River dynamics – at the origin of biodiversity and good ecological status

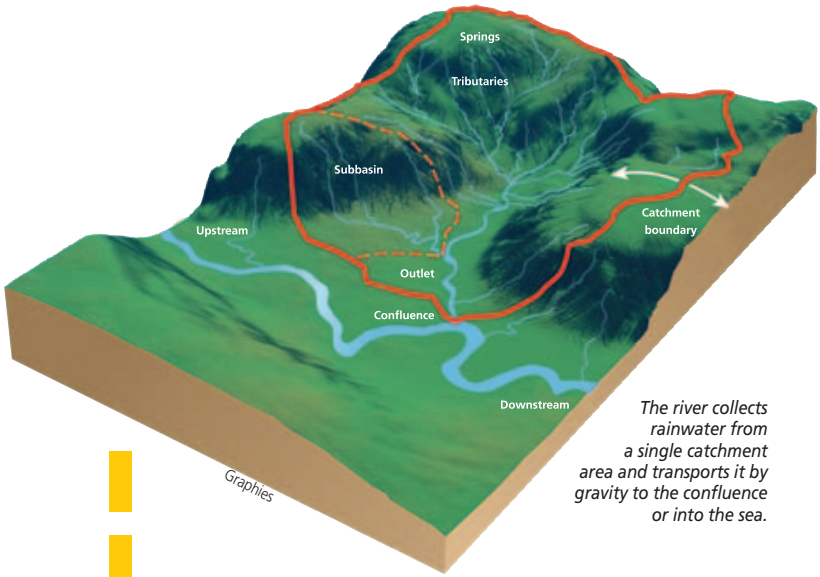
The main points:

- Rivers are heterogeneous environments which are dynamic and mobile in space and time.
- The effective functioning of rivers underpins the services provided by ecosystems: flood regulation, fertilisation of alluvial plains, biodiversity, etc.
- Regarding habitats, as the heterogeneity increases over space and time, so does the biological diversity and the spontaneous resistance to modifications and stresses, also referred to as "resilience".
- Respecting the river dynamics contributes to the achievement of good ecological status, as required by the Water Framework Directive.

By travelling the length of a river from upstream to downstream, season after season or after an interval of several years, one can observe modifications to the landscape and the associated environments. Evolutions of the form of rivers and their habitats are referred to as "river dynamics" and are explained by physical and biological phenomena. It is essential to understand river dynamics in order to preserve these phenomena which are one of the driving forces for the biodiversity of the river system.

The river – a physically dynamic system

A river is a system which collects and transports under the effect of gravity rain water and spring water downstream from a single catchment area. The gradient of the river and flow rate determine the energy of the system. The morphological diversity of rivers has not occurred by chance. It depends on the climate, geology and topography of the catchment.



The river collects rainwater from a single catchment area and transports it by gravity to the confluence or into the sea.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Examples of river morphology, from its source towards the sea. From top to bottom: the Ain (Jura): headwaters with a gorge bed; the Hulle (Ardenne): intermediate river zone with a sinuous bed; the Touques (Calvados): lowland river with a meandering bed; the Drôme (Drôme): lowland river with a braided channel.

The form of rivers is not fixed but evolves in space and time. Precipitation (conditioned by the climate), the geological nature of the substrate and the gradient (dependent on the relief) are important causes of the morphological adjustments of rivers. A combination of these three parameters governs the specific power of the river and determines its dynamics[1].

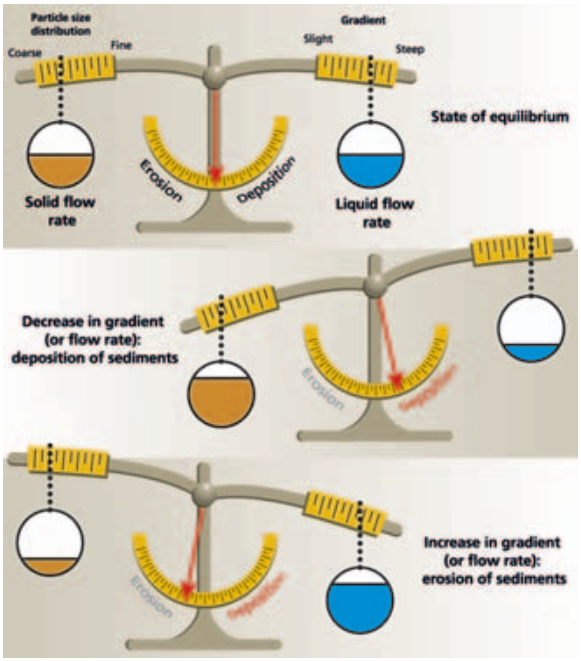
A system controlled by flow rate and sediment transfer

Any relatively unaltered river erodes, transports and deposits solid materials originating from the upstream areas of the catchment and from its banks which are subject to lateral erosion processes.

Erosion/deposition processes, influenced by the flow rate and gradient, help to create the longitudinal and transversal geometry of the main channel and its planform (referred to as the "river style"). Therefore, the amount of materials transported, the cohesive qualities of the riverbanks and the power of the river will dictate whether there will be a meandering bed, a braided channel, etc.

The liquid flow rate (Q) which varies according to the season and precipitation, and the solid flow rate (Qs), consisting of fine and coarse materials, are the source of erosion/deposition processes. They contribute to the morphological adjustments of the river.

A river operating in a dynamic equilibrium is characterised by regular fluctuations between erosion and deposition. This concept is shown by the Lane's Scale diagram *(opposite)*.



Graphies

Lane's Scale (according to E.W. Lane and W. Borland) illustrates the principle of the dynamic equilibrium of rivers. A river with a high liquid flow rate and/or a steep gradient becomes loaded with solid materials at a given point. When the liquid flow rate drops and/or the gradient decreases, the river loses energy and deposits the materials which it has been transporting up to this point. Fine elements are deposited at a slower flow rate than coarse elements. The river's longitudinal profile is stable when there is a balance between the sediments deposited and those being introduced.

Preferential erosion and deposition zones

Preferential erosion and deposition zones can be observed in all rivers.

In the bends of sinuous or meandering rivers, the outside (or "concave") bank is a preferential erosion zone due to the effect of centrifugal force, whereas the inside (or "convex" bank) is a preferential material deposition zone.

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1 : Outside bank, preferential erosion zone
2 : Inside bank, preferential deposition zone

1 - The specific power of a river is given by the product of the gradient of the river and its flow rate.

In the longitudinal direction, deposition occurs at changes in the gradient and in areas where the river bed has widened. The coarsest deposits form flow patterns called "riffles" (shallow, fast-flowing zones).

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Repeated sequence of riffles in three rivers of varying widths: the Allier (Puy-de-Dôme) – width of 30 metres; the Drugeon (Doubs) – width of 3 m and the Lambron (Calvados) – width of 1.5 m.

Successive areas of riffles and glides (slow and deep zones situated in concavities) alternate in the majority of sinuous or meandering rivers.

Riverbank protections (riprap, sheet piling, etc.) prevent rivers that have the capacity to increase their sediment load from actually doing so. In this case, the flow energy can no longer be dissipated by transporting the bed load. Instead, it is transferred downstream, aggravating erosion of the river bed or its banks.

Bare riverbanks and riparian vegetation contribute to establishing the morpho-dynamic balance of the river: relatively unconsolidated banks allow the river to increase its sediment load, whereas riparian vegetation ensures their protection against excessive erosion.

Main channels and floodplains shaped by flooding

A flood is a relatively sudden increase in the flow rate of a river, which generally results in a very visible rise in the water level. A flood is characterised by its recurrence interval (or return period). For example, the biennial flood Q2years has a one-in-two chance of occurring during the year and the hundred-year flood Q100years has a one-in-a-hundred chance of occurring during the year.

Morphogenic floods shape the river bed. While major floods (Q50 or rarer) make major modifications to the bed morphology, frequent but less intense flooding (every one to three years) is responsible for shaping the mean or "equilibrium" longitudinal, transversal and planform geometry of the river. The flow rates of these floods correspond closely to the bankful discharge in a river operating in a balanced state. This flow rate allows for the regular and efficient movement of coarse solid materials (the bed load), thus contributing to the regeneration of the alluvial environments in the main channel (river bed and alluvial banks which are exposed for some of the year).

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River with bankful discharge or morphogenic flood flow

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River with an overtopping flood flow. The main channel is delimited by the riparian vegetation.

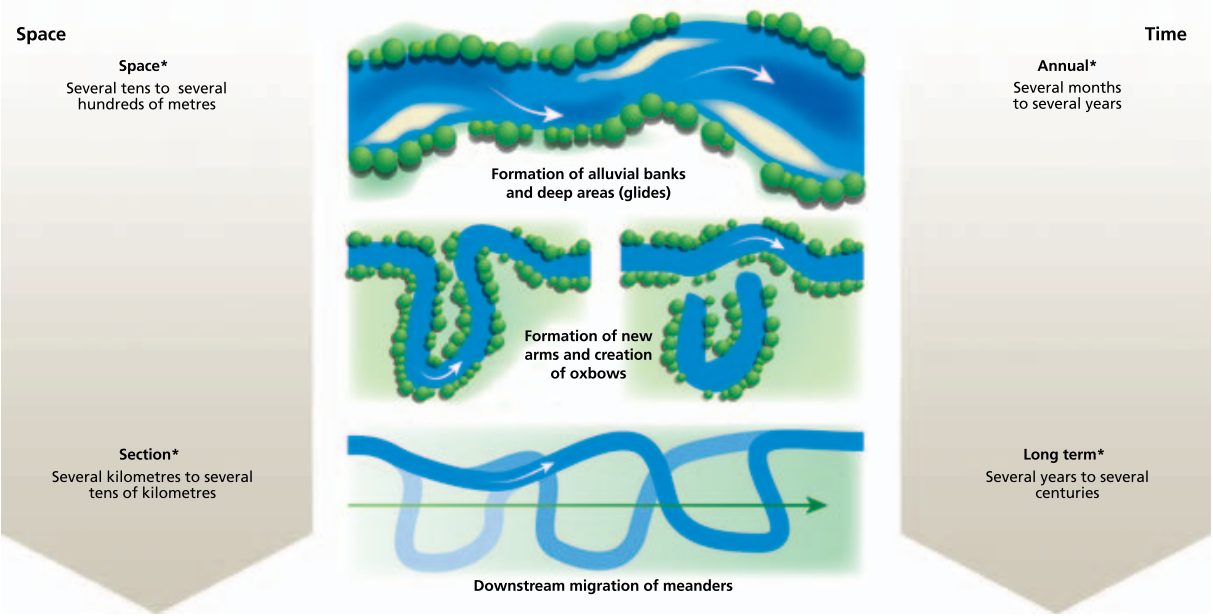
Flooding that exceeds the bankful discharge spills out into the floodplain and contributes to the efficient operation of alluvial plain ecosystems. Floods contribute to supplying water to side arms, and recharging the water table, purifying water and bringing fine materials and fertile elements into the alluvial plain, which plays an important role in storing flood water, and reduces the maximum flood flow rate downstream.

For further information about the services provided by ecosystems, read the information sheet: "Why restore? – Many services to society depend on the quality of aquatic environments".

The river – a dynamic system

The main channel of a river, under the influence of river flow and sediment transfert, is often in a state of flux. Alluvial banks are formed and then swept away by floods, glides are formed, new arms are created while others are abandoned, and meanders migrate. The regular evolution of river bed morphology is referred to as the "dynamic equilibrium" and is evidence that the river is "doing well" from a hydromorphological point of view. This natural mobility varies according to different scales of space and time, which can be referred to as the spatio-temporal dynamics (see diagram on the following page).

From the spatio-temporal dynamics originates the need to maintain a dedicated area in which the river can evolve. This is referred to as the mobility area on active or potentially active rivers, i.e. on rivers with frequent morphological adjustments, or referred to as the functionality area on others. This area guarantees the efficient operation of the river system in the long term: dissipation of the river's energy by adjustment of the gradient, sediment



Graphies

Spatio-temporal dynamics of the river, showing the river dynamics.

loading due to the erosion of river banks, creation and regeneration of associated environments (oxbows), exchanges with the water table, stability of the bottom of the main channel (reduced risk of incision), etc.

For further information about river hydromorphology, read: "Eléments d'hydromorphologie fluviale", JR. Malavoi, J.P. Bravard, published in 2010.

The river and its corridor – an area of biodiversity

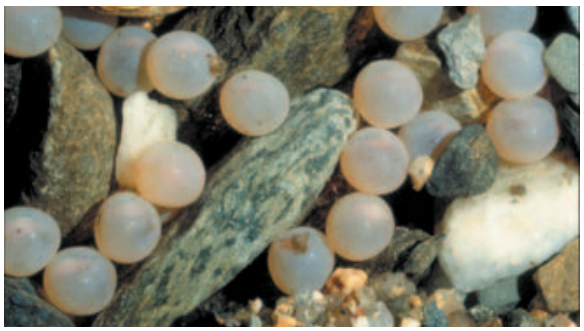
River morphology is the result of river dynamics. This morphology results in a mosaic of aquatic and river habitats for numerous plant and animal species.

The morphology and hydraulic regimes evolve very markedly from upstream to downstream sections. Macrophyte (aquatic plant), fish and invertebrate species are consequently very different in the headwaters and downstream reaches of rivers.

The main channel

The nature of the biological populations in the river depends on the heterogeneity of the main channel. Fish, according to their daily activities (feeding, resting and reproduction), or their different stages of development (egg, fry, adult), often require a range of habitats in the river. These habitats are mainly characterised by the depth of water, flow velocity and size of granular material, and these parameters characterise the flow patterns: riffles, glides, runs, rapids, cascades, etc. Certain fish make daily journeys of several tens of metres to several hundred metres between these different flow patterns. For reproduction, the journeys may be significantly longer.

On the other hand, alluvial banks, which are exposed for part of the year, form habitats for certain terrestrial animal and plant species. These include resting, nesting and hunting areas for certain birds.



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Example of habitat in the main channel required for the reproduction of certain species: loose gravel sheltering sea trout eggs, which provides suitable conditions for oxygenating the eggs.

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Example of exposed habitat in the main channel with species that may be associated with it at a certain time of day: cormorants on an alluvial bank which acts as a rest area.

River banks and riparian vegetation

River banks and riparian vegetation are sources of the diversification of the aquatic and riparian habitat. Riparian vegetation facilitates the introduction of dead wood and organic matter into the river. Its root systems provide reproduction areas for certain fish and invertebrates. Its exposed parts are favourable to mammals and birds. The river bank, according to its geology and nature, may also form a habitat, especially for birds such as the sand martin and the kingfisher.

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Example of a species nesting in the banks of certain rivers: the sand martin.

Interface between the main channel and the river bank

The river bank forms an interface zone between the water and land. This transitional zone is extremely rich at the biological level. Invertebrates, which feed on organic debris and/or micro-organisms, benefit from more favourable conditions for development, thanks to the more abundant supports – tree roots, dead wood, higher aquatic plants and semi-aquatic plants - which provide habitats for food resources. Fish and crayfish hide in shelters under banks, thus avoiding predation.

Side arms

Side arms, whose quality depends on the river dynamics (overflows and connections with the main channel), are essential habitats for certain species. Flooded meadows are also favourable to the reproduction of certain fish species such as pike and amphibians such as the common frog. These zones are also exploited by birds, including migratory species such as the corn crake, which find their food and breeding sites in these zones.

For further information about the upstream and downstream distribution of species, read the information sheet: "Types of rivers".

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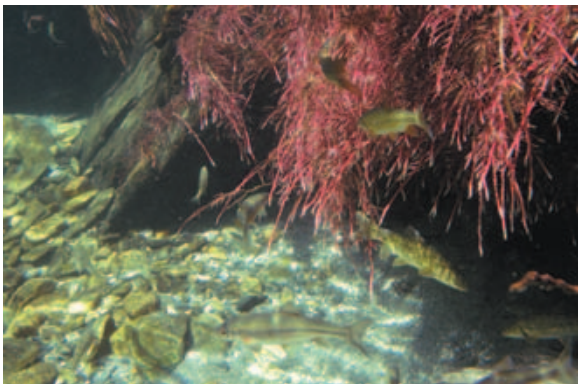

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Examples of submerged habitats in the main channel, occupied by aquatic species at different stages of their development or daily cycle. From top to bottom: stone blocks forming a shelter for a «white-clawed» crayfish; aquatic invertebrate larva seeking food in the gravel; root system at the base of a riverbank used as a hiding place by a community of fish.

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Example of an exposed habitat in the main channel and a species with which it may be associated at a particular time of the day: an otter lying in wait on woody debris.

The aquatic and riparian corridor

On a larger scale, the river and the riparian strip that line it form corridors which allow for the movement of certain species over long distances by water (migratory fish and semi-aquatic mammals) or by land and air (birds, bats and semi-aquatic mammals). They thus contribute to the diversity and quality of the aquatic environment and riverside land.

These movements mean that any conditions found locally must also exist at the scale of the entire river system (river, corridors and flood plain). The riparian corridor is a key component of the "Trame verte et bleue" (Green and blue infrastructures) of the French "Grenelle 2 Environnement" Act adopted in August 2009.

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Examples of species adapted to aquatic environments, carrying out their essential activities in side arms. From top to bottom: common toads reproducing in a side arm; male emperor dragonfly feeding on a sympetrum; jack-pike in the vegetation of an alluvial meadow; European pond turtle (endangered species) resting on dead wood in an oxbow.

For further information about corridors:
CSPNB (2008). "L'arbre, la rivière et l'homme", MEDAT ID4E:64, downloadable from the following address: http://www.ecologie.gouv.fr/L-arbre-la-riviere-et-l-homme.htm/

Obligations of the Water Framework Directive and the "Grenelle de l'environnement" (French Environmental forum)

The Water Framework Directive (WFD) aims to achieve a good standard of quality for European water. In addition to the chemical quality of water, its targets are the biological quality of water and river continuity. The re-establishment of the biological balance and biodiversity means restoring a functional level approaching what may be termed the reference status i.e. prior to their disruption.

Biological systems are conditioned by the structure of the physical environment. The re-establishment of a river's morpho-dynamic operation will help to improve its ecological status, as required by the WFD. This will also contribute to restoring river continuity in watercourses and improving the operation of the ecosystems and ecotones which promote diversity.