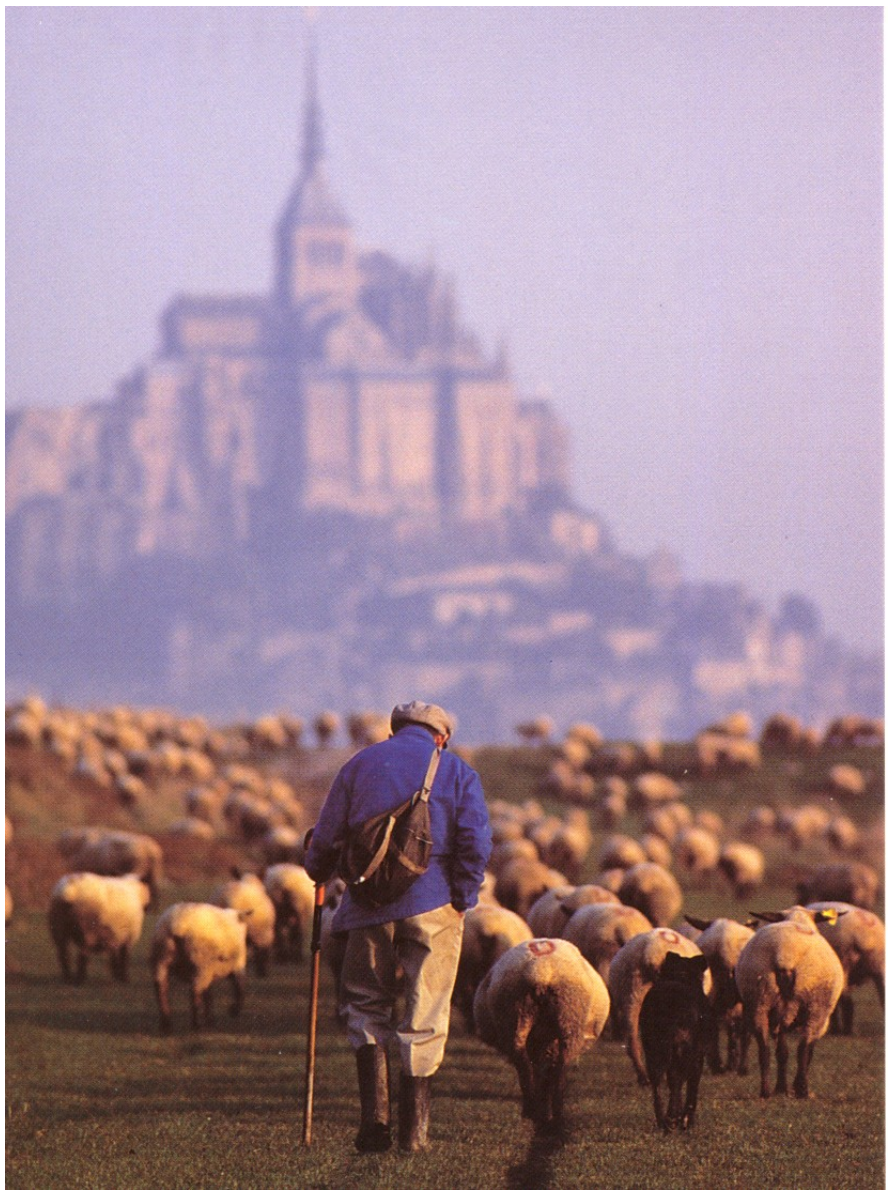
WATER IN CELTIC COUNTRIES
Guimaraes, Portugal, July 11-14, 2005

EXCHANGES BETWEEN SYSTEMS : FROM RIVER CATCHMENT TO COASTAL MARINE WATER



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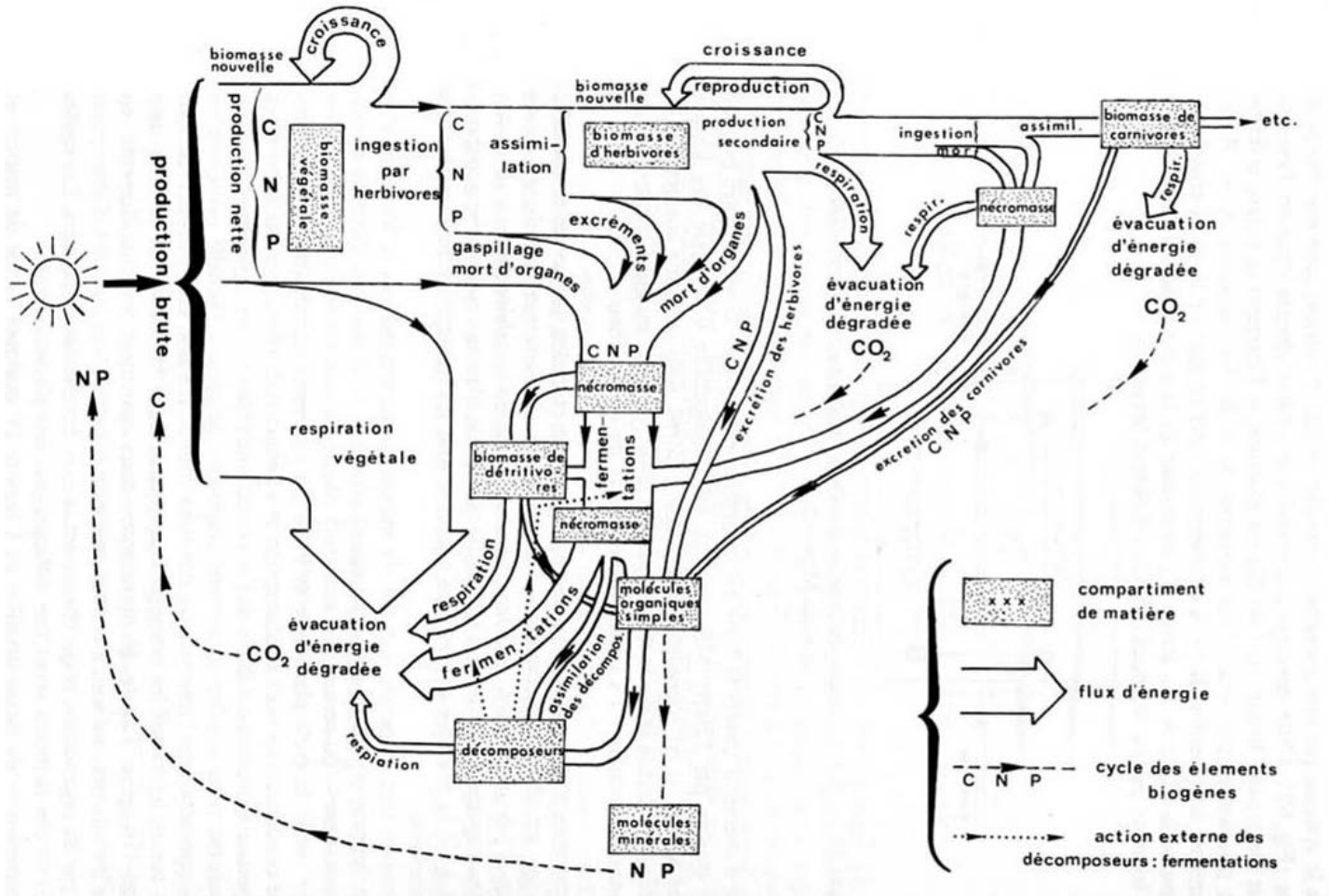
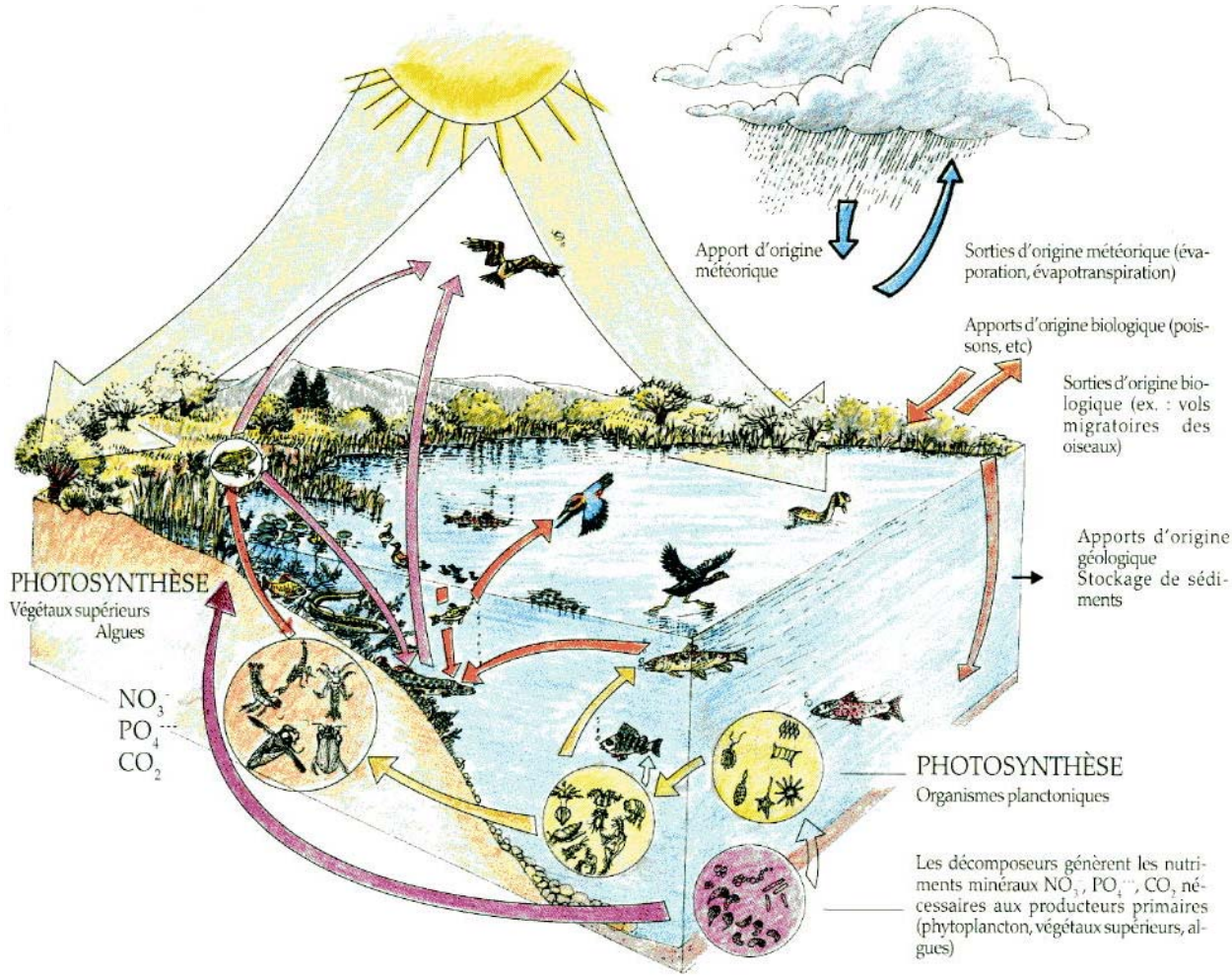
Since Haeckel, 1866, the aim of ecology was to understand the strong relations linking organisms to their physico-chemical environments

“Ecosystem” defined by Tansley in 1935 is the basic concept of Ecology.



During many years thanks to hydrobiologists as Forel (1895, research in Leman Lake) and particularly Lindemann (1942, comparative study of three lakes), ecologists have emphasized a large number of useful studies on the flow of material and energy inside ecosystem.

These studies described how the energy, that initially comes from solar radiation captured by plant (photosynthesis) is used by all the consumers of the trophic network of the ecosystem.



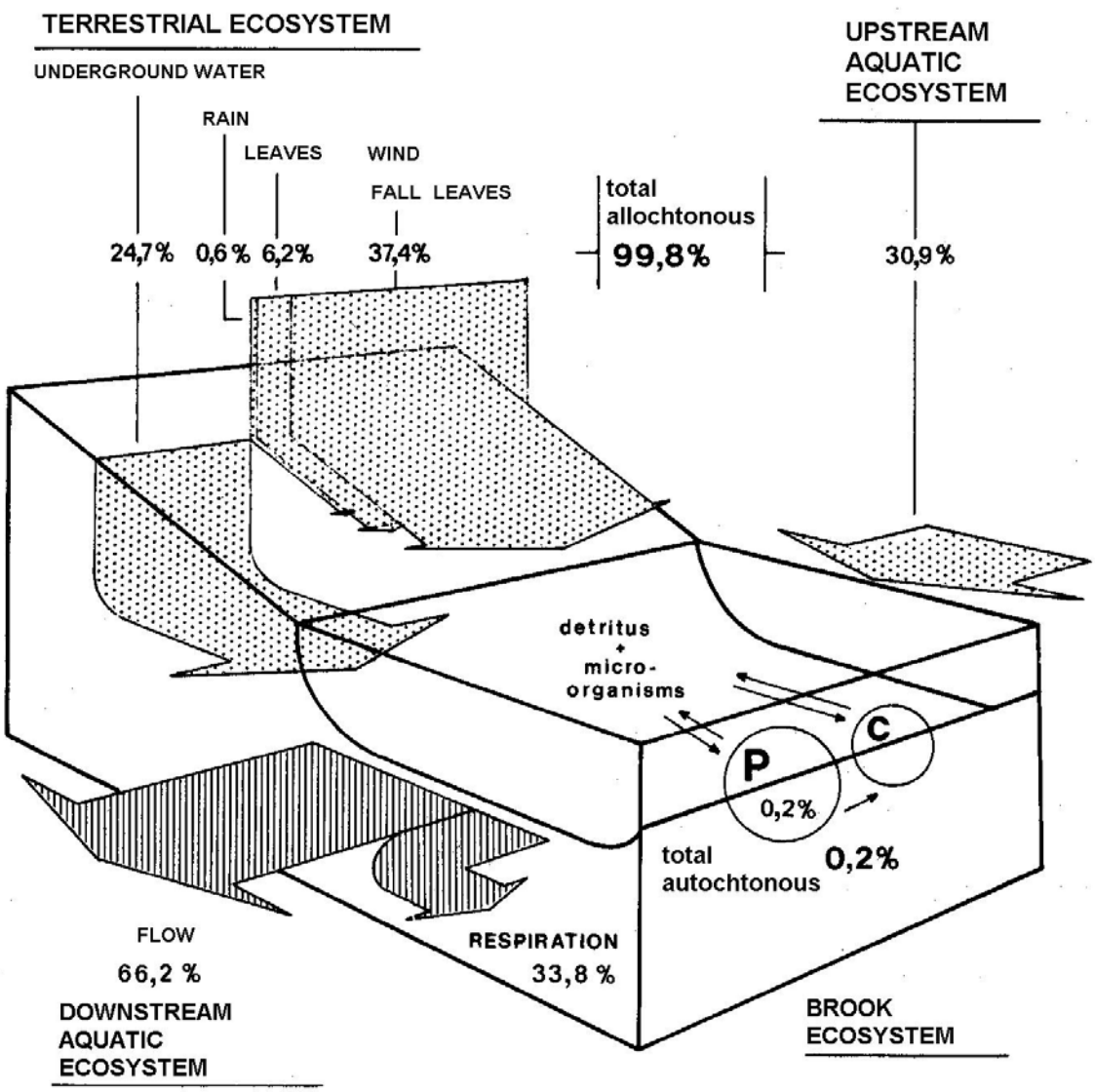
The concept of « coupling system » (Hasler, 1974), also developed by hydrobiologists is a real progress in the « ecosystem approach ».

It points out the fact that ecosystems are associated in a complex of ecosystems. It promotes the idea that there are exchanges between terrestrial and aquatic ecosystem and that it is necessary to develop research on the mutual benefits of the exchanges for each component (terrestrial and aquatic) of these complex of ecosystems.

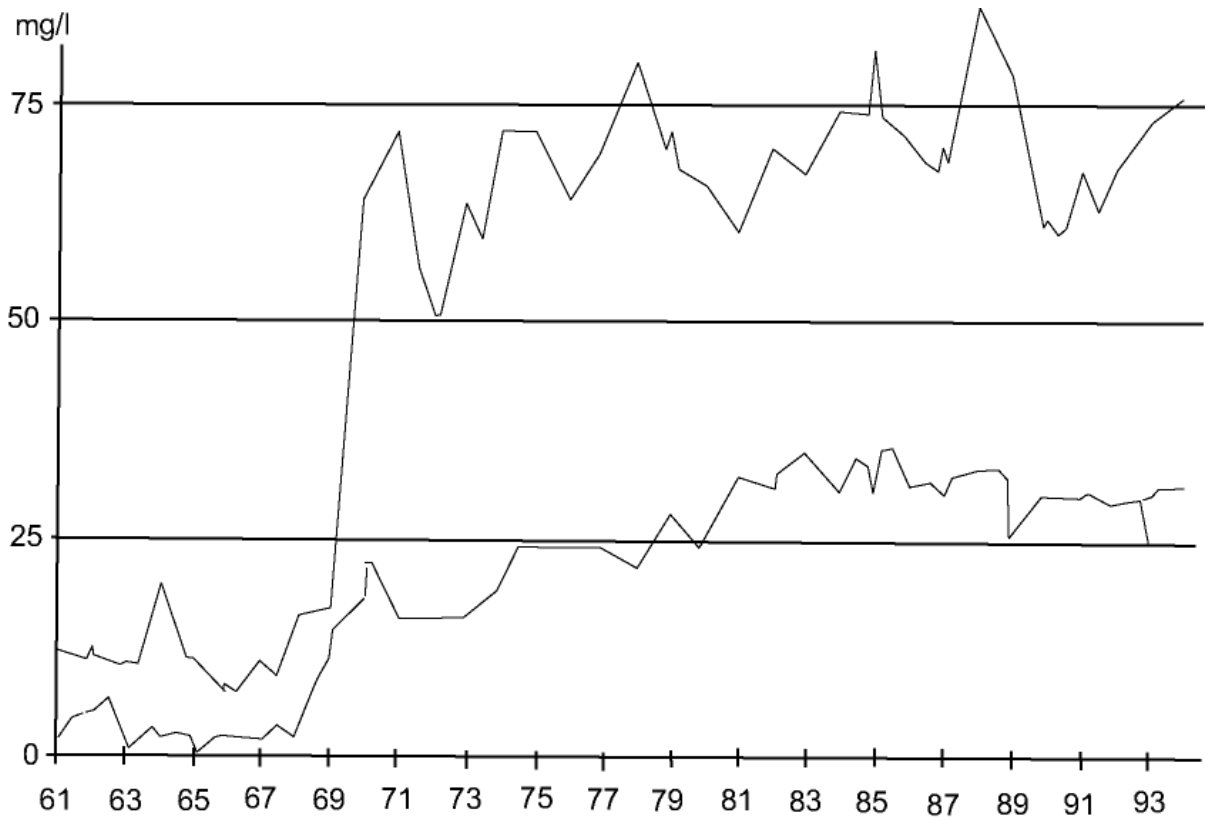
Nauman (1921) was one of the first to realize the importance of the drainage basin as a source of nutrients for lakes. The amount of available nutrients exported by the catchment determines the « trophic state » of lakes (oligo, meso, eutrophy).

But one of the best papers promoting the concept of coupling system is that of Teal (1962) on the energy flow in the salt marsh ecosystem of Georgia (USA).

Teal showed that 45% of the high salt marsh's plant production is exported in estuarine water.
Suggesting that the salt marsh produces more material than can be degraded or stored within the system and that the excess is exported to coastal marine waters, Odum (1980) proposed the « OUTWELLING HYPOTHESIS » as a new approach to explain – together with the upwelling concept – the ocean productivity.
He said at this time « the salt marshes are the richness of the ocean ».
The "coupling system" concept was extended to rivers on the basis of Likens research (1970). Z One of the major conclusions of a study comparing a forested area with an inforrested area of a river basin, was that, as a schematic view of energy flow in a riversystem, in forested areas, 99,8% of diverse inputs are due to allochtonous production.



The result of the experimental researches developed by Likens lead to consider the consequences of changes in land cover and land use of the catchment basin on the importance of transfer of nutrients, pollutants and energy to river.
The link between changes of agricultural practices and nitrate load in water was rapidly understood in France.
In the region where agriculture is most intensive nitrate loads increased the most (Concaret, 1976).



Nitrate load evolution in water catchment since 1962 (Yone country, France) (from Chrétien et *al*, 1974)

Among the principal causes of such trends we may outline the clearing of rivers, riparian areas and catchments, and the extension of maize culture associated to nitrate fertilization and bare soils in winter (Lefeuvre, 1970).

The natural systems (riparian forests, wetlands) and developed systems (wet meadows) represent efficient filters for nutrients and contaminant transported by runoff and surface waters toward rivers.
Thus the retention rates of nitrogen compounds reach up to 80% in an alluvial forest where they are only 8% of neighboring cultivated meadows (Peterjohn et Corell, 1984).

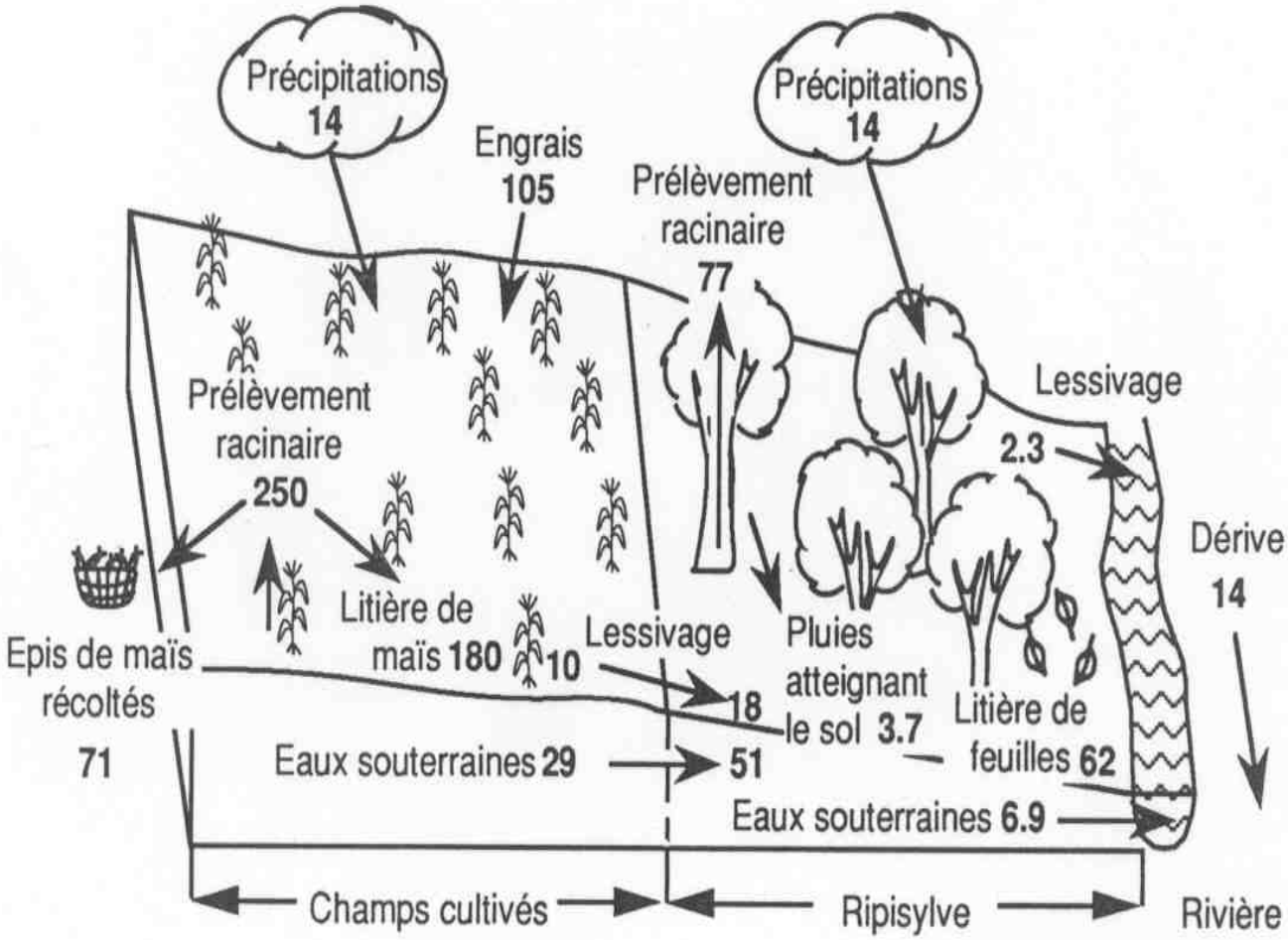
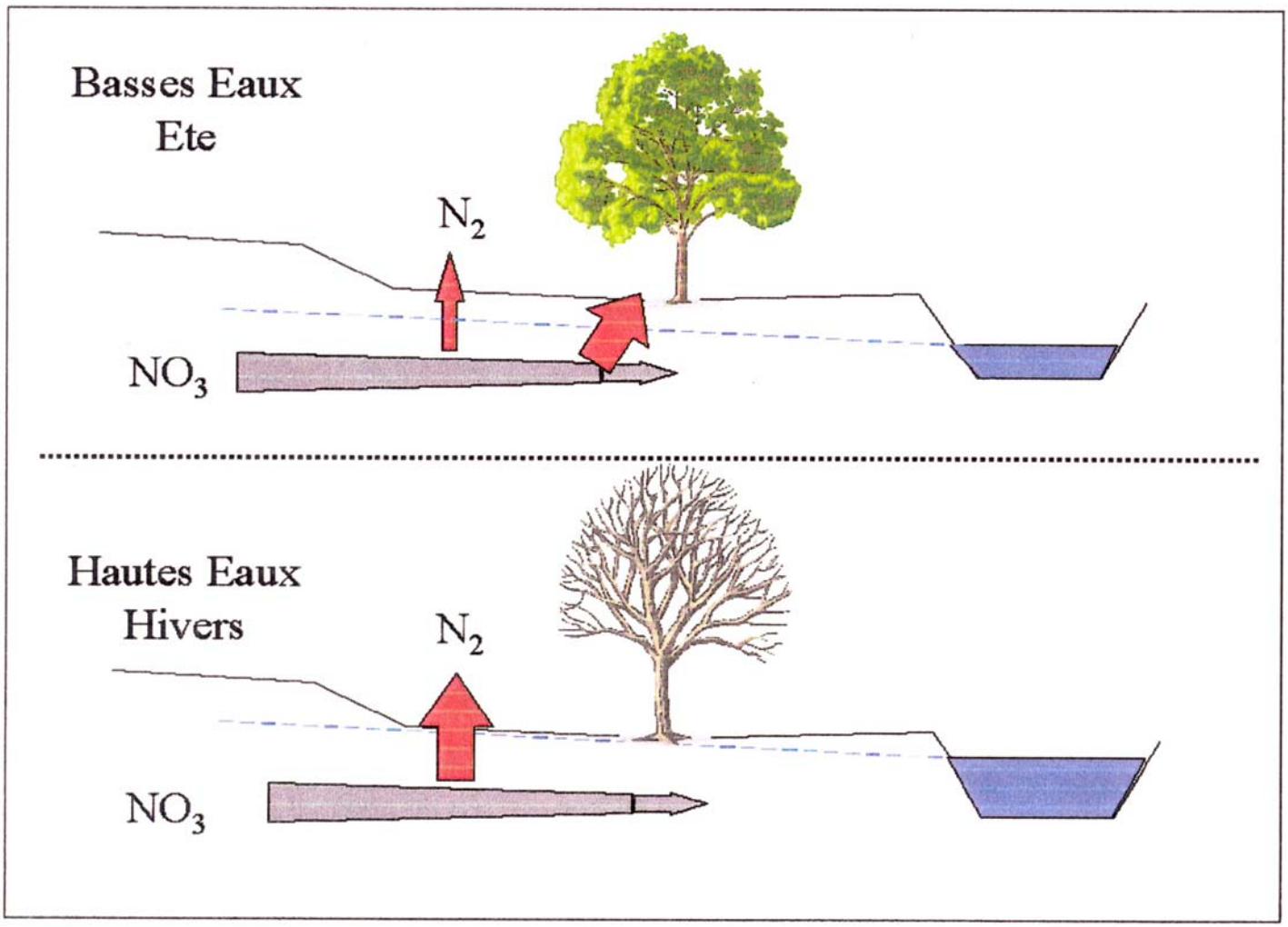


Diagram of flow and total nitrogen cycle in a catchment basin (Rhône River) (from Perterjohn and Correll, 1984).

Pinay (1986) assessed that the denitrification capacity of alluvial forests of Garonne River was about 50 mg/m2/day of nitrogen. In general riparian vegetation stores nitrogen during the growing season and release it as litter which will then be mineralized.

Nitrate produced in such way is available for denitrifying micro-organisms during high water of the end of the winter or beginning of spring.



In 1985, we tried to integrate all the new international knowledge to understand the functioning of a bay in relation with the inputs from continental river discharge. For that, we selected the Mont-Saint-Michel Bay.

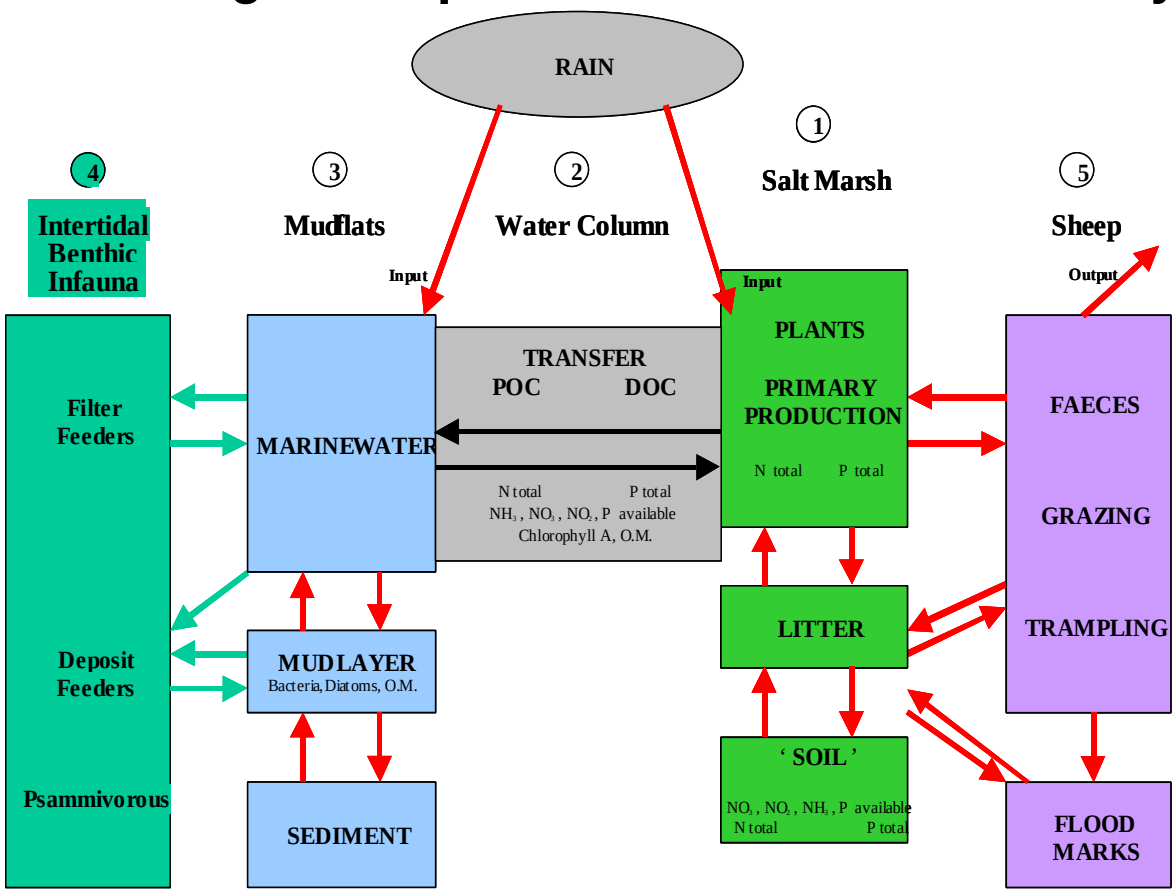
The surface of this bay is about 500 km² including 250 km² of mudflats and sandy sediments and 50 km² of salt marshes and 150 km² of polders. This bay receives the water of three main rivers systems, the catchment covering a total of 3352 km².

Image Spot 1999 traîtée par J. Le Rhun (UMR PRODIG)

« How is it possible to produce 12 000 tons of mussels, 6 000 tons of oysters and to host about 50 000 waterfowls birds during winter time when the waters of this bay are so turbid and well mixed that the net production of phytoplancton is near zero?»

Using Teal's research we focused on the role of salt marshes to produce organic matter and to balance the lack of phytoplancton production.
The conceptual model we used was quite different from those used in USA because the European salt marshes slightly differ from the American salt marshes and also because in the Mont Saint Michel Bay parts of saltmarshes are grazed by sheep.

A CENTRAL SCIENTIFIC ISSUE ?
Outwelling concept : in Mont Saint-Michel Bay

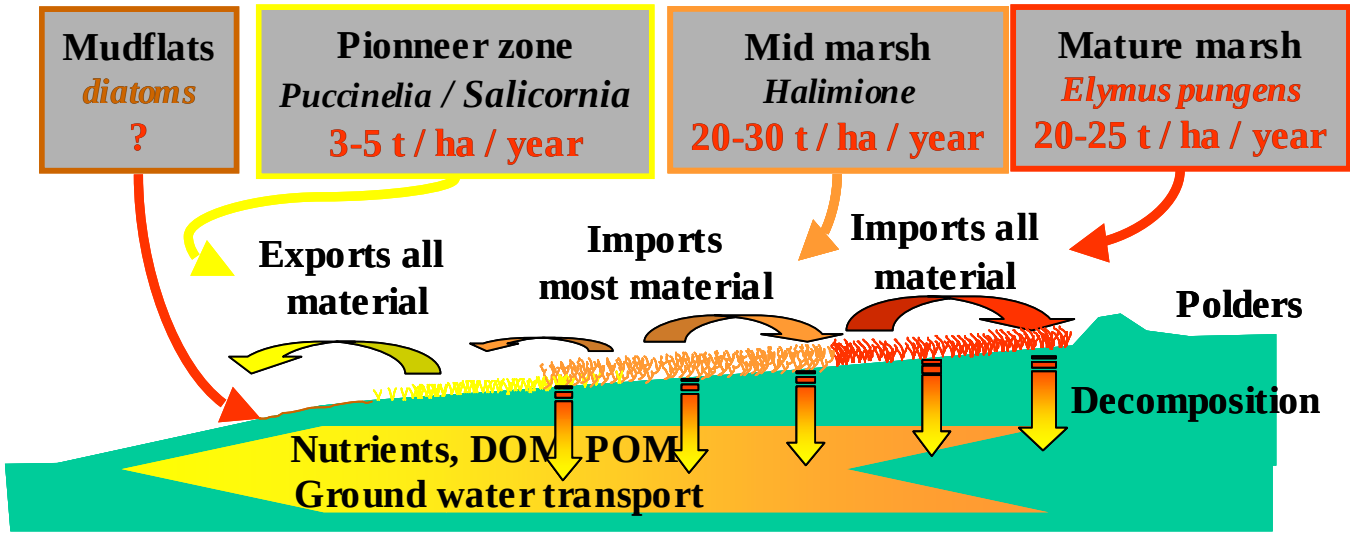


Primary production of natural and grazed salt marshes and exchanges with mudflats and marine coastal water.

In natural situation, the immature marshes (low marshes) have a low productivity. The higher productivity occurs in the middle marshes where the main species *Atriplex portulacoïdes* produces between 20 T/ha/an and 36 T/ha/an.

The productivity is also very high in the high marshes where *Elymus aethericus* and *Festuca rubra* are the dominant species (mature marshes). The young immature marshes are flood dominated systems where there is a net import of sediment and a net export of organic matter. Mature marshes and especially middle marshes are also ebb dominated and are net exporters of organic matter (DOC and POC) and nutrients.

Production of organic material & integration into the food web



Integration into the food web

- *Orchestia gammarellus*
- *Mytilus edulis*
- *Macoma balthica*

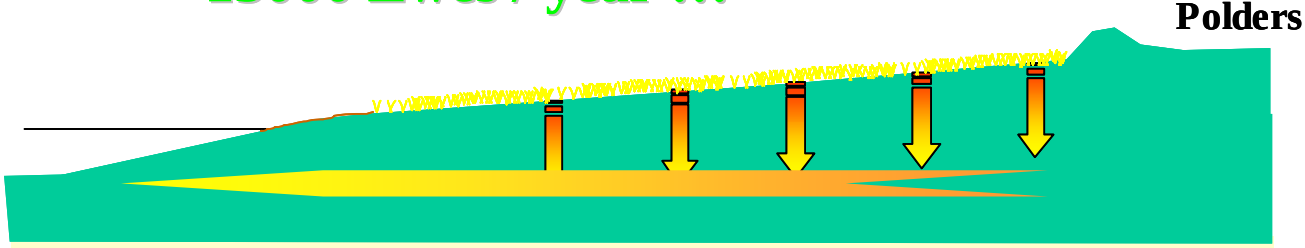
Globally,

Importation of organic litter

Export of Organic Matter & Nutrients

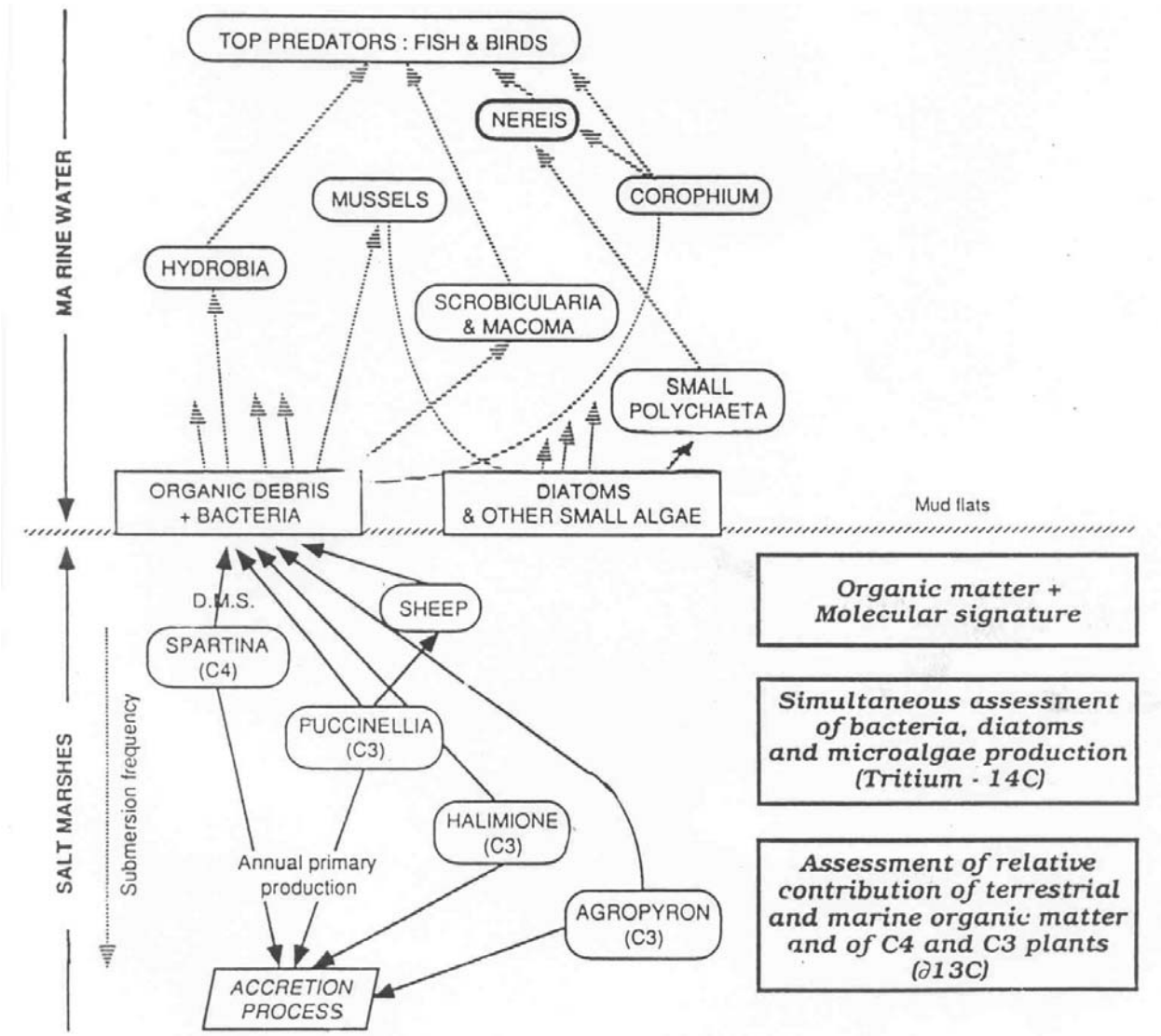
Effects of cattle grazing

13000 Ewes / year …



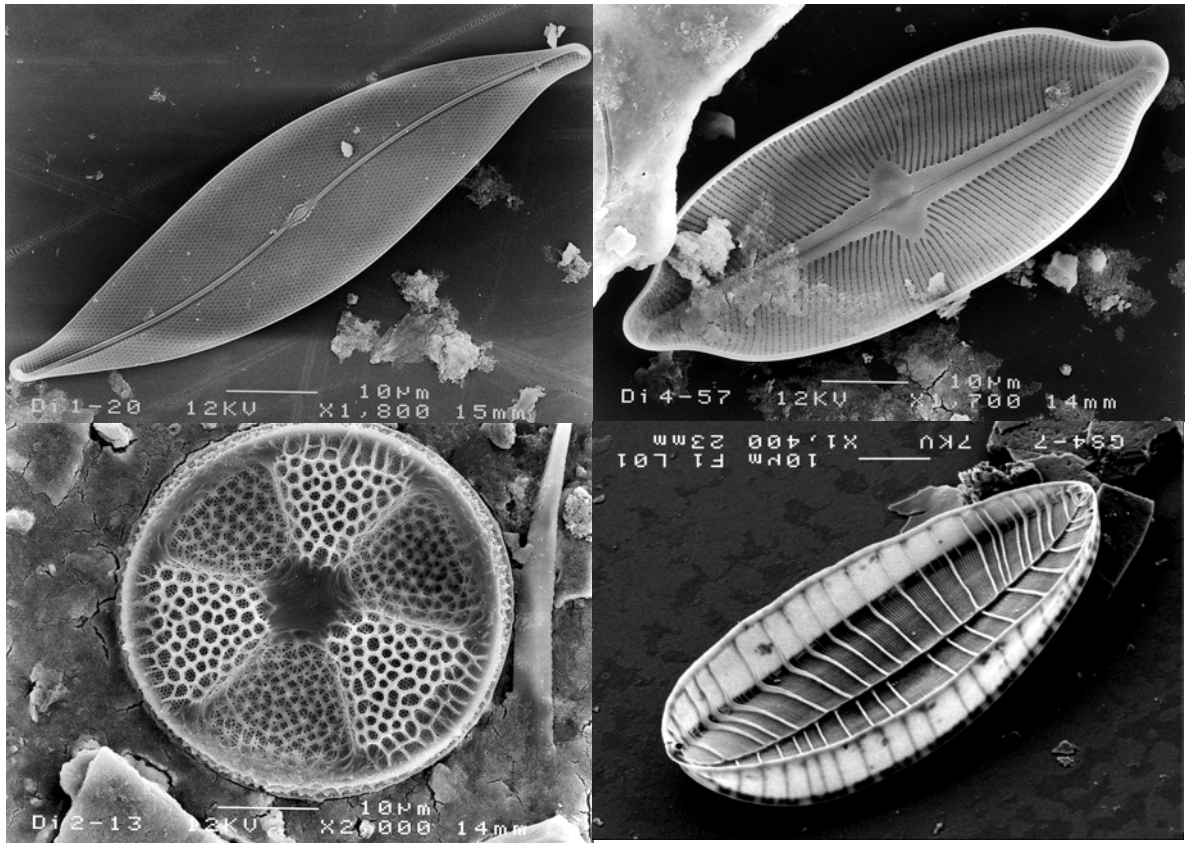
The grazing reduces productivity and outwelling function of salt marshes.

The use of stable isotopes and biomolecular fingerprints as fatty acids and osmoticum shows that the organic matter produced by salt marshes can be directly consumed by marine invertebrates.



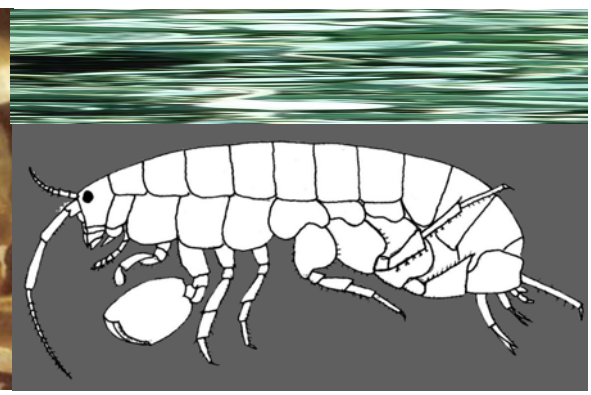
Some of the organic matter exchange processes studied in the Bay of Mont Saint Michel.

This organic matter and nutrients also contribute to the enrichment of mud flats. This enrichment allows the development at low tide of microphytobenthos (diatoms) that are used by deposit feeders. At the flow the superficial zone of mudflats and diatoms are removed, dispersed in the water column and used by filter-feeders as mussels and oysters.

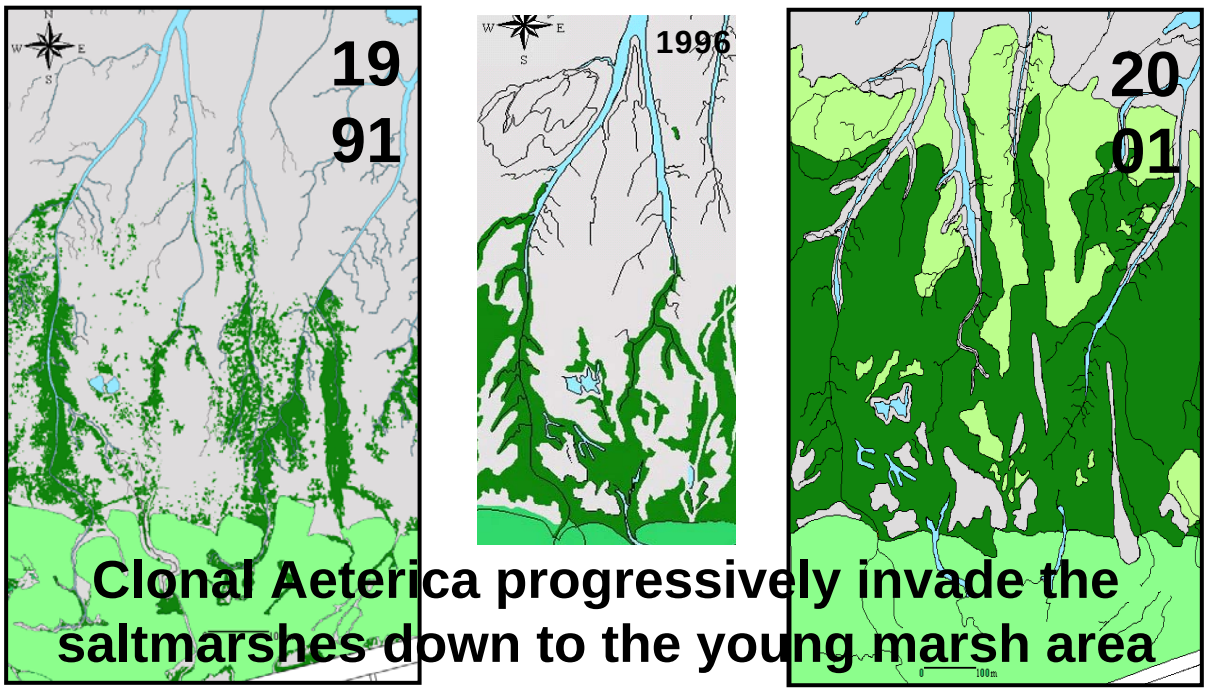


The exchange between salt marshes and marine water is completed by transfer of organic matter by fishes as mullets and sea-bass.

Sea-bass juveniles invade creeks and saltmarshes at the flow. During this flood period, many of them arrive with an empty stomach and leave salt marshes with a full stomach: the main food item is the crustacean *Orchestia gamarellus* which forage *Atriplex* dead litter.



During the past ten year, a new problem appeared : the spread of the native clonal grass *Elymus aethericus*. Formerly confined to the high marsh, this species is progressively invading the middle and low marshes. This invasion mainly leads to the replacement of *Atriplex portulacoïdes.*



Surface du schorre non occupée par le chiendent

Nombreux îlots d'*Elymus athericus* en front d'invasion

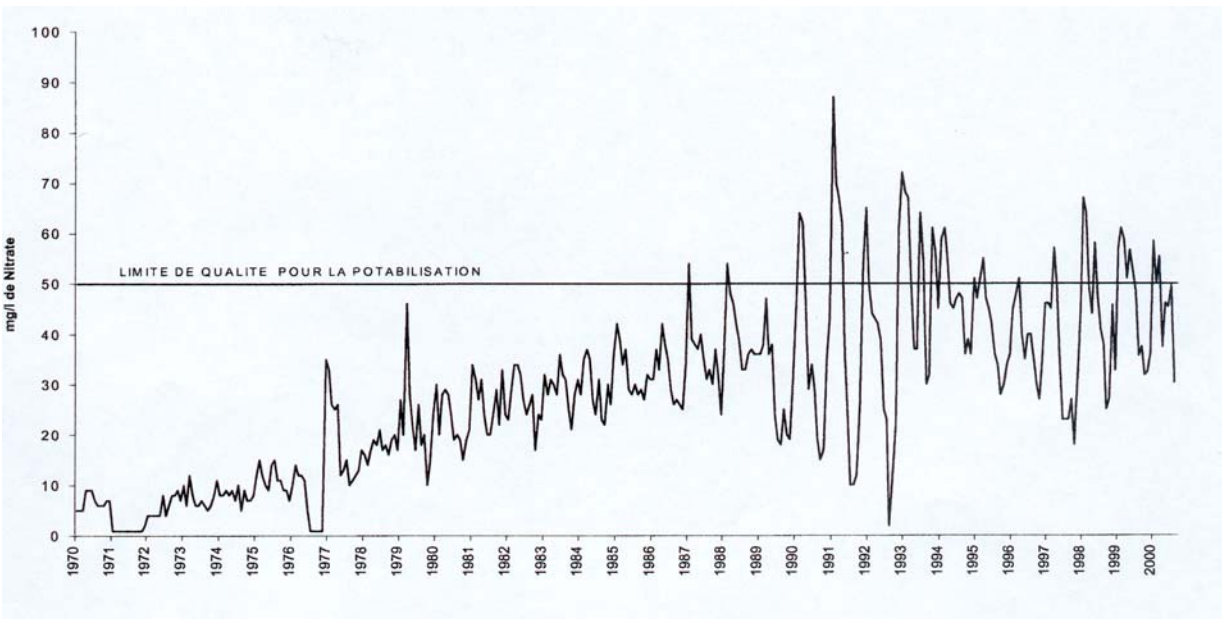
Groupement monospécifique dense à *Elymus athericus*

Zone fauchée à *Elymus athericus* (75%) et *Festuca rubra* (25%)

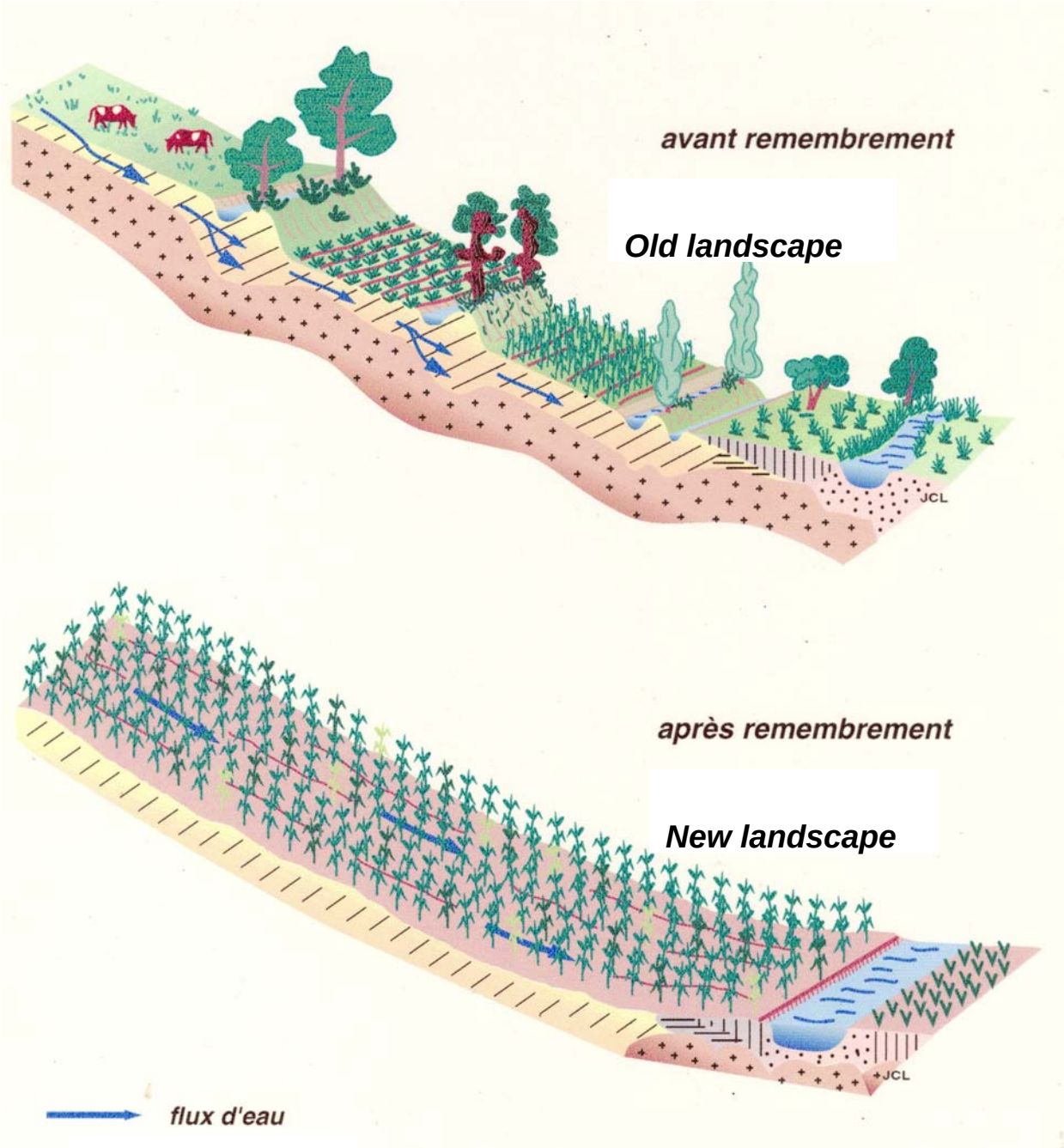
Because of its greater lignin content, the litter of *Elymus* decays slowly and the high production of this plant is trapped inside the marsh.

Several functions of the salt marsh may be modified by such an invasion and especially the exportation capacity.

Laboratory experiment shows that the amount of osmoticum produced by *Elymus* increases when the plant is frequently flooded. This increase is proportional to the load of nitrate in the sediment. So, this invasion could be mainly due to eutrophication of the coastal water by rivers as The Couesnon.

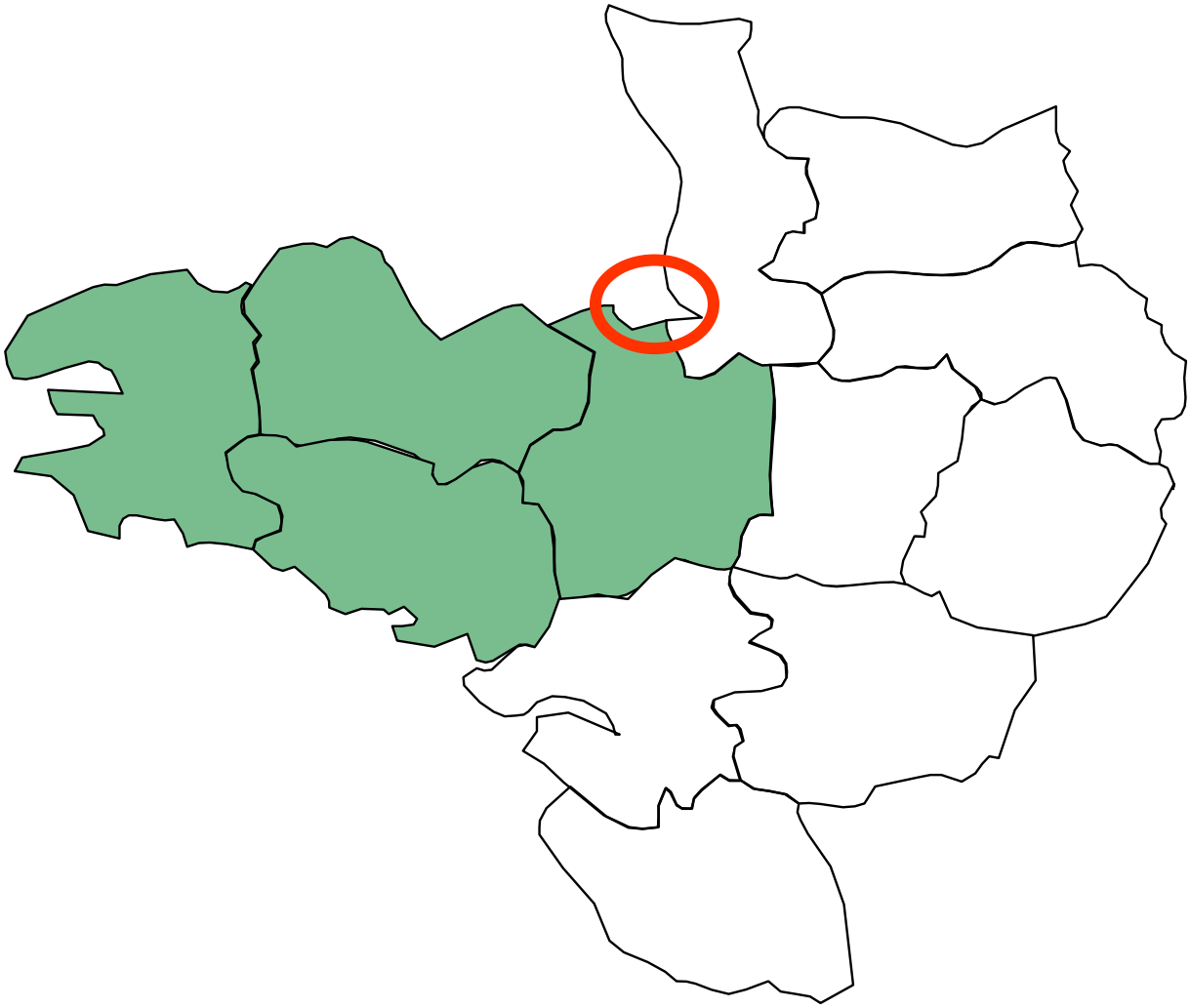


In The Couesnon river the loads of nitrate have increased regularly since the 1970’s and loads over 50 mg/l are regularly recorded since the 1990ies.
This is related to the clearing bocage and intensification of agricultural practices in the catchments.


avant remembrement
Old landscape
JCL
après remembrement
New landscape
JCL
flux d'eau

Water flow

All these researches show how the ecosystem balance of a littoral system can be disturbed or even compromised by the increase of one category of usage supported by lobbies. The littoral economy is based upon the direct or indirect exploitation (fishery, shell culture, tourism, cattle breeding, hunting, etc) of the primary productivity of the saltmarshes and related mudflats. The development of intensive agriculture that takes no account of the environmental issues regularly destroy the integrity of the land ocean biogeochemical and water transfers. Many key role system as wetlands, hedgerows, permanent meadows are destroyed and cannot play any role in the control of part of the excess of nutrients produced by cattle, pork and poultry intensive breeding and intensive agriculture. These findings were largely demonstrated in a region like Brittany by considerable research on landscape ecology in bocage systems.



Despite a considerable research effort and knowledge production to explain how and why our freshwater and marine resources decline continuously, it is disappointing, if not dramatic, to realize that the behavior of politicians, decision makers, food industries, farmers has not changed during the last 30 years. That's why Brittany is now considered at the international level as the model of what we should not be done in terms of environmental management.

The authors thank Alain Radureau (Zone-Atelier La Baie du Mont Saint Michel et ses bassins versants)