HyMoCARES

Integrating the Ecosystem Services approach in planning and operational activities affecting river hydromorphological processes

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Hydromorphological restoration of the Upper Drac river

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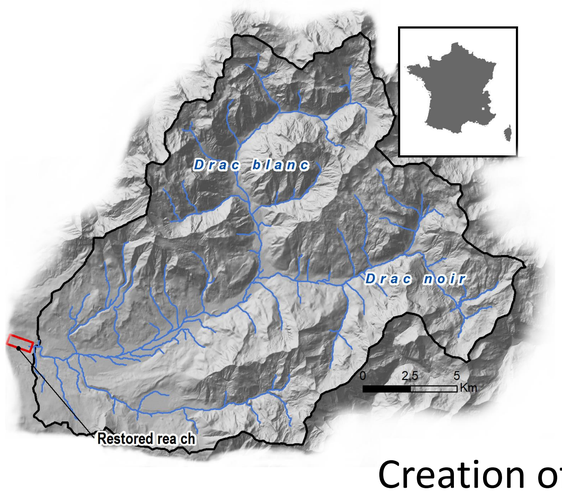
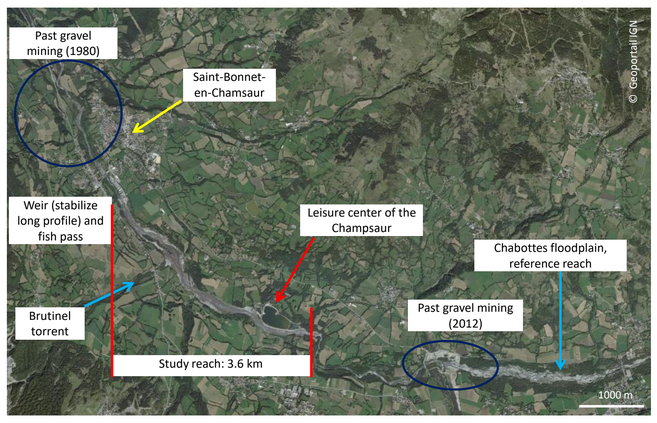
Drac restoration site



Drainage area (in km²)	340
Location	44°39'17''N, 6°6'23''E
Length of the study reach (in km)	3.7
Active channel width (in m)	110
Channel slope (in m/m)	0.01
Planform morphology	Braided pattern



Creation of a new wide and shallow channel with 355 000 m^3 of coarse sediments from adjacent alluvial terraces and other complementary sources

Restoration project between 11/2013 and 04/2014

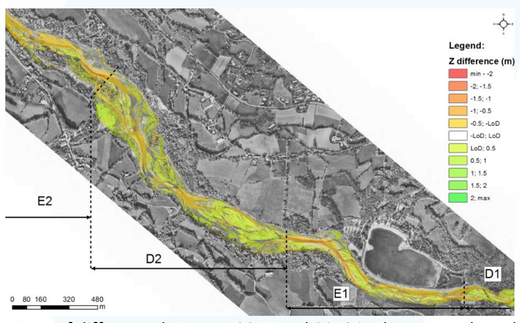
Physical monitoring

High resolution topographic surveys

Date of the survey	Type of survey	Data source	Before (B) After (A) restoration Spatial coverage
08/02/2011	Airborne LiDAR	CD05/Sintegra	B (Ricoux-Sautet, 35 km)
15-28/10/2013	Airborne LiDAR	CLEDA/Vinci	B (St. Bonnet, 3.5 km)
11-17/04/2014	dGPS survey	CLEDA/Vinci	A (St. Bonnet, 3.5 km)
10/09/2015	Airborne LiDAR	CD05/Sintegra	A (Ricoux-Sautet, 35 km)
22/09/2016	Airborne LiDAR	CD05/Sintegra	A (St. Bonnet, 3.5 km)
04-05/09/2017	UAV-SfM*	Irstea	A (St. Bonnet, 3.5 km)
18-20/09/2018 26-27/09/2018 04/10/2018	UAV-SfM**	Irstea	A (St. Bonnet, 3.5 km)
18/10/2018	Airborne LiDAR	CLEDA/OPSIA	A (Orcières/Les Borels-Sautet, 45 km)

* using RGB and IR cameras
** using RGB camera

Repetitive topographic surveys of the restored reach (DEMs) are overlayed to produce change detection maps. These DEMs are derived from 3D point clouds (3D points to TIN and to DEM) from airborne LiDAR surveys and from the processing of UAV high resolution images with SfM photogrammetric technics

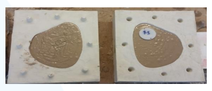


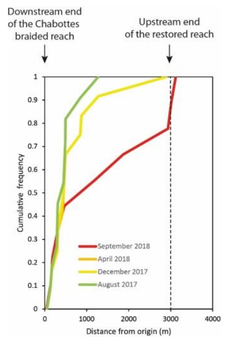
UAV campaigns with topo / bathy dDGPS GCP and high resolution photos

DEM of difference between 2015 and 2018 in the restored reach, based on airborne LiDAR surveys, showing the formation of a network of anabranches, typical of the braiding fluvial pattern

Sediment mobility

A set of 161 tags has been inserted in artificial gravels and deployed in the braided Chabottes plain upstream of the restoration site, to evaluate the bedload transit time from this major sediment source and the restored reach



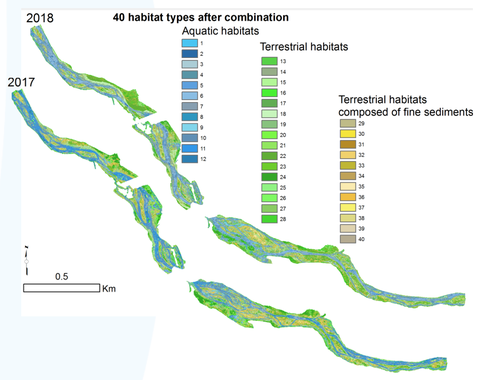


Transport distances for several dates on the Drac (Chabottes plain)

Physical habitats mapping

Combination of two major criteria controlling distribution of aquatic and terrestrial species which were preliminary discretized into classes:

- A proxy of the size of the substrate (roughness of the 3D point clouds)
- The relative elevation to the water level



For terrestrial habitats, the location of fine sediments is also included.
The combination of the classes forms 40 differents habitat types which can be further clustered and their distribution compared between 2017 and 2018 UAV campaigns with some diversity indicator (e.g., Shannon Index)

Main results

The monitoring of the morphological restoration of the Upper Drac clearly reveals a very efficient spontaneous recovery of braiding conditions along the 3-km widened and replenished river reach. Bedload tracing experiment confirm a rapid dispersion of gravels from the Chabottes plain, which is the main sediment reservoir upstream of the restored reach. This strong coarse sediment connectivity is a positive point for the resilience of the braided pattern in the restored reach. The bed relief index also confirms a favourable morphological trajectory which evolves towards reference conditions, as observed in the reference reach

The detailed typology of habitats shows a low variability of habitats distribution at the reach scale, and at a sub-reach scale (segment of 200m in length) excepted in the large braided area (in the median part of the restored reach) where the diversity index increase significantly between 2017 and 2018. This braided area was composed of several shallow channels in 2017. A simplification of the number of channels in 2018 allowed some terrestrialization (fine sediment deposits) associated with a general refinement of the sediment size. At the braided area scale more frequent habitat types (like shallow channel with medium size gravel bed) tends to lower the Shannon index in 2017, compared to 2018, where habitat types are more equally distributed. This shows that Shannon index may be too sensitive to unfrequent habitat types. This has been confirmed with a clustering analysis, that show some steps in the Shannon index distribution (calculated for various numbers of clusters grouping the original 40 types).

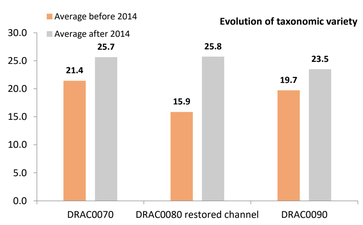
Ecological monitoring

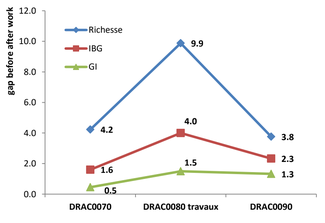
Based on the existing ecological data collected by the different river managers, an evaluation protocol has been applied along the Drac restoration work area. Different compartments have been investigated, at different scales (station, restored channel, river reach), compared to a witness site. The following table shows the data used for the Drac assessment before/after restoration work :

Ecological monitoring	*Agence de l'eau RMC (2016 to 2023) + AFB (1989 to 2017)*	*Département des Hautes-Alpes (2018 and 2019, data used since 2004)*
Hydrobiological monitoring	Invertebrate Macro Sampling, Diatom Sampling by Agence de l'Eau investigations	Water quality assessment by monitoring benthic invertebrate fauna according to quantitative and qualitative methods
Hydrology	*No investigation*	Four gaugings on 4 stations : Orcières, Pont du Fossé, Chabottes and Saint Bonnet en Champsaur 4 times a year.
Thermal monitoring	*No investigation*	Aerial thermal investigation during low-water periods to define refugia zones for aquatic species on Drac River using a method developed by the CNRS + continuous monitoring for the temperature parameter on a control station (Drac In Pont du Fossé) and directly in the restored area (Drac in Saint Bonnet)
Physico chemical parameters	Measurements of physico-chemical parameters in situ, Macro Pollutant Analyzes by Agence de l'Eau	Punctual survey of all the physicochemical parameters (T°, O2, Conductivity and pH) on the 4 stations: Orcières, Pont du Fossé, Chabottes and Saint Bonnet en Champsaur each year + Continuous monitoring of those parameters at the control station and in the restored area.
Fishes inventory	Sampling fish stands by AFB Complementary measures on alluvial spawning grounds by AFB	Using AFB and Agence de l'eau investigations for the assessment of the evolution of the Drac River
Habitats and Riparian Dynamics	*No investigation*	mapping of the riparian habitats from Pléiades satellite images and aerial photographs + field investigations

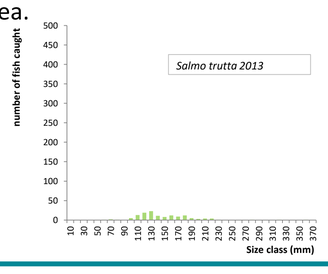
Hydro-biological results

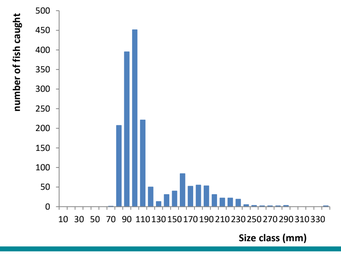
By improving the water quality due to a better water treatment, the taxonomic variety is better along the whole upper Drac section. However, this improving is much important in the restored area by the combine effects of better water quality and habitat recreation.





The comparison of fishes investigations shows an important increasing of the fish-populations of *Salmo sp* on the restorted area.

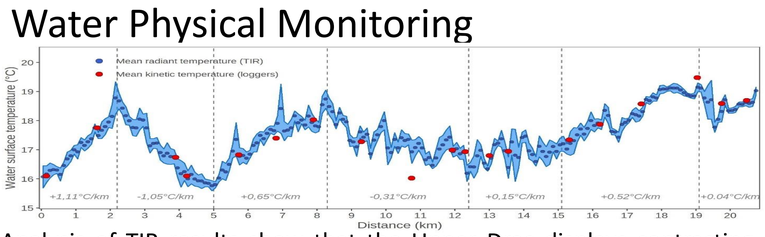




Riparian environments

Following the restoration work, the functional units diversified with the colonization of the unvegetated alluvial banks by pioneer and herbaceous vegetation. A strong spatial dynamic of the hydrological functional unit (water class) is observed: the erosive processes (exposed bars towards water) are partly compensated by the processes of deposits (water towards alluvium). A functional break is always present between the riparian fringe and the outer woody strip. Intermediate strata (herbaceous and shrubby) do not provide the successional relay (Gramond D., 2018).

Water Physical Monitoring



Analysis of TIR results show that the Upper Drac displays contrasting behaviors and that these are controlled by the density and characteristics of cold-water inputs. Temperature decreases in the 'reference' section but increases in the restored section despite both showing a braided morphology. The results show that the restoration has had no positive impact (not yet) on the thermal gradient.

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