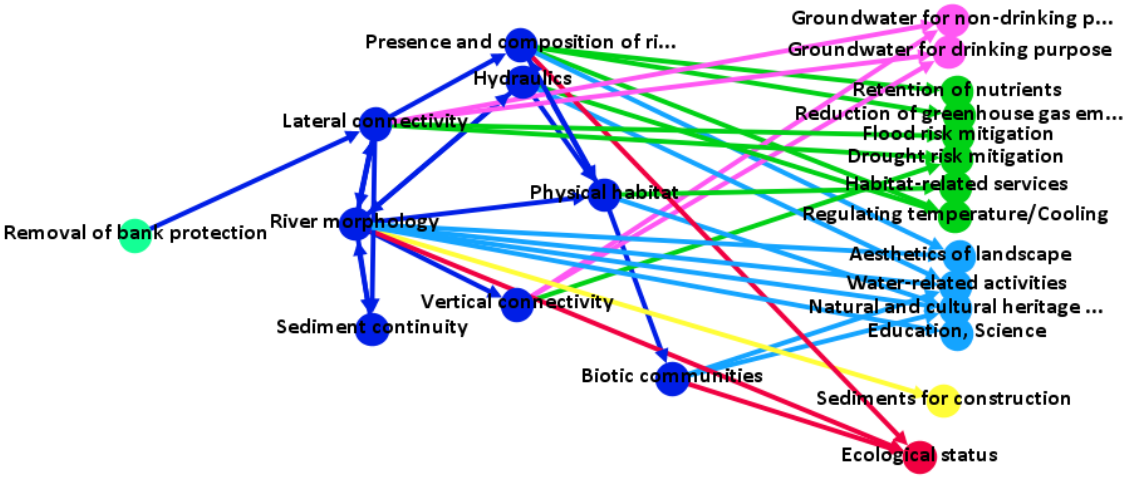


Figure 8 Hydromorphological functions and ES for "Removal of bank protection restoration action".

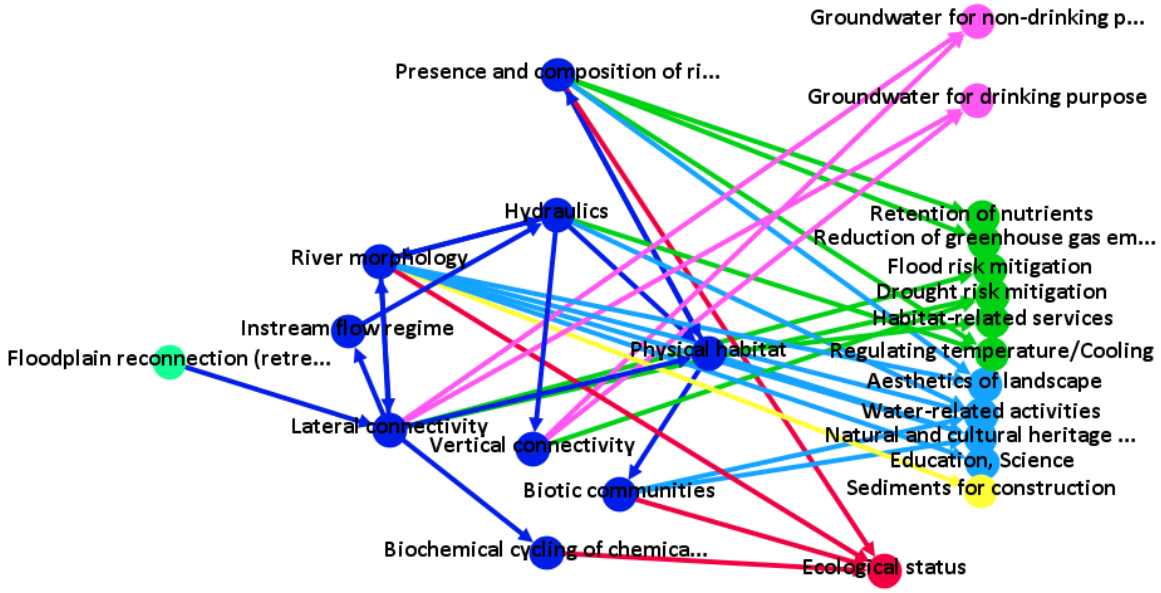


Figure 9 Hydromorphological functions and ES for "Floodplain reconnection (retreat of the levees)".

2 ES selection

2.1 Avisio River downstream Pezzè reservoir

Following the HyMoCARES framework, the ecosystem services affected by the restoration actions are summarized in Table 3. We selected the services that have been found relevant according with the local agencies.

Table 3 River ecosystem services suggested in deliverable DT.1.2 (Second column), highlighted as relevant for the case studies (Third column) with some additional comments (Fourth column).

Ecosystem service	D.T.1.2.1	Relevant	Comments
Cultivated crops			
Plant resources for agricultural use - Pasture			
Surface water for drinking purpose	X		
Ground water for drinking purpose	X		
Surface water for non-drinking purposes in industry and agriculture	X	X	
Ground water for non-drinking purposes in industry and agriculture	X		
Plant-based resources from agriculture, short rotation coppice, forestry			
Retention of nutrients	X	X	
Reduction of greenhouse gas emission / carbon sequestration	X	X	
Flood risk mitigation	X	X	Maintenance of the reservoir capacity by removing sediments from the basin and reintroducing them downstream
Drought risk mitigation	X	X	
Soil formation in floodplains			
Regulating temperature/Cooling (water bodies and ground)	X	X	
Habitat-related services	X	X	
Aesthetics of landscape	X	X	
Natural and cultural heritage	X	X	
Education, Science	X	X	
Water-related activities	X	X	
Hydropower	X	X	
Navigation	X		
Sediments for construction	X	X	
Ecological status	X	X	

2.2 Avisio River downstream Stramentizzo reservoir

Following the HyMoCARES framework, the ecosystem services affected by the restoration actions are summarized inTable 4. We selected the services that have been found relevant according with the local agencies.

Table 4 River ecosystem services suggested in deliverable DT.1.2 (Second column), highlighted as relevant for the case studies (Third column) with some additional comments (Fourth column).

Ecosystem service	D.T.1.2.1	Relevant	Comments
Cultivated crops			
Plant resources for agricultural use - Pasture			
Surface water for drinking purpose	X		
Ground water for drinking purpose	X		
Surface water for non-drinking purposes in industry and agriculture	X	X	
Ground water for non-drinking purposes in industry and agriculture	X		
Plant-based resources from agriculture, short rotation coppice, forestry			
Retention of nutrients	X	X	
Reduction of greenhouse gas emission / carbon sequestration	X	X	
Flood risk mitigation	X	X	**Maintenance of the reservoir capacity by removing sediments from the basin and reintroducing them downstream**
Drought risk mitigation	X	X	
Soil formation in floodplains			
Regulating temperature/Cooling (water bodies and ground)	X	X	
Habitat-related services	X	X	
Aesthetics of landscape	X	X	
Natural and cultural heritage	X	X	
Education, Science	X	X	
Water-related activities	X	X	
Hydropower	X	X	
Navigation	X		
Sediments for construction	X	X	
Ecological status	X	X	

2.3 Adige River (Ischiello)

Following the HyMoCARES framework, the ecosystem services affected by the restoration actions are summarized inTable 4. We selected the services that have been found relevant according with the local agencies.

Table 5 River ecosystem services suggested in deliverable DT.1.2 (Second column), highlighted as relevant for the case studies (Third column) with some additional comments (Fourth column).

Ecosystem service	Emerged from D.T.1.2.1	Relevant for the case study (Ischiello)	Comments
Cultivated crops		X	This ES was not included in D.T.1.2.1. In our case, it is affected by the requalification operation, since existing crops in the floodplain were removed.
Plant resources for agricultural use - Pasture			
Surface water for drinking purpose			
Ground water for drinking purpose	X		
Surface water for non-drinking purposes in industry and agriculture			
Ground water for non-drinking purposes in industry and agriculture	X		
Plant-based resources from agriculture, short rotation coppice, forestry			
Retention of nutrients	X	X	
Reduction of greenhouse gas emission / carbon sequestration	X	X	
Flood risk mitigation	X		
Drought risk mitigation	X		
Soil formation in floodplains		X	
Regulating temperature/Cooling (water bodies and ground)	X	X	
Habitat-related services	X	X	
Aesthetics of landscape	X	X	
Natural and cultural heritage	X	X	
Education, Science	X	X	
Water-related activities	X		
Hydropower			
Navigation			
Sediments for construction	X	X	
Ecological status	X	X	

3 ES analysis

For each case study, please describe: a) the protocol chosen in DT.3.3.1 (BA, BACI etc.); b) the indicators used for the ES analysis; c) the data used for the analysis.
Please provide the final results of the ES analysis that should be used for the online maps (shapefile, Excel or a table that explicitly links every segment with ES value).

3.1 Avisio River downstream Pezzè reservoir

According with available data, with tools selected for hydromorphological assessment and with DT.1.3, we selected a set of indicators to perform the analysis of the ES. As soon as in this case the areas are not equivalent, we weighted each indicator for the percentage of the total area covered by each sub-unit if necessary.

Table 6 Ecosystem services, indicators and data

Ecosystem service	Indicator	Data
Aesthetics of landscape	See D.T1.3	WFD, IDRAIM, GIS data
Drought risk mitigation	Volume of groundwater (used wells as proxy)	
Ecological status	Ecological status/potential	WFD index
Education, Science	Rare morphologies	
Flood risk mitigation	Area	Data about 200 years floods (modelled) with low risk
Habitat-related services	IFF	IFF
Hydropower	Energy production (MWh/y)	Discharge data, head, MF
Natural and cultural heritage	Sites relevant for species conservation and UNESCO site	Natura 2000 sites maps
Reduction of greenhouse gas emission / carbon sequestration	Carbon sequestration (ton/ha/y), see D.T1.3	LULC + IPCC data
Regulating temperature/Cooling (water bodies and ground)		
Retention of nutrients	Indicator adapted from Burkhard et al., 2014. See D.T1.3	LULC
Sediments for construction	License and volume extracted	
Surface water for non-drinking purposes in industry and agriculture	Volume withdrawn for non-drinking purposes (l)	Withdrawals

Ecosystem service	Indicator	Data
Water-related activities (Sport fishing)	Fishing license (local persons and visitors)	Number of fishing licenses

3.1.1 ES assessment pre-intervention

Aesthetics of landscape

The aesthetics of landscape is one of the most subjective services to assess. A questionnaire could not be set up, thus we decided to use the indicator adapted from Hermes et al. (2018). In D.T1.3.1 the indicator has been moved to the "Natural and cultural heritage" service after an agreement within the project partnership.

Table 7 Value of the indicator for each sub-unit in which the case study is divided.

Id	indicator
1	0.43
2	0.09
3	0
4	0.53
5	0.37

Drought risk mitigation

In this area the groundwater data are not available or the groundwater resources are negligible. Two wells are present in the sub-unit 5, suggesting that it is the sub-unit that might provide this service. However, since the two wells are used for drinking water, this resources should be considered in the Drinking Water service, which is a service not relevant in this area.

Ecological status

According with the data from the WFD, all the sub-units are in good ecological status.

Table 8 Value of the indicator for each sub-unit in which the case study is divided.

Id	Ecological status
1	Good
2	Good
3	Good
4	Good
5	Good

Education, Science

As described in D.T1.3.1, this service has been assessed by calculating the proportion of the area that is a priority site and/or a rare morphology. Rare morphology is mostly a multi-channel morphology present in the area.

Table 9 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total area (ha)	Percentage	Standardized indicator
1	0	3.11	0	0
2	3.05	84.84	0.04	0.5
3	0	36.16	0	0
4	10.76	141.83	0.08	1
5	3.95	122.24	0.03	0.375

Flood risk mitigation

This service is assessed using the proportion of the total area for each sub-unit that is considered as fluvial areas that are flooded every 200-years and where the risk is null, expressed as hectares and normalized.

Table 10 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total Area (ha)	Percentage	Standardized indicator
1	0	3.11	0	0
2	21.05	84.84	0.25	0.34
3	5.19	36.16	0.14	0.19
4	103.11	141.83	0.73	1
5	59.58	122.24	0.49	0.67

Habitat-related services

For the habitat related service, we calculate for each sub-unit and each IFF score the area. The final score of the sub-unit is selected as described in D.T1.3.1.

Table 11 Value of the indicator for each sub-unit in which the case study is divided.

Id	Iff value	Standardized indicator
1	3	0.5
2	4	0.75
3	3	0.5
4	3	0.5
5	3.5	0.625

Hydropower

For the calculation of this use we applied the CASiMiR Hydropower tool, which calculates the megawatt/hour per year. There are no withdrawals for small hydropower plants in the case study, thus we calculate this use taking as reference the Pezzè reservoir and the hydropower plant of Predazzo for technical data (hydraulic head, efficiency), and we used the streamflow data from the Soraga gauged station. The value of this service is constant for the whole study area, and it is equal to 12082 yearly Mw/h.

Natural and cultural heritage

This service has been assessed by calculating the percentage of the total area occupied by priority sites or UNESCO sites. In our case, we had only a small proportion covered by priority habitats, according with Natura 2000.

Table 12 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total area (ha)	Percentage	Standardized indicator
1	0	3.11	0	0
2	0	84.84	0	0
3	0	36.16	0	0
4	0.189	141.83	0.001	1
5	0	122.24	0	0

Reduction of greenhouse gas emission / carbon sequestration

The chosen indicator for this service is the carbon uptake/sequestration indicator proposed in the Invest model. For details see D.T1.3.1.

Table 13 Value of the indicator for each sub-unit in which the case study is divided.

Id	Tonnes/C	Total area (ha)	Maximum theorethical capacity	Indicator
1	110.90	3.11	270.95	0.41
2	1029.8	84.84	7381.02	0.14
3	217.98	36.16	2940.8	0.07
4	3205.36	141.83	10779.36	0.3
5	4239.35	122.24	10533.91	0.4

Regulating temperature/Cooling (water bodies and ground)

The data available for this area does not show any effect of the water bodies and fluvial corridors on local average temperature in any month for the period 1981-2010. This is likely due to the low resolution of the temperature data available for this area, that does not allow to quantify the variations.

Retention of nutrients

Data for retention of nutrients were not available, thus we decided to apply the approach suggested in Burkhard et al. (2014), based on expert opinion and Land use/ Land Cover. For details see D.T1.3.1.

Table 14 Value of the indicator for each sub-unit in which the case study is divided.

Id	Value	Standardized indicator
1	0	0
2	5	1
3	3	0.6
4	2	0.4
5	5	1

Sediments for construction

Surface water for non-drinking purposes in industry and agriculture

The indicator is the litre per withdrawal for each area for each non-drinking purpose, normalized.

Table 15 Value of the indicator for each sub-unit in which the case study is divided.

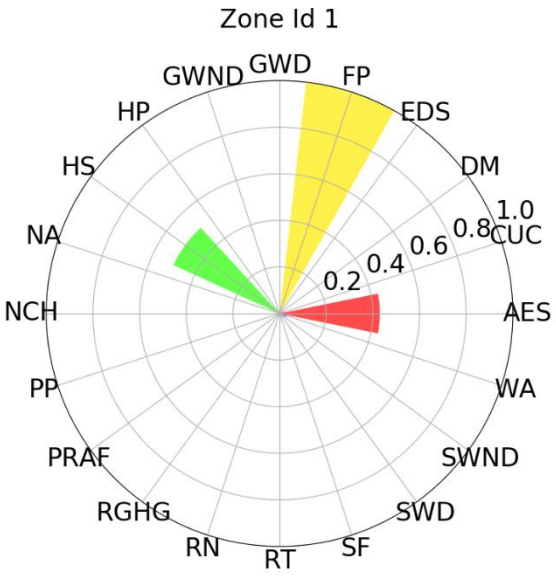
Id	Litre per area	Standardized indicator
1	0	0
2	80	1
3	3.64	0.046
4	3.37	0.042
5	18	0.225

Water-related activities

For each sub-unit, we choose as indicator the number of fishing license from different local fisher associations. We used the average number of yearly values for 2013-2017 period, considering both associated persons and tourists that usually buy temporary permits. The fisher associations are from upstream to downstream Associazione Pescatori Moena (Zone 1), Associazione Pescatori Valle di Fiemme (2,3,4) Associazione Pescatori Cavalese (5) and Associazione Pescatori Molina-Castello di Fiemme (5). Several tributaries are included in the territory of each association, thus the number of licenses is only a proxy of the service.

Id	Average number of licenses	Total area (ha)	License per ha	Standardized indicator
1	304.6	3.11	97.9	0
2	2012.4	84.84	8.3	1
3	2012.4	36.16	8.3	1
4	2012.4	141.83	8.3	1
5	1185.8	122.24	9.8	0.52

The ES values are summarized in Figure 10.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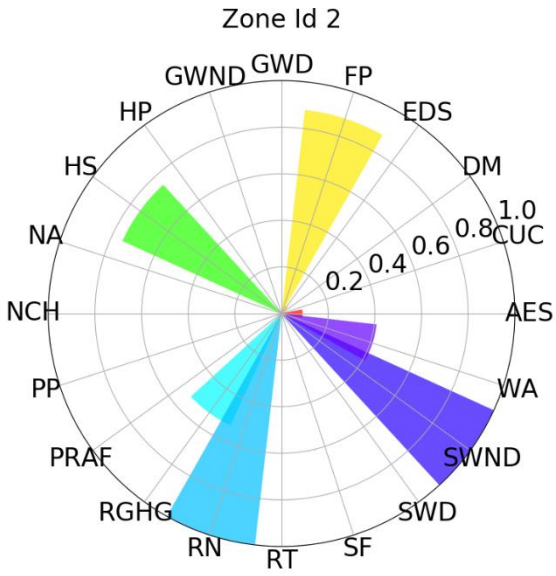
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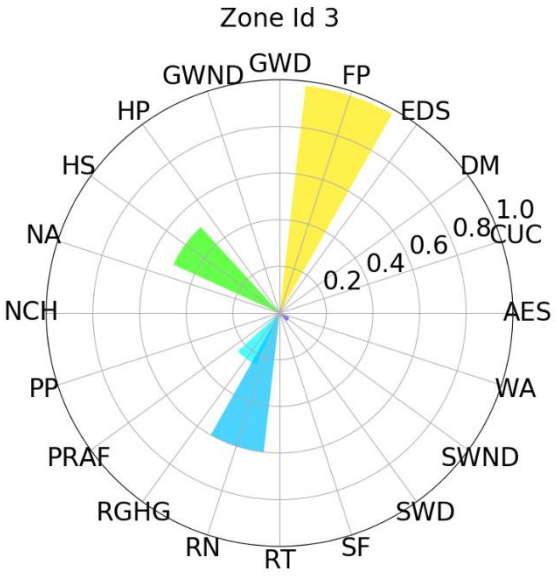
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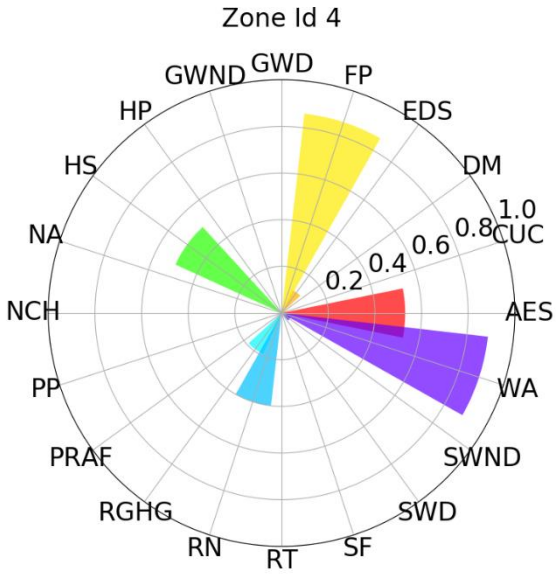
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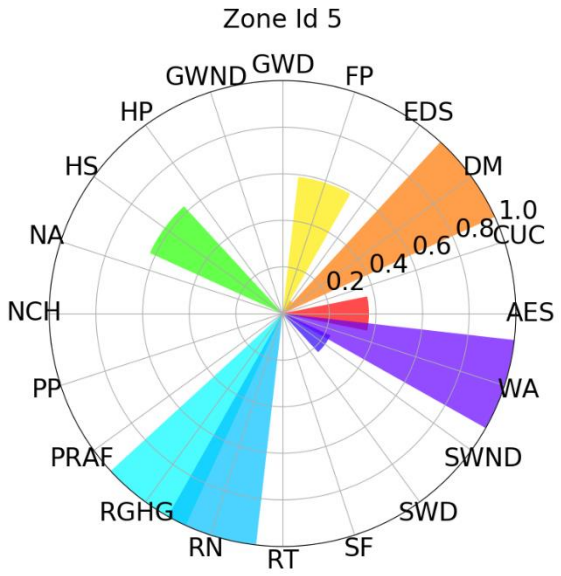

Figure 10 Summary of the ES values in each sub-unit, numbered from upstream to downstream.

Table 16 summarizes the indicator value for the ES.

Table 16 Summary of the ES indicator value.

Id	AES (score)	DM	FP (ha)	HS (score)	NCH (Ha)	RGHG (Tonnes C)	RT	RN (score)	EDS (Ha)	S	SWNP (l)	WA (n)	ESP (score)
1	0.43		0	3	0	110.90		0	0		0	304.6	Good
2	0.09		21.05	4	0	1029.8		5	3.05		80	2012.4	Good
3	0		5.19	3	0	217.98		3	0		3.64	2012.4	Good
4	0.53		103.11	3	0.189	3205.36		2	10.76		3.37	2012.4	Good
5	0.37		59.58	3.5	0	4239.35		5	3.95		18	1185.8	Good

Table 17 summarizes the score for the ES.

Table 17 Summary of the scores for the ES

Id	AES	DM	FP	HS	NCH	RGHG	RT	RN	EDS	S	SWNP	WA	ESP
1	0.43		0	0.5	0	0.41		0	0		0	0	0.8
2	0.09		0.25	0.75	0	0.14		1	0.04		1	1	0.8
3	0		0.14	0.5	0	0.07		0.6	0		0.046	1	0.8

4	0.53		0.73	0.5	0.001	0.3		0.4	0.09		0.042	1	0.8
5	0.37		0.49	0.625	0	0.4		1	0.03		0.225	0.52	0.8

To assess the contribution of each sub-unit to ES provision, we weighted the indicators by the total area. The values are summarized in Table 18. The weighting of the scores by the area can highlight if some small sub-units largely contribute to the ES provision of the area. Conversely, if the difference in areas are large as in this case, the normalization can greatly underestimate the value of the ES in small areas.

Table 18 ES values weighted by the proportion of the total area.

Id	Proportion of the total area	AES	DM	FP	HS	HP	NCH	RGHG	RT	RN	EDS	S	SWNP	WA	ESP
1	0.01	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0.01
2	0.22	0.13	0	0.07	0.16	0.22	0	0.12	0	0.22	0.04	0	0.22	0	0.22
3	0.09	0.01	0	0.03	0.05	0.09	0	0.02	0	0.06	0	0	0	0	0.09
4	0.37	0.37	0	0.37	0.18	0.37	0.37	0.07	0	0.15	0.08	0	0.02	0	0.37
5	0.31	0.16	0.31	0.29	0.2	0.31	0	0.31	0	0.31	0.03	0	0.07	0	0.31

3.1.2 ES assessment post-intervention

The release of fine artificial sediment from Pezzè reservoir appears to not have a strong effect on ES, because fine sediment does not remain on the river bed for a long time. After 3-4 months, the ecological quality returns to the previous value (APPA 2012). However, the last release took place in May 2019 and the analyses of possible effects on hydromorphology are still on-going. Possible effects might be on habitat due to the increase in fine sediments.

3.2 Avisio River downstream Stramentizzo reservoir

According with available data, with tools selected for hydromorphological assessment and with DT.1.3, we selected a set of indicators to perform the analysis of the ES. As soon as in this case the areas are not equivalent, we weighted each indicator for the percentage of the total area covered by each sub-unit if necessary.

Table 19 Ecosystem services, indicators and data

Ecosystem service	Indicator	Data
Aesthetics of landscape	See D.T1.3	WFD, IDRAIM, GIS data
Drought risk mitigation	Volume of groundwater (used wells as proxy)	

Ecological status	Ecological status/potential	WFD index
Education, Science	Rare morphologies	
Flood risk mitigation	Area	Data about 200 years floods (modelled) with low risk
Habitat-related services	IFF	IFF
Hydropower	Energy production (MWh/y)	Discharge data, head, MF
Natural and cultural heritage	Sites relevant for species conservation and UNESCO site	Natura 2000 sites maps
Reduction of greenhouse gas emission / carbon sequestration	Carbon sequestration (ton/ha/y), see D.T1.3	LULC + IPCC data
Regulating temperature/Cooling (water bodies and ground)		
Retention of nutrients	Indicator adapted from Burkhard et al., 2014. See D.T1.3	LULC
Sediments for construction	License and volume extracted	
Surface water for non-drinking purposes in industry and agriculture	Volume withdrawn for non-drinking purposes (l)	Withdrawals
Water-related activities (Sport fishing)	Fishing license (local persons and visitors)	Number of fishing licenses

3.2.1 ES assessment pre-intervention

Aesthetics of landscape

The aesthetics of landscape is one of the most subjective services to assess. A questionnaire could not be set up, thus we decided to use the indicator adapted from Hermes et al. (2018) In D.T1.3.1 the indicator has been moved to the "Natural and cultural heritage" service after an agreement within the project partnership.

Table 20 Value of the indicator for each sub-unit in which the case study is divided.

Id	Indicator	Standardized indicator
1	0.1	0.1
2	0.4	0.4
3	0.23	0.23
4	0.1	0.1
5	0.12	0.12
6	0.18	0.18
7	0.04	0.04
8	0.19	0.19
9	0.02	0.02
10	0.42	0.42
11	0.56	0.56

Drought risk mitigation

In this area the groundwater resources data are not available. As a proxy, we used the actual use of the groundwater resource expressed by the number of wells and their withdrawal capacity.

Id	Number of wells	Total Q (l)	Standardized indicator
1	0	-	0
2	0	-	0
3	0	-	0
4	0	-	0
5	0	-	0
6	0	-	0
7	0	-	0
8	1	4	0.29
9	0	-	0
10	0	-	0
11	2	13.81	1

Ecological status

According with the data from the WFD, all the sub-units are in good ecological status. However, as shown in the following table, several water bodies in the sub-units are categorized as “good (at risk)”, meaning that the ecological status as to be controlled with particular care.

Table 21 Ecological status scores.

Id	Status
1	Good
2	Good (at risk)
3	Good (at risk)
4	Good (at risk)
5	Good (at risk)
6	Good (at risk)
7	Good (at risk)
8	Good (at risk)
9	Good
10	Good
11	Good

Education, Science

As described in D.T1.3.1, this service has been assessed by calculating the proportion of the area that is a priority site and/or a rare morphology. Rare morphology is mostly a multi-channel morphology present in the area.

Table 22 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total area (ha)	Percentage	Standardized indicator
1	0	48.37	0	0
2	4.74	64.53	0.07	0.47
3	0	27.51	0	0
4	0	17.23	0	0
5	0	6.06	0	0
6	0	8.34	0	0
7	0	8.64	0	0
8	0.22	18.44	0.01	0.07
9	0	3.62	0	0
10	0.12	97.81	0	0
11	27.39	181.17	0.15	1

Flood risk mitigation

This service is assessed using the proportion of the total area for each sub-unit that is considered as fluvial areas that are flooded every 200-years and where the risk is null, expressed as hectares and normalized.

Table 23 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total Area (ha)	Percentage	Standardized indicator
1	24.51	48.37	0.51	0.89
2	23.22	64.53	0.36	0.63

3	0.62	27.51	0.02	0.04
4	0.11	17.23	0.01	0.02
5	0.05	6.06	0.01	0.02
6	0	8.34	0	0
7	0	8.64	0	0
8	0.5	18.44	0.03	0.05
9	0	3.62	0	0
10	4.32	97.81	0.04	0.07
11	103.93	181.17	0.57	1

Habitat-related services

For the habitat related service, we calculate for each sub-unit and each IFF score the area. The final score of the sub-unit is selected as described in D.T1.3.1.

Table 24 Value of the indicator for each sub-unit in which the case study is divided.

Id	Iff value	Standardized indicator
1	5	1
2	5	1
3	4.5	0.875
4	4	0.75
5	4	0.75
6	4	0.75
7	4.5	0.875
8	3.5	0.625
9	4.5	0.875
10	4	0.75
11	3.5	0.625

Hydropower

For the calculation of this use we applied the CASiMiR Hydropower tool, which calculates the megawatt/hour per year. There are no withdrawals for small hydropower plants in the case study, thus we calculate this use taking as reference the Pezzè reservoir and the hydropower plant of Predazzo for technical data (hydraulic head, efficiency), and we used the streamflow data from the Soraga gauged station. The value of this service is the same as for the area upstream the dam because the water release is downstream the study area in another river (Adige River). The value of this ES is 12082 yearly Mw/h.

Natural and cultural heritage

This service has been assessed by calculating the percentage of the total area occupied by priority sites or UNESCO sites. In our case, we had only a small proportion covered by priority habitats, according with Natura 2000.

Table 25 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total area (ha)	Percentage	Standardized indicator
1	0	48.37	0	0
2	0	64.53	0	0
3	0	27.51	0	0
4	0	17.23	0	0
5	0	6.06	0	0
6	0	8.34	0	0
7	0	8.64	0	0
8	0	18.44	0	0
9	0	3.62	0	0
10	0	97.81	0	0
11	88.18	181.17	0.49	1

Reduction of greenhouse gas emission / carbon sequestration

The chosen indicator for this service is the carbon uptake/sequestration indicator proposed in the Invest model. For details see D.T1.3.1.

Table 26 Value of the indicator for each sub-unit in which the case study is divided.

Id	Tonnes /C	Total Area(ha)	Maximum theorethical capacity	Indicator
1	2724.26	48.37	4208.19	0.65
2	3663.96	64.53	5614.11	0.65
3	1022.66	27.51	2393.37	0.43
4	991.75	17.23	1499.01	0.66
5	37.88	6.06	527.22	0.07
6	400.7	8.34	725.58	0.55
7	463.01	8.64	751.68	0.62
8	646.71	18.44	1604.28	0.4
9	173.62	3.62	314.94	0.55
10	5611.68	97.81	8509.47	0.66
11	1850.9	181.17	15761.79	0.12

Regulating temperature/Cooling (water bodies and ground)

The data available for this area does not show any effect of the water bodies and fluvial corridors on local average temperature in any month for the period 1981-2010. This is likely due to the low resolution of the temperature data available for this area, that does not allow to quantify the variations.

Retention of nutrients

Data for retention of nutrients were not available, thus we decided to apply the approach suggested in Burkhard et al. (2014), based on expert opinion and Land use/ Land Cover. For details see D.T1.3.1.

Table 27 Value of the indicator for each sub-unit in which the case study is divided.

Id	Value	Standardized indicator
1	5	1
2	5	1
3	3	0.5
4	5	1
5	3	0.5
6	5	1
7	5	1
8	3	0.5
9	5	1
10	5	1
11	4	0.75

Sediments for construction

Surface water for non-drinking purposes in industry and agriculture

The indicator is the litre per withdrawal for each area for each non-drinking purpose, normalized.

Table 28 Value of the indicator for each sub-unit in which the case study is divided.

Id	Litre per area	Standardized indicator
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	127	1
11	3	0.02

Water-related activities

To our knowledge, the only relevant activity in the area is sport fishing. The river might be use by private kayakers and canoers, but official data about these activities are not available. The fisher association

responsible for this reach is the Associazione Pescatori Dilettanti Trentini. They shared the data with the HyMoCARES partners, but unfortunately they don't divide the licenses in water bodies and they manage several different river basins (Fersina River, Avisio River, main stem Adige River). Hence, it was not possible to use the number of licenses in this case because data at the minimum required detail are lacking.

For each sub-unit, ES values are summarized in the following figures.

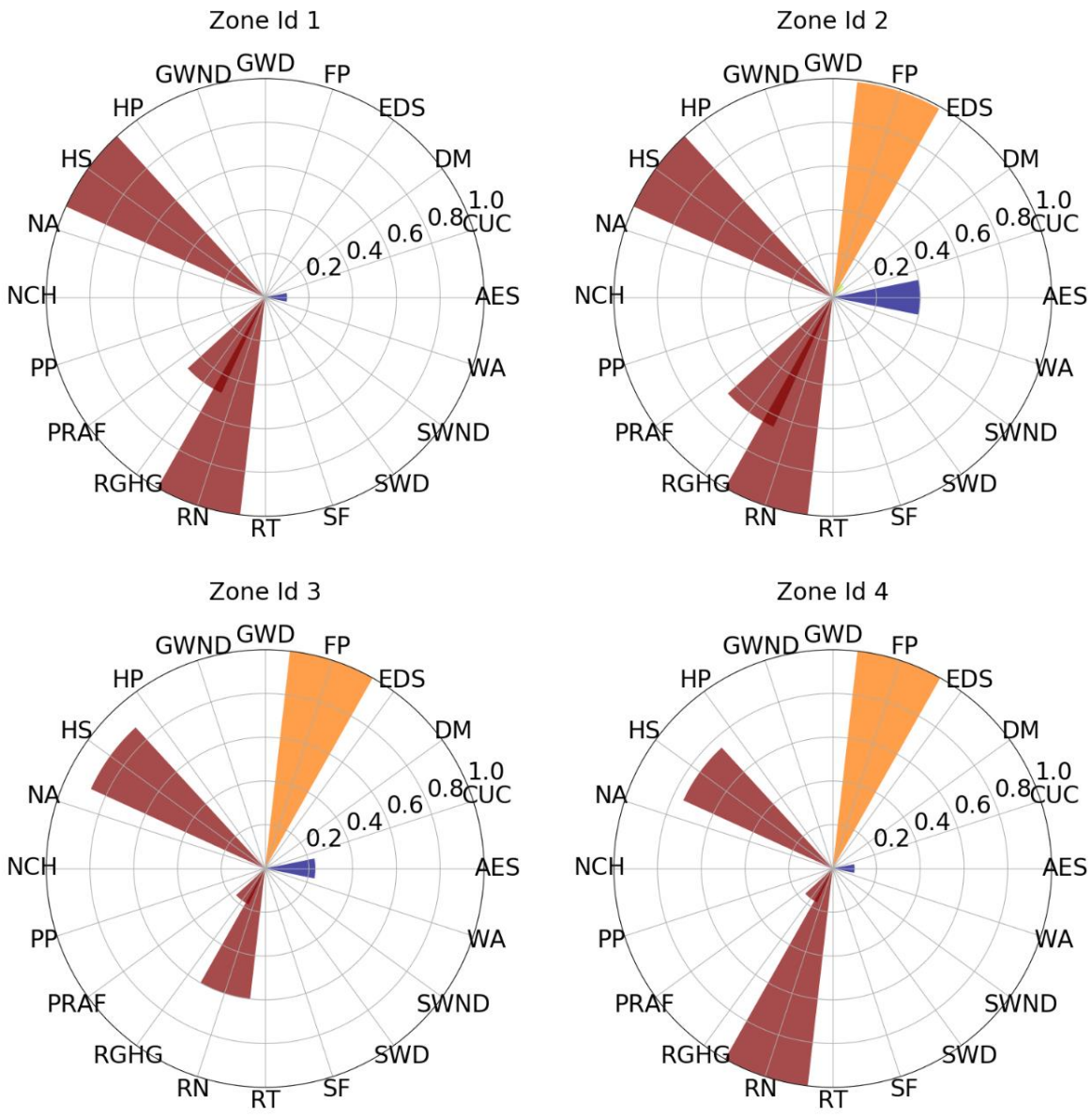

Figure 11 Summary of the ES values in sub-unit 1 to 4, numbered from upstream to downstream.

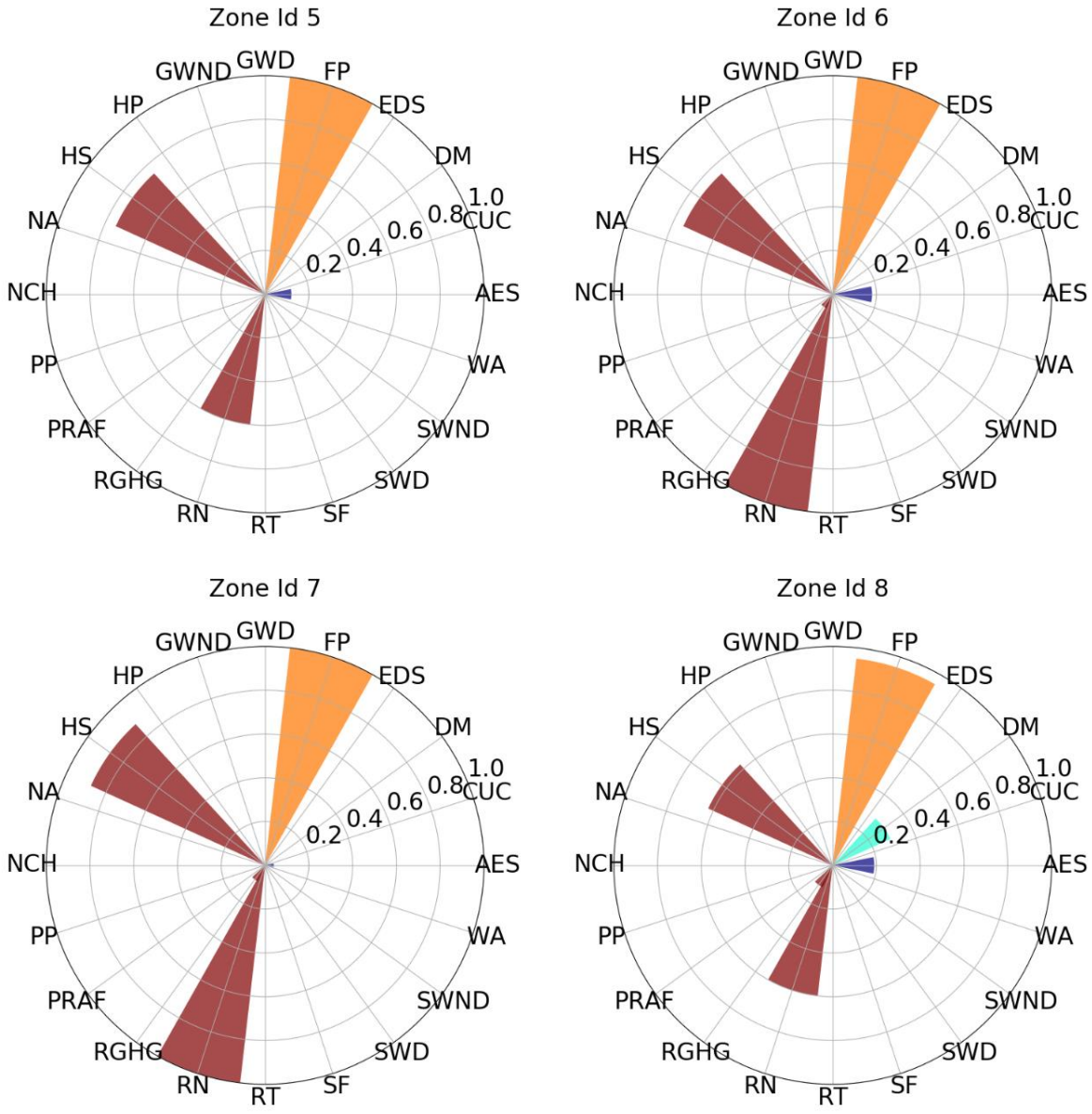

Figure 12 Summary of the ES values in sub-unit 5 to 8, numbered from upstream to downstream.

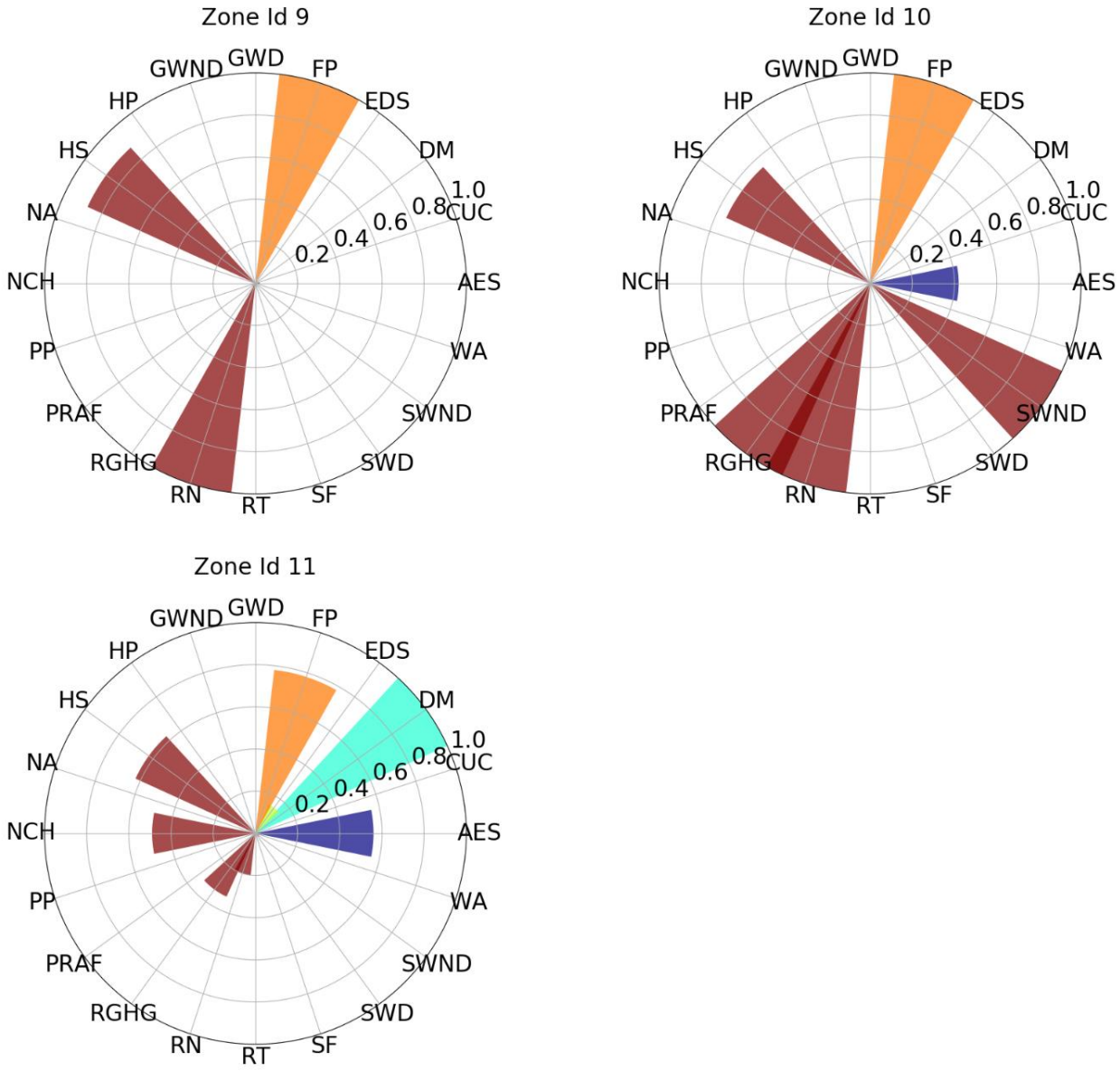

Figure 13 Summary of the ES values in sub-unit 5 to 8, numbered from upstream to downstream.

Table 29 Summary of the ES indicator value.

Id	AES (score)	DM	FP (ha)	HS (score)	NCH (Ha)	RGHG (Tonnes C)	RT	RN (score)	EDS (Ha)	S	SWNP (l)	WA (n)	ESP (score)
1	0.1		24.51	5	0	2724.26		5	0		0		Good
2	0.4		23.22	5	0	3663.96		5	4.74		0		Good (at risk)
3	0.23		0.62	4.5	0	1022.66		3	0		0		Good (at risk)
4	0.1		0.11	4	0	991.75		5	0		0		Good (at risk)

Id	AES (score)	DM	FP (ha)	HS (score)	NCH (Ha)	RGHG (Tonnes C)	RT	RN (score)	EDS (Ha)	S	SWNP (l)	WA (n)	ESP (score)
5	0.12		0.05	4	0	37.88		3	0		0		Good (at risk)
6	0.18		0	4	0	400.7		5	0		0		Good (at risk)
7	0.04		0	4.5	0	463.01		5	0		0		Good (at risk)
8	0.19		0.5	3.5	0	646.71		3	0.22		0		Good (at risk)
9	0.02		0	4.5	0	173.62		5	0		0		Good
10	0.42		4.32	4	0	5611.68		5	0.12		127		Good
11	0.56		103.93	3.5	88.18	1850.9		4	27.39		3		Good

Table 30 Summary of the scores for the ES

Id	AES	DM	EDS	FP	HS	NCH	RGHG	RN	SWND	WA	ESP
1	0.1	0	0	0.89	1	0	0.65	1	0		0.8
2	0.4	0	0.07	0.63	1	0	0.65	1	0		0.7
3	0.23	0	0	0.04	0.875	0	0.43	0.5	0		0.7
4	0.1	0	0	0.02	0.75	0	0.66	1	0		0.7
5	0.12	0	0	0.02	0.75	0	0.07	0.5	0		0.7
6	0.18	0	0	0	0.75	0	0.55	1	0		0.7
7	0.04	0	0	0	0.875	0	0.62	1	0		0.7
8	0.19	0.29	0.01	0.05	0.625	0	0.4	0.5	0		0.7
9	0.02	0	0	0	0.875	0	0.55	1	0		0.8
10	0.42	0	0	0.07	0.75	0	0.66	1	1		0.8
11	0.56	1	0.15	1	0.625	0.49	0.12	0.75	0.02		0.8

To assess the contribution of each sub-unit to ES provision, we weighted the indicators by the total area. The values are summarized in Table 18. The weighting of the scores by the area can highlight if some small sub-units largely contribute to the ES provision of the area. Conversely, if the difference in areas are large as in this case, the normalization can greatly underestimate the value of the ES in small areas.

Table 31 ES values weighted by the proportion of the total area.

Id	% of the total area	AES	DM	EDS	FP	HS	NCH	RGHG	RN	SWND	WA
1	0.1	0.01	0	0	0	0.1	0	0.05	0.1	0	
2	0.13	0.05	0	0.01	0.13	0.13	0	0.09	0.13	0	
3	0.06	0.01	0	0	0.06	0.05	0	0.01	0.03	0	
4	0.04	0	0	0	0.04	0.03	0	0.01	0.04	0	
5	0.01	0	0	0	0.01	0.01	0	0	0.01	0	
6	0.02	0	0	0	0.02	0.01	0	0	0.02	0	
7	0.02	0	0	0	0.02	0.02	0	0	0.02	0	
8	0.04	0.01	0.01	0	0.04	0.02	0	0	0.02	0	
9	0.01	0	0	0	0.01	0.01	0	0	0.01	0	
10	0.2	0.09	0	0	0.2	0.15	0	0.2	0.2	0.2	
11	0.38	0.21	0.38	0.06	0.29	0.24	0.18	0.12	0.08	0.01	

3.2.2 ES assessment post-intervention

The effects of the release of sediment from Stramentizzo reservoir have been only modelled, since this measure has not been put in practice. In general, downstream from the reservoir, the sediment fraction between 1 – 10cm is missing and slightly reappears only thanks to the contribution of the small, unregulated natural tributaries, which cannot compensate the sediment deficit. Since 1973 the Avisio river downstream of the Stramentizzo reservoir reduced its width by almost 4 times from an average of 55 m down to about 15 m. This is reflected by an increase of the proportion of vegetation in the river corridor, which is now up to 70-90%. It is very likely that both armoring (and channel adjustments with extensive riparian vegetation encroachment on the formerly active channel have caused major changes in the spatial and temporal availability of river habitat. Consequences might be on ES directly depending on habitat quality like habitat related services, with a reduction in the natural population of fish, which in turn may influence water activities like angling. The change in vegetated areas may influence services depending on land cover and land use, like nutrient retention and reduction of GHG.

3.3 Adige River (Ischiello)

According with available data, with tools selected for hydromorphological assessment and with DT.1.3, we selected a set of indicators to perform the analysis of the ES. In this case, we can compare ES (if possible) before and after the invervention. Thus, the normalization has been done considering the before-after results, to highlight the variations of the ES induced by the restoration action.

Table 32 Ecosystem services, indicators and data

Ecosystem service	Indicator	Data
Aesthetics of landscape	See D.T1.3	WFD, IDRAIM, GIS data

Cultivated crops	Area	LULC 2008-2015
Ecological status	Ecological status/potential	WFD index
Education, Science	Rare morphologies	
Habitat-related services	IFF	IFF
Natural and cultural heritage	Sites relevant for species conservation and UNESCO site	Natura 2000 sites maps
Reduction of greenhouse gas emission / carbon sequestration	Carbon sequestration (ton/ha/y), see D.T1.3	LULC + IPCC data
Regulating temperature/Cooling (water bodies and ground)		
Retention of nutrients	Indicator adapted from Burkhard et al., 2014. See D.T1.3	LULC
Sediments for construction	License and volume extracted	

3.3.1 ES assessment pre-intervention

Aesthetics of landscape

The aesthetics of landscape is one of the most subjective services to assess. A questionnaire could not be set up, thus we decided to use the indicator adapted from Hermes et al. (2018). In D.T1.3.1 the indicator has been moved to the "Natural and cultural heritage" service after an agreement within the project partnership.

Id	Standardized indicator
1	0.5

Cultivated crops

Cultivated crops has been quantified based on cultivated area and using Land Cover – Land Use Corine classes (MAES 3). The data are standardized on the total area.

Id	Area (ha)	Standardized
1	5.75	0.35

Ecological status

The ecological status of the study area is good.

Education, Science

As described in D.T1.3.1, this service has been assessed by calculating the proportion of the area that is a priority site and/or a rare morphology. Rare morphologies were not present before the intervention.

Table 33 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total area (ha)	Percentage	Standardized indicator
1	0	16.48	0	0

Habitat-related services

For the habitat related service we applied habitat modelling techniques to assess the habitat suitability and quality of grayling (young and adult) and marble trout (young and adult), before and after the restoration. The details are in the deliverable for the AT3.3.

As indicator, we choose the area before-after the intervention for each species and life stage, at 8 increasing discharges. We normalized using the formula in DT.1.3 to improve graphs readability.

The final indicator is the average of the normalized score for life stage and species values at the different discharges.

Table 34 Value of the indicator for each sub-unit in which the case study is divided.

Id	Grayling young score	Grayling adult score	Marble trout young score	Marble trout adult score	Indicator
1	0.22	0.37	0.27	0.32	0.29

Natural and cultural heritage

This service has been assessed by calculating the percentage of the total area occupied by priority sites or UNESCO sites. The whole site in this case is a protected area.

Table 35 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total area (ha)	Percentage	Standardized indicator
1	16.48	16.48	1	1

Reduction of greenhouse gas emission / carbon sequestration

The chosen indicator for this service is the carbon uptake/sequestration indicator proposed in the Invest model. For details see D.T1.3.1.

Table 36 Value of the indicator for each sub-unit in which the case study is divided.

Id	Tonnes/C	Total Area(ha)	Maximum theorethical capacity	Indicator
1	253.53	16.48	1334.98	0.19

Regulating temperature/Cooling (water bodies and ground)

The data available for this area does not show any effect of the water bodies and fluvial corridors on local average temperature in any month for the period 1981-2010. This is likely due to the low resolution of the temperature data available for this area, that does not allow to quantify the variations.

Retention of nutrients

Data for retention of nutrients were not available, thus we decided to apply the approach suggested in Burkhard et al. (2014), based on expert opinion and Land use/ Land Cover. For details see D.T1.3.1.

Table 37 Value of the indicator for each sub-unit in which the case study is divided.

Id	Value	Standardized indicator
1	3	0.6

Sediments for construction

Data to calculate this ES were not available.

For each sub-unit, ES values are summarized in the following figure.

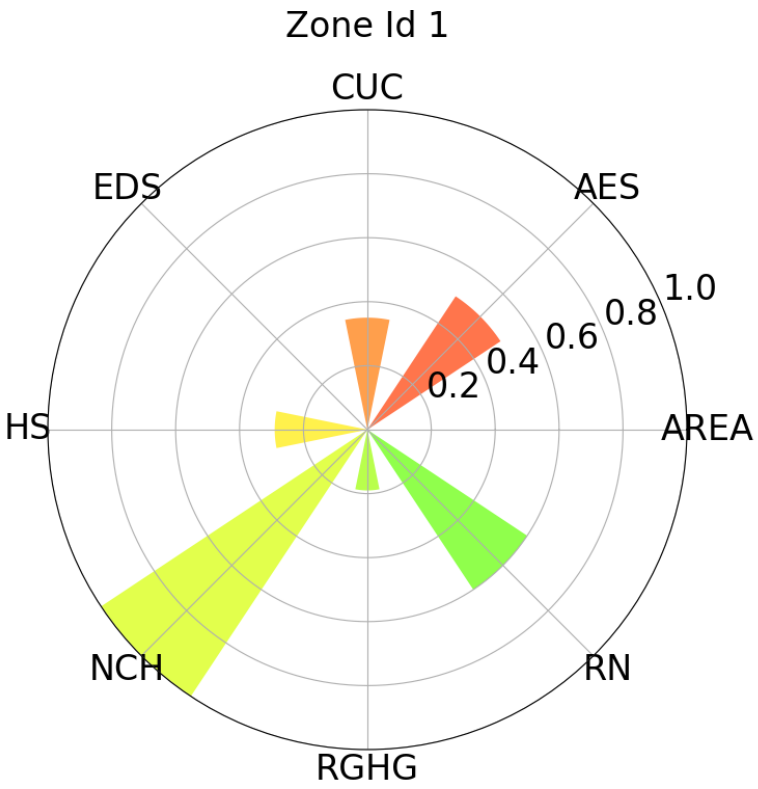

Figure 14 Summary of the ES values.

3.3.2 ES assessment post-intervention

Aesthetics of landscape

The aesthetics of landscape is one of the most subjective services to assess. A questionnaire could not be set up, thus we decided to use the indicator adapted from Hermes et al. (2018). In D.T1.3.1 the indicator has been moved to the "Natural and cultural heritage" service after an agreement within the project partnership.

Id	Standardized indicator
1	0.75

Cultivated crops

Cultivated crops has been quantified based on cultivated area and using Land Cover – Land Use Corine classes (MAES 3). The data are standardized on the possible minimum (0) and the total area.

Id	Area (ha)	Standardized
1	2.57	0.16

Ecological status

The ecological status of the study area is good.

Education, Science

As described in D.T1.3.1, this service has been assessed by calculating the proportion of the area that is a priority site and/or a rare morphology. Rare morphology is mostly a multi-channel morphology present in the area.

Table 38 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total area (ha)	Percentage	Standardized indicator
1	1.44	16.48	0.03	1

Habitat-related services

For the habitat related service we applied habitat modelling techniques to assess the habitat suitability and quality of grayling (young and adult) and marble trout (young and adult), before and after the restoration. The details are in the deliverable for the AT3.3.

As indicator, we choose the area before-after the intervention for each species and life stage, at 8 increasing discharges. We normalized using the formula in DT.1.3 to improve graphs readability.

The final indicator is the average of the normalized score for life stage and species values at the different discharges.

Table 39 Value of the indicator for each sub-unit in which the case study is divided.

Id	Grayling young score	Grayling adult score	Marble trout young score	Marble trout adult score	Indicator
1	0.26	0.46	0.77	0.60	0.52

Natural and cultural heritage

This service has been assessed by calculating the percentage of the total area occupied by priority sites or UNESCO sites. The whole site in this case is a protected area.

Table 40 Value of the indicator for each sub-unit in which the case study is divided.

Id	Area (ha)	Total area (ha)	Percentage	Standardized indicator
1	16.48	16.48	1	1

Reduction of greenhouse gas emission / carbon sequestration

The chosen indicator for this service is the carbon uptake/sequestration indicator proposed in the Invest model. For details see D.T1.3.1.

Table 41 Value of the indicator for each sub-unit in which the case study is divided

Id	Tonnes/C	Total Area(ha)	Maximum theorethical capacity	Indicator
1	236.66	16.48	1334.98	0.18

Regulating temperature/Cooling (water bodies and ground)

The data available for this area does not show any effect of the water bodies and fluvial corridors on local average temperature in any month for the period 1981-2010. This is likely due to the low resolution of the temperature data available for this area, that does not allow to quantify the variations.

Retention of nutrients

Data for retention of nutrients were not available, thus we decided to apply the approach suggested in Burkhard et al. (2014), based on expert opinion and Land use/ Land Cover. For details see D.T1.3.1.

Table 42 Value of the indicator for each sub-unit in which the case study is divided.

Id	Value	Standardized indicator
1	3	0.6

Sediments for construction

Data to calculate this ES were not available.

For each sub-unit, ES values are summarized in the following figure.

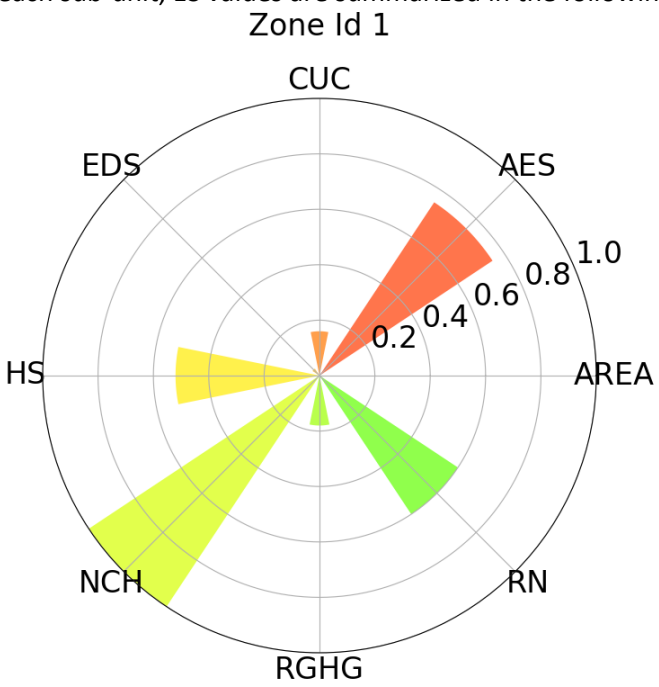

Figure 15 Summary of the ES values.

In Table 43 we show the values for ES.

Table 43 Raw values for ES

	Id	AES (score)	CUC (ha)	EDS (ha)	HS (score)	NCH (ha)	RGHG (tonnes)	RN (score)
Pre	1	0.5	5.75	0	0.29	16.48	253.53	0.6
Post	1	0.75	2.57	1.44	0.52	16.48	236.66	0.6

The following table shows the scores for the ES before and after the intervention.

	Id	AES	CUC	EDS	HS	NCH	RGHG	RN
Pre	1	0.5	0.35	0	0.29	1	0.19	0.6
Post	1	0.75	0.16	0.03	0.52	1	0.18	0.6

4 Conclusions and perspectives

4.1.1 Avisio River upstream Stramentizzo reservoir

The release of fine artificial sediment from Pezzè reservoir appears to not have a strong effect on ES, because fine sediment does not remain on the river bed for a long time. After 3-4 months, the ecological quality returns to the previous value (APPA 2012). However, the last release took place in May 2019 and the analyses of possible effects on hydromorphology are still on-going. Possible effects might be on habitat quality due to the increase in fine sediments.

4.1.2 Avisio River downstream Stramentizzo reservoir

The effects of the release of sediment from Stramentizzo reservoir have been only modelled, since this measure has not been put in practice. In general, downstream from the reservoir, the sediment fraction between 1 – 10cm is missing and slightly reappears only thanks to the contribution of the small, unregulated natural tributaries, which cannot compensate the sediment deficit. Since 1973 the Avisio river downstream of the Stramentizzo reservoir reduced its width by almost 4 times from an average of 55 m down to about 15 m. This is reflected by an increase of the proportion of vegetation in the river corridor, which is now up to 70-90%. It is very likely that both armoring (and channel adjustments with extensive riparian vegetation encroachment on the formerly active channel have caused major changes in the spatial and temporal availability of river habitat. Consequences might be on ES directly depending on habitat quality like habitat related services, with a reduction in the natural population of fish, which in turn may influence water activities like angling. The change in vegetated areas may influence services depending on land cover and land use, like nutrient retention and reduction of GHG.

4.1.3 Adige River (Ischiello)

The restoration action had generally a positive effect on the ES. As summarized in Table 44, the biggest increase was for the Aesthethic of landscape and Habitat services: the first one because the removal of the levee and the opening of the lateral channel increased the diversity of the reach, the second one because the lateral channel increased the habitat for species and life stages, especially for marble trout (*Salmo trutta marmoratus*) both adult and young life-stage. Table 1The lateral channel might be an educational site to explain river morphological dynamics and forms to the public, and it has already been studied in several research works. Due to the opening of the lateral pool, the cultivated area decreased, thus this service has partially been lost. In general, the restoration action had a positive effect on the relevant ES.

Table 44 Difference after-before in ES scores.

	AES	CUC	EDS	HS	NCH	RGHG	RN
After - before	0.25	-0.19	0.03	0.23	0	-0.01	0

5 References

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