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***"Planting trees and seeing them grow seems to me a great happiness.
The peace wich our souls are hungry for,
the peace that all men caress as supreme good in a futur world,
the peace that I can only enjoy here, far from the noise of cities!
Giuseppe Garibaldi"***

Written accompanying the ancient Italian stone pine (*Pinus pinea* L.). The flag tree or banner tree, carved and anemorphosed by the sea winds, that General Garibaldi planted in Island of Caprera, during February 16-1867, the day of the birth of Clelia, the first of the children he had since his last marriage with Francesca Armosino.

***"Planter et voir grandir des arbres me procure une grande joie.
La paix que nos âmes envient,
la paix que tous les hommes caressent comme un bien suprême dans un monde futur,
je ne peux que la ressentir uniquement ici, loin du bruit de la ville!"
Giuseppe Garibaldi***

Écrit qui accompagne l'ancien Pin Pignon (*Pinus pinea* L.). Arbre drapeau, sculpté et anemomorphosé par les vents marins ; que le Général Garibaldi a planté sur l'Île de Caprera lors du 16 février 1867, la date de naissance de Clelia, le premier des enfants qu'il a eu de son dernier mariage avec Francesca Armosino.

***"Il piantare e veder crescere gli alberi mi sembra una grande felicità.
La pace che è fame delle anime nostre, quella pace che tutti gli uomini carezzano come bene
supremo in un mondo futuro,
io non la gusto che qui, lontano dal fracasso delle città!
Giuseppe Garibaldi"***

Scritto che accompagna l'antico Pino domestico (*Pinus pinea* L.), a bandiera, scolpito e anemorforato dai venti marini, che il Generale Garibaldi piantò a Caprera il 16 febbraio 1867, giorno della nascita di Clelia, primogenita dei figli avuti dal suo ultimo matrimonio con Francesca Armosino.

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1. INTRODUCTION

1.2 Preamble

Europe's natural habitats are increasingly deteriorating and related wild species are threatened. This negative trend is the result of our needs, linked to the society development issues (economic growth, urbanization, deforestation, human population growth, pollution and soil uses). This, although the development of many national and international policies on environmental issues that let us to pay more attention to the environment also in urban and territory planning (CLERGEAU & BLANC, 2013); or to the point that the same areas could undergone under several protection measures at the same time (LALANNE, 2017).

Policies and actions evidently are not always effective due to the incomplete knowledge, bias, or exploitation of the environmental conservation issues.

This makes possible to understand how the amount of protection measures not always make the difference. The most important value is the quality (efficiency and effectiveness), not the quantity of these measures per surface. The quality of protection measures depends to the evolution of the scientific concepts and point of views; and it is propaedeutic to the knowledge of the territory. To foster the quality of these measures (policies, actions, projects, etc.) it is strictly necessary to improve the knowledge of the territory (observations, and descriptions) by the study of environment issues and related biodiversity issues: i.e.: distributions, impacts, status, heritage, productivity, threats, dynamics (natural, anthropogenic and mixed), and monitoring the effects of the measures carried out.

The “know-how to better manage” motto in vogue especially from 70s, remains a valid concept, since the success in the natural environments management can only be achieved looking for an increasing knowledge of the environment (BIORET, 2003) as underlined by LALANNE (2017). The notion summarized by this motto was developed after the setting up of the protected areas institution, landscape conservation policies, biodiversity protection actions, and by some international agreement like the Ramsar convention (1971), the “Birds” EU Directive (1979) the EU Natura 2000 network and the related “Habitats” Directive (1992).

Since the early 2000s, in the framework of the implementation of the Water Framework Directive. (2000/60 / EC), the study of Macrophytes was recognized as environmental evaluation tools by the European community, underlining the importance of plants and vegetation as bio-indicators.

These, combined with further initiatives impose to the European community member states a periodic evaluation of the conservation status of populations, species and habitats of Community interest: increasing the needs to know the Landscape and the environment characteristics, together with the needs to describe the territory biodiversity. This, also in function of land use changes and climate changes (global changes) monitoring.

Actually, France does not have a map of the natural and semi-natural vegetation covering its whole territory (LALANNE, 2017). For that reason, French government decided to implement the knowledge acquisition on natural and semi-natural vegetation, by a national mapping and research program for natural and semi-natural vegetation called CarHAB, launched by the Ministry of Ecology (LALANNE, 2017). This mapping is indispensable to improve the evaluation of the status (preservation vs. anthropization) of habitats, especially them of EU Community interest (European obligation within the framework of the Habitat directive). The knowledge of ecological gradients, the ecosystems complexity and dynamics, will be very useful to better asses their services, the impact human activities, the relevance of protected areas network, the

efficacy of environmental policies, and the elaboration of the national red lists of habitats (LALANNE, 2017).

Estuaries represent a very important system for human uses, and they are very important for their biodiversity issues. Generally, these environments are considered of very high importance following “Birds” and “Habitats” EU directives together within the “Ramsar convention”. National and local administrations improved these directives and conventions by laws, regulations, restrictions, prohibitions and actions – following the different realities, peculiarities and risks. Estuaries are commonly considered very rich in species, very productive in biomass and as important sources of ecosystem services (MUCHIUT *et al.*, 2008).

Estuarine environments are characterized by significant tides, and currents that could be very strong. Estuaries generally include a wide mosaic of environments such as reed beds, salt marshes, forests, fens, meadows, aquatic communities, mud flats, shoals, sandbanks, gravel or pebbles bars, freshwater marshes, pools...

The estuaries undergone over the century under some changes following the human pressure and human needs. In fact, some estuaries shelter ports, cities, industrial areas or where transformed by barrages, canalization, deforestation, reclamation, soil uses... These changes often limited or threaten the services and the functionality of these ecosystems, altering the water quality (i.e.: salt, oxygen and nutrients contents), influencing the water dynamic, the estuarine functionality, the species presences and the vegetation expression.

Estuarine ecosystems are degrading almost everywhere in the World (LOTZE *et al.*, 2006); following the Global critical status of water bodies concerning Seas and Oceans, large river bottom valleys and even mountain streams, as shown by the WWF report in collaboration with the University of Vienna, entitled: "Save the Alpine Rivers - 2014". Estuaries are more or less constantly traversed by waters contaminated by various pollutants from micro to macro types, and they are not only influenced by local conditions, but also by pollutants carried by Oceans and rivers flows (BROWNE *et al.*, 2010).

In this context, some researches were carried out about estuarine systems, and some phytoassociations and plant landscape portions were described; but a systemic knowledge and a wider study on these plant landscape systems was never carried out before in France.

For all that, these ecosystems have been chosen within the CarHAB pilot study areas, as “Estuaries project” trying to fill these gaps and to provide a first scientific support for a in depth and wider knowledge on estuaries plant landscape; and to improve a common shared approach and methodology to study estuarine ecosystems and related vegetation survey.

This Thesis titled «Plant landscape and models of French Atlantic estuarine systems» was financed by the French ministry of Environment within the French National program of natural and semi-natural habitats cartography (CarHAB, convention 2100992970); and it was realized under an international (Italy-France) PhD Study co-tutorship agreement between Università degli Studi di Camerino [University of Camerino, Italy] and Université de Bretagne Occidentale (Brest, France) [University of Western Brittany, Brest, France].

1.3 The CarHAB Project framework

The French Ministry of the Environment, Energy and Sea (MEEM) in collaboration with the National Natural History Museum, Natural Heritage Service (MNHM-SPN), set up the National Inventory of Natural Heritage which targets several objectives ensuring the development of a National reference bank on biodiversity knowledge, based on data of national

programs from different types, including TAXREF (program for a taxonomic repository); HABREF (for habitat repository); and from NATURA 2000, ZNIEFF, red lists, habitats lists, vegetation prodrome, action plans, plant and vegetation inventories, habitat status (etc.), to be integrated into a nature and landscape information system (SINP). In this context, as part of the National Strategy for Biodiversity (SNB) 2011-2020, the French Ministry of the Environment initiated a program on mapping land habitats called “Cartographie nationale des habitats terrestres (CarHAB)”, in partnership with: Federation of National Botanical Conservatories (FCBN), National Institute of Geographical and Forest Information (IGN), National Science and Technology Research Institute for the Environment and Agriculture (IRSTEA), National Natural History Museum (MNHN), French Phytosociological Society (SFP), University of Western Brittany (UBO, Géoarchitecture Lab), Clermont-Auvergne University (UCA, UNIVEGE), “Jean Monnet” University of Saint-Étienne (ISTHME Lab), University of Upper Brittany “Rennes 2”, (LETG Lab), Avignon University (IMEP Lab)^{1,2,3,4}.

Europe has a long and well-documented tradition of vegetation science and mapping. In this context, France played a long history, following the Phytosociological Braun-Blanquet (or Zurich-Montpellier) school. The potential natural vegetation map of France at a 1:200000, a significant work from the second half of the XXth century, not strictly follows a phytosociological methodology. In recent years most French habitat and vegetation maps were produced at regional or local scale but a wider overview of habitats in a National scale is more difficult to have. The production of vegetation maps has been significant in France however, the actual vegetation maps have not been updated (LEGUÉDOIS *et al.*, 2011).

The 1992 European habitat directive fostered the attention on habitats of community interest, increasing the needs on vegetation distribution and conditions knowledge; fostering also the habitats and vegetation surveys, monitoring and mapping. The CarHAB project follows this tradition to upload and trying to redefine a vegetation map of France at a 1:25 000, following the phytosociological and land phytosociological approaches, in order to obtain more information on vegetation distribution and spatialization of plant communities and habitats. This project aims also to discuss and develop a more shared methodology, evaluating the state of the art, proposals and outlooks.

Vegetation patterns, reflects environmental conditions and human activities, characterizing the landscape, habitats, the land conservation status. The CarHAB approach is based on an inductive and semi-deductive method that describes the vegetation systems.

This program is based on the “dynamic phytosociology” and the “landscape dynamico-catenal” (or dynamic catenal) approaches. These subjects have the advantage of a systematic and integrated analysis of the biotic and abiotic components and the complexity of the ecological systems of the plant landscape (GÉHU, 2006). Preliminary research program steps consist to review the actual knowledge, experiences and practices on plant mapping, vegetation studies and Phytosociology science, to establish a shared typology and to obtain a vegetation map of the vegetation series of France. CarHAB research program, combining the actual and potential vegetation represents a flagship program for the French national biodiversity strategy and to develop the European Habitats Directive, together with other national, local and international programs on Plants, Vegetation, Habitats, Cartography, Landscape and Soil uses purposes.

¹ <https://inpn.mnhn.fr/actualites/lire/1241/>

² <http://www.trameverteetbleue.fr/outils-methodes/donnees-mobilisables/projet-carhab>

³ <http://letg.cnrs.fr/article869.html>

⁴ <http://m.irstea.fr/linstitut/nos-centres/grenoble/emgr/qualite-indicateurs-et-evaluation-environnementale-des>

According to ICHTER *et al.*, (2017) the methodology adopted for this project consists in a combination of practices and bibliographical review (state of the art), and evaluating also the international experiences from other countries. CarHAB methodology was chosen after taking into account the following issues:

- any comprehensive overview of wide vegetation-habitat mapping in Europe is available (large surfaces maps with large geographical scale, in which the denominator is small);
- difficulties to access some literature (grey literature, unpublished works, un-available copies, language issues...);
- according to MOLNÁR *et al.* (2007), the practices and methodological issues are rarely standardized, discussed or shared within the scientific world and protected areas or land managers.

The CarHAB program organization was validated by a working group composed by representatives of CarHAB technical committee and the European Topic Centre on Biological Diversity (ETC-BD). For these issues a national working group has been established⁵ in order to review bibliography, the actual status of knowledge on the subject; and to discuss on definitions, methodology, expertise, publications, test advancements, and to ensure the coordination between research project partners (CHALUMEAU & BIRET 2013, 2017; ICHTER *et al.*, 2014; CHOISNET *et al.*, 2016, 2018; LALANNE, 2017; MARCENO', 2017; BIRET *et al.*, 2018).

Two reviews carried out (ICHTER *et al.*, 2012, ICHTER *et al.*, 2015) bring together the European experiences of vegetation mapping and methodologies that use the phytosociological and synphytosociological approaches.

The CarHAB program follow three main components:

- tools (typology, methodology, definitions, modeling, standardization, physiognomic and ecological "white background");
- cartographic methodology (mapping, synthesis of mapping experiments, field tests);
- semiology, informatics systems and geographical information systems (GIS).

The French Botanical Conservatories network started some tests (CHOISNET *et al.*, 2014a,b,c; ISENMANN and SANZ, 2015; LUQUE *et al.*, 2015; PANAIOTIS *et al.*, 2015; CATTEAU *et al.*, 2016). Other studies were realized to set up a methodology in different areas and biogeographic contexts on larges areas:

- Armorican Massif, by Chalumeau (CHALUMEAU *et al.*, 2014, 2018; CHALUMEAU, 2018);
- Corsica, by Delbosc (DELBOSC, 2015, 2016; DELBOSC *et al.*, 2014, 2015, 2016, 2017a,b, 2018a,b,c; BIRET *et al.*, 2017; TANNÉ *et al.*, 2018);
- French Channel-Atlantic coastal vegetation by Demartini (DEMARTINI *et al.*, 2017; DEMARTINI, 2016; BIRET and DEMARTINI, 2013, 2014; BIRET *et al.*, 2014, 2015a,b, 2016, 2017);
- Temperate mountain range from Limagne to the "Chaîne des Puys", by Roux (ROUX *et al.*, 2017; ROUX, 2017).
- Steppic vegetation of the Crau plain, by Courtial (in progress).
- Mediterranean vegetation of the Associations and sigmassociations of the Bas-Vivarais (Ardèche), by Choisnet (CHOISNET *et al.*, 2014, 2018).
- French Atlantic Estuaries by Cianfaglione (CIANFAGLIONE & BIRET, 2015, 2017; CIANFAGLIONE *et al.*, 2016).

⁵ <http://patrinat.mnhn.fr/programmes/22/CarHAB>

1.4 Research questions and hypotheses

The aim of this Thesis is to study the vegetation and Plant Landscape of Estuarine Atlantic systems of France, trying to understand the functioning and the plant distribution patterns. The goal of this work is to develop a spatio-temporal predictive model based on actual and potential vegetation, using the dynamico-catenal approach; trying to carry out a theoretical common model of functioning and ecological gradients of estuaries. This, in order to make a basis to improve estuarine system classification, the related geography and ecological studies, and to help the monitoring and assessment of land uses and the global changes.

Estuaries represent a very complex ecosystems recognized as crucial or important at some levels: biodiversity, natural resource exploitation, infrastructures, global changes issues, social themes and economic topics - at local, national and international scales. Estuaries have been chosen between the pilot study site within the CarHAB research project framework, for these reasons and for the peculiarities of its vegetation. The evolution of the environment-society interactions, and the related changes issues, are fundamental to understand the possible trajectories in the vegetation dynamic, estuaries functioning and natural resources management (including landscape, biodiversity, water and soil uses). The combination of ecological and society visions raises acutely the questions of the functioning and the management of these ecosystems (i.e.: agro-sylvo-pastoral, urbanization, industrialization, conservation, hunting and fishing purposes). Following these purposes, estuarine ecosystems were mostly subjected to human activities for centuries, deeply influencing the geographical characteristics as well as the plant communities with uses sometimes contraposed or with colliding interests.

This work aims to understand how the dynamico-catenal phytosociology can contribute to characterize the structure, the determinism, the dynamics and the distribution of vegetation series and geoseries of French estuaries. The aim of this Thesis is also to study the French Atlantic estuarine ecological and geographical system to deepen the vegetation knowledge of these ecosystems, to contribute at the French vegetation map, and to set up a synphytosociological methodology for estuarine systems, for which no equivalent research work had been carried out previously in France.

The scientific approach and related concepts applied to the study area are discussed, in the advantage of representing three levels of vegetation organization: plant community (plant association), dynamic (series) and plant landscape (geoseries) integrated following geographical and ecological variables defining patterns like Phytocoenoses, plant association, Tessella, Series, Catena and related complexes following the spatio-temporal scale.

This, in order to the following main research questions:

- Is it possible to define a general common model of a estuary ecological gradients, functioning and plant landscape?
- What are the most important geographical and ecological characteristics influencing the plant patterns in estuaries?
- How vegetation traits, distribution and models could help to classify estuary types?

In addition, this work aims to foster the French National vegetation map, and to answer to the already mentioned problematic and questions, based on the dynamico-catenal (syn)phytosociological science (DELBOSC, 2015; DEMARTINI, 2016; ROUX, 2017), contributing to the shared theoretical and methodological discussion on bibliography, experiences,

definitions and practices within the CarHAB network. Trying to see also how could phytosociological and synphytosociological methods and concepts be useful in limnology, landscape and habitats studies, and to answering the previous questions.

The plant mapping work is carried out, with a double purpose: surfaces evaluation and chorology study based on sigmetal and geosigmetal units. All of these elements aim to improve the understanding of the structural patterns and the dynamics of Estuarine vegetation landscapes.

In France, most of the estuarine vegetation types were being described until now, with some exception concerning ruderal and segetal vegetation, which remain less studied (GAMISANS, 1975; DE FOUCAULT, 1984, 2008; BOULLET, 1986; BARDAT *et al.*, 2004; BIRET, 2010). Following the alteration of landscape and vegetation, we do not know the potential vegetation of some areas. Other areas, starts to show a possible potential vegetation only recently, after a lot of years or even centuries of soil uses stop or decreasing (i.e.: THEURILLAT, 1992; CHYTRÝ, 1998; CIANFAGLIONE, 2014; SENDER & MAŚLANKO, 2015; SENDER *et al.*, 2017; PEDROTTI, 2004, 2013, 2017; PERRIN *et al.*, 2018). This open some more questions about actual potential vegetation:

- How secondary communities could contribute to characterize the vegetation series in any way, and at in any level?
- How much the actual vegetation communities are in balance with the natural or anthropic dynamics?

It is not always possible to know trajectories and balances due to the lack of certain available historical data, because land and soil are still too used on very large surfaces; or because landscape forms were heavily altered (polderization, reclamation, barrages, land filling, excavation, mining, canalization, pollution, urbanization, erosion, deforestation, desertification, species lost, species introduction...). If not otherwise specified, the figures and tables that follows are elaborated by the author.

2 - GENERAL CONCEPTS AND PRINCIPLES

2.1. History and state of knowledge in phytosociology, and landscape phytosociology

The 2010 recurrence and celebrations of the phytosociology centenary, was an opportunity to trace the history and the evolution of this science (BIORET, 2010; GÉHU, 2010a,b, 2014; PIGNATTI, 2010; BIONDI, 2011).

According to GÉHU (2011) vegetation sciences have their origins in the writings of Alexander VON HUMBOLDT (1805), considered as being the founder of the vegetation science for its descriptive analysis actually known of "Physiognomic" (or physiognomic) type. He mentions, the Andean Cordillera landscapes, grouping plants communities in "societies" distributed altitudinally, according to the climatic gradients. In this context, von Humboldt was among the first scientists to recognize the ecological gradients, where species are replaced or altered in form along environmental gradients, such as a "cline" forming along a rise in elevation.

This "primordial" physiognomic approach tends very quickly to integrate two disciplines: the phytogeography (FLAHAULT, 1901) and the plant ecology (REITER, 1885). From this multidisciplinary context, in 1896, J. Paczoski replace the word "Florologie", that he had created in 1891, by that of "Phytosociologie" (DASZKIEWICZ, 2004).

Geographers, botanists, ecologists, geographers, cartographers and biologists have during this period discussed, evolved and placed strong bases on the sciences of vegetation and phytosociology. Between them we can mention: Beck, Binz, Blanc, Brunier, Cayer, Clements, Combres, Drude, Diels, Engler, Gadeceau, Ganong, Geiger, Ghiridon, Gradmann, Graebner, Grisebach, Harshberger, Hardy, Jaccard, Krassnoff, Leeuw, Litwinoff, Ludwig, Moss, Oliver, Schouw, Schimper, Tansley, Warming and Smith (DE WILDEMAN, 1910).

The 1910s mark a turning point between the traditional phytogeography and the current phytosociology, with the definition of the plant association by Ch. Flahault and C. Schröter (GÉHU 2010a,b, 2014), and others proposals at the 1910 Brussels international congress of Botany (DE WILDEMAN, 1910), where the plant association was accepted as fundamental unit of the Synecology. The thesis of Braun-Blanquet (1915), focused especially on these study aspects representing a milestone in this science.

According to VAN DER MAAREL (1975), PIGNATTI (1995); PIROLA (1999); CRISTEA *et al.*, (2004); GÉHU (2006) and UBALDI (2012) we can assume that the modern Phytosociology takes place with the works of Braun-Blanquet which increase and elaborate the conceptual, methodological and typological framework basis and its applications (BRAUN-BLANQUET, 1915, 1921, 1928), establishing a Phytosociological school leading the International Station of Mediterranean and Alpine Geobotany "Station Internationale de Géobotanique Méditerranéenne et Alpine (SIGMA)": a research center founded by W.C. De Leeuw and R. Combes initiative, and diriged by Braun-Blanquet from its foundation in 1930, until its disappearance in 1980 (GÉHU, 2010a).

The English version of this science name "Plant sociology" came from an American version of Braun-Blanquet book of Phytosociology (BRAUN-BLANQUET *et al.*, 1932). This name was conceivably favoured by his collaborators of that book version (G.D. Fuller and H.S. Conard).

According to MOLINIER (1959, 1962) and BRAUN-BLANQUET (1964) the vegetation were approached statically for a long time, and the process of dynamics analysis rested on a fixist descriptive vision, often very subjective, emphasizing the difficulty of having a direct and complete perception of dynamics in plant associations during our lifetime, prejudices and others still critical issues (GUINOCHET, 1973; MUCINA, 2010).

From the 1970s, the context of classical Sigmatic Phytosociology (also called synphytosociology or landscape phytosociology) widens conceptually (RIVAS-MARTÍNEZ, 1976; BÉGUIN *et al.*, 1979; TÜXEN, 1979; GÉHU & RIVAS-MARTÍNEZ, 1981; SCHWABE, 1989; GILLET *et al.*, 1991; THEURILLAT; 1992a, 1992b; LAZARE, 2009; BIONDI *et al.*, 2011). Works multiplied worldwide, to improve the knowledge of the vegetation, and also the ways to do, supported by various critics, additions, proposals and adjustments based on different experiences related to schools and study areas. According to PEDROTTI (2013), from the same period, studies of plant communities mainly take novelty within the integration of vegetation dynamics in time and space (TÜXEN, 1973, 1978; FALIŃSKI, 1986, 1998, 1999; FALIŃSKI & PEDROTTI, 1990). The dynamico-catenal phytosociology has made possible to better integrate vegetation dynamics by describing more finely the trajectories of vegetation series.

During this period, novelty concerned also a strongest integration of geographical, landscape, soil uses and ecological data, creating a lot of composite thematic maps types based on vegetation. PEDROTTI (2013) propose to distinguish the integrated phytosociological studies and maps in two types of integration:

- in time and space (the proper integrated phytosociological maps);
- in thematic issues (i.e.: ecological, social, agronomical, geographical, geologic, soil, climatic, zoology, and others info concerning biodiversity, populations, soil use, economy, urbanism, landscapes factors, environmental values, functions, structures...).

The integration of these thematic in some way recall also the definition of “Géoarchitecture”; term already in use previously but reopened by the architect “Le Corbusier” (Charles-Edouard Jeanneret-Gris) between 1945 “*Les Trois établissements humains*” and 1946 “*Manière de penser l’urbanisme*” (SARAGOSA, 2015; PETRILLI A., 2006), when he decided to extend the scope of his preoccupations to spatial planning and the environment, going largely beyond architecture and urbanism. The task, in his eyes, required multiple skills ranging from the natural sciences to those of man and society.

We can consequently recall the “Geobotany” and “Geobotanical cartography” that according to (PIGNATTI, 1976; PEDROTTI, 2013) respectively are “a broad science that deals with the study of species and of vegetation communities in relation to the environment; it includes other, perhaps more familiar sciences, such as plant geography, plant ecology, and chorology, and phytosociology (plant sociology). Geobotanical cartography is a field of thematic cartography that deals with the interpretation and representation, in the form of maps, of those spatial and temporal phenomena that pertain to flora, vegetation, vegetated landscapes, vegetation zones, and phytogeographical units”. RÜBEL (1912) first used the term “geobotanical cartography”, but only for the mapping of vegetation. Nevertheless, its meaning was amplified later to include the mapping of all phytogeographic, phytocoenotic and phytosociological aspects, as emphasized by PIGNATTI (1959), and FALIŃSKI (1991, 1993, 1999). The production of a geobotanical map represents the last stage in a cognitive process that begins with observations in the field and continues with the collection of sample data, interpretation of the phenomena observed, and their appropriate cartographic representation; geobotanical cartography is closely tied to the concepts and scope of geobotany in general (PEDROTTI, 2013).

An example for both type of vegetation map integration in the same area, was taken by PEDROTTI (2013) in the Montemonaco Municipality (Ascoli Piceno Province, Central Italy) within a wide range of mapping styles and thematic solutions around the world.

In plant mapping is possible to integrate vegetation in time and in space, and at the same time the integration could involve one or more thematic issues. This kind of complex multiple integration is facilitated in realization and treatments by computerized data processing use. All the novelty and uploads from 70's let to start or foster some modern applications to the Environmental monitoring, Human-nature heritages, Land management and Conservation of natural resources (PIGNATTI, 1976; GÉHU 1976, 1977, 1979a; GÉHU & GÉHU-FRANCK, 1981; RIVAS-MARTÍNEZ, 1987a, 1987b; BIONDI & COLOSI, 2005; LOIDI *et al.*, 2011). Since the end of the XXth century, the methodologies for studying vegetation dynamics have multiplied according to various scalar typologies. Plant science and Cartographic approaches, were further fostered thanks to the evolution of new survey and mathematic tools, laboratory and soil tools computers and information technology that have contributed to the research complexity and precision implementation, helping the complex integration of thematic, spatio-temporal dimensions, and dynamics (FALINSKI & PEDROTTI, 1990; BIRET *et al.*, 2000; BLASI *et al.*, 2000; PINTO-GOMES *et al.*, 2003; BIONDI *et al.*, 2004; CAPELO *et al.*, 2007; CATORCI *et al.*, 2009; MOBAIED *et al.*, 2015; DELBOSC *et al.*, 2017b).

2.1. Vegetation and mapping principles

2.1.1. Phytosociology, plant map and the dynamico-catenal approach

Phytosociology is the science of plant communities, so the plant sociology. The basic studies unit of the classic phytosociology is the "plant association" (also called Phytoassociation), that constitutes a homogeneous plant community in a homogeneous environmental unit (floristically homogeneous community in a ecological homogeneous surface). The Phytoassociation constitute the first level analysis of the plant landscape, according to GÉHU (1986, 1991a, 2006b). Plant association directional dynamics is then considered when progressive (such as: primary or secondary succession and regeneration) and regressive directions (such as: degeneration, and regression) in terms of time sequence. The former are conceived to tend from actual condition toward the hypothesized higher environmental equilibrium; the latter on the contrary tend to move away from this higher equilibrium (FALIŃSKI, 1986, 1991, 1994, 1999).

Recalling BRAUN-BLANQUET (1915) the plant Association is a plant community, more or less stable (non static, but in terms of clear identity and repeatability), and in equilibrium with the environment. Thus, it will be characterized by a determined floristic composition in which certain exclusive elements, or almost the characteristic species, reveal by their presence a particular and autonomous ecology. Braun-Blanquet continued that the in-depth study of plant associations have to take into account all the synecological phenomena and consider each association from every point of view. The description must be followed by an ecological part including the enumeration of the biological forms, of the biology, geography, genetic and other characteristics which include the origin and the evolution of the plant assemblages (grouping, community...). Thus, contemporary phytosociology is the science of plant groupings, that is to say, syntaxa (GÉHU 2014).

To allow a greater clarity in terms generally used in plant community science approaches, we need to distinguish between plant associations, plant community, phytocoenosis and plant grouping (PEDROTTI, 2013; CRISTEA *et al.*, 2016). All these terms describe plant assemblages but they are used with different nuances. Plant Association is a type of plant community also known as plant phytoassociation (WEBER *et al.*, 2000; DENGLER *et al.*, 2008; DENGLER, 2017). Plant grouping is a more generic term to call plant assemblages. Phytocoenosis is used for plant that lives together, interacting within an ecosystem.

Following PEDROTTI (2013) a phytocoenosis is a concrete vegetation stand in the field, as opposed to a community, which is a theoretical concept, based on a full-floristic vegetation samples called relevés – consisting in a concrete object of study. As the same is for the species (the theoretical concept) and the related specimen (the concrete object of study). Similarly to the Taxa for the taxonomy, syntaxonomy organize the Syntaxa in a hierarchical system where the association is the basic unit (instead of the species) and the phytosociological relevé (the vegetation survey) is the related methodological fundament; having each syntaxa a phytosociological *Typus* (or type, incl: *holotypus*, *homotypus*, *lectotypus*...).

The Phytosociological relevés consists in a survey species set per unit area of study, with related cover (even sociability rates) that distinguish, describe, belong or characterize the plant association with its original combination of species as:

- characteristics or characteristic species - the most closely related ones;
- companions or companion species - the midranges species, often used to distinguish variation within the plant associations;
- occasional or accidental species - the less represented or lesser representative species.

The syntaxonomy consist in hierarchical units of progressively higher ranks:

Classe (class),
Ordo (or order),
Alleantia (alliance),
Associatio (association).

These units can be subdivided as follows:

Sub-classe,
Sub-ordo,
Sub-alleantia,
Sub-associatio.

When necessary, plant association units could be further distinguished to underline their characteristics in: *variantes*, *facies*, seasonal aspects, *forma*...

In his thought, Braun-Blanquet states that the in-depth study of associations will have to take into account all the synecological phenomena and consider each association from every point of view. The descriptive part must be followed by an ecological part including the enumeration of the biological forms, the biological, environmental, genetics issues...

In turn, the plant association definition proposed by Braun-Blanquet was subject to subsequent critics or update proposal attempts (BIORET, 2010). Among these, we can cite GUINOCHET (1973), GÉHU & RIVAS-MARTÍNEZ (1981), and GÉHU (1991a).

For GUINOCHET (1973) and DE FOUCAULT (1984) the plant association is a polythetic category defined by a certain number of characters generally related to the plant species original combination: accentuated, but not exclusively determined, by the characteristic species.

According to GÉHU & RIVAS-MARTÍNEZ (1981), the plant association concept, like the species concept is an abstract concept that emerges from a set of "individuals" of an association (nearly) possessing in common the same floristic, statistical, ecological, dynamic, chorological and historical characteristics. For them, the association individual, studied by the survey, is the only concrete object of a plant association in phytosociology and syntaxonomy. Exactly like only the studied specimen is the only concrete object of a species in systematics and taxonomy (botany, zoology, paleontology, mycology, protistology, bacteriology, virology...). This comparison between taxonomy and syntaxonomy leave to glimpse in a certain manner the similarities that go in the direction of other concepts and definitions, that propose plant communities functioning as super-individuals (supra-organism, holobiont-like system, eusociality, superorganisms...) consisting in a unique complex of some species ecological interactions (WILSON, 1976; HÖLDOBLER *et al.*, 2011; LÜTTGE *et al.*, 2016; TURNER, 2016).

Sigma (Σ -) phytosociology, synphytosociology, landscape phytosociology or plant landscape sociology is the science of plant associations (WERGER, 1974; GÉHU & RIVAS-MARTÍNEZ 1981, GÉHU 2010a). According to PEDROTTI & CANULLO (1995), PEDROTTI (1998, 1999, 2000, 2004, 2013), GÉHU (1995b), based on phytosociological data (distribution, ordination and dynamics of plant Associations), the landscape phytosociology not only makes it possible to establish a typology of vegetation series (and series types), but also to represent the state of the vegetation, the different levels of vegetation organization and plant-landscape integration through the production of thematic map. The different types of maps, associated or not with the analysis of landscape indices, allow many applications environmental issues; biodiversity management; and spatial planning of the territory.

Following GÉHU (1991a), the landscape phytosociology focuses on describing and classifying vegetation series in an ordered system, seeking for a hierarchical standard system. To its holistic nature, this integrative system, is useful to develop valuable tools in the field of biomonitoring; bio-evaluation; nature-cultural heritage assessment; biodiversity threats; geography; agriculture; architectural and ecological surveys. It is possible to measure from this way the degree of naturalness-artificialization of the landscapes, to define the richness and the phytocoenotic diversity of a site, or to evaluate environmental risks (GÉHU, 1979c; GÉHU & GÉHU, 1979; BOULLET & GÉHU, 1991).

Sigmatist phytosociology can be defined as the part of geobotany or ecology that studies plant communities and their relationship to the environment (GÉHU, 2006b). But also as a part of geography, landscape and geoarchitecture subjects as discussed in the introduction.

The studies of plant community's complexes and plant landscape complexes culminated in the 1970s with a modern inductive approach to the plant landscape, or synphytocoenology (TÜXEN, 1973, 1978a, 1979).

According to GÉHU (2006b), the sigmatist phytosociology can be defined as the part of geobotany or ecology that studies plant communities and their relationship to the environment: alias the science of plant associations (GÉHU & RIVAS-MARTÍNEZ 1981; GÉHU 2010a). GÉHU (2006b) defines it as the plant landscape science (or integrated landscape phytosociology), which includes:

- sigmatist phytosociology;
- dynamic or serial phytosociology (synphytosociology);
- catenal phytosociology (geosynphytosociology).

More precisely, the Synphytosociology studies the sets of dynamically linked plant groups within the vegetation series (GÉHU, 1986). The goal of geosynphytosociology is the analysis

and classification of catenal and geographical phenomena of geoseries (GÉHU 1986, 1991a, 2006b).

Recently, the synphytosociology has also been the subject of syntheses and reviews describing the different stages of its development (THEURILLAT 1992a, GÉHU 2004). The desire to bring knowledge to these disciplines resulted in the dissemination of a number of articles and books, following its evolution (BRAUN-BLANQUET, 1928, 1964; TOMASELLI, 1956; GUINOCHE, 1973; PIGNATTI, 1976; RIVAS-MARTÍNEZ, 1976; BÉGUIN *et al.*, 1979; GÉHU & RIVAS-MARTÍNEZ, 1981; RIVAS-MARTÍNEZ, 1987b; GÉHU, 1991a; DE FOUCAULT, 1986a, 1986b; THEURILLAT 1992a; DIERSCHKE, 1994; LAHONDÈRE, 1997; LACOSTE & SALANON, 1999; BOUZILLÉ, 2007; LAZARE 2009a; ROYER, 2009; BIONDI 2011; CHALUMEAU & BIRET 2013).

2.1.2. Terroir and Territory biogeographical definition

2.1.2.1. Large territories

According to GÉHU (2006b), biogeography is the branch of geography studying the distribution and the causes of species distribution on the Earth. He precise that for botanists, biogeography is the science that taking into account the knowledge of current and past distribution of Taxa and Syntaxa; that in interdisciplinary cooperation with other related disciplines analyze the Planet surface (the *Oikos* and the Landscape at same time) bio-geo organization (typology and hierarchy). According to RIVAS-MARTÍNEZ (1985), the main biogeographic subdivisions and typology of the Planet are respectively:

empire, sub-empire, region (or circle of vegetation), sub-region, super-province or domain, province, sub-province, sector, sub-sector, district, subdistrict and Tessella.

In biogeography, the bioclimate is an important concept. For Biology and Geography it consist in a climate or climatic zone considered or defined in relation to living organisms and their distribution. Bioclimate is essential to characterize the to study vegetation distributional patterns. At the same time, geobotany is the branch of biogeography that is concerned with the geographic distribution of plant species. In other hand Ecology expresses assonant concept being a branch of biology which studies the interactions among organisms and their environment (biotic and abiotic interactions), due in a large part to its interdisciplinary nature complex origin (EGERTON, 2001). In fact, not surprisingly, for some authors, the Biogeographer Alexander von Humboldt is considered an early pioneer in ecological thinking; dewing inspiration from Isaac Newton, developing a form of "terrestrial physics", alias the ecology (ROSENZWEIG, 2003; HAWKINS, 2001; KINGSLAND, 2004).

Following the HETTNER (1927, 1923) concept, the chorology consists in the study of the causal relations between geographical phenomena occurring within a particular region, and the study of the spatial distribution of organisms exactly like the biogeography; the goal of the chorological point of view is to know the character of regions and places through comprehension of the existence together and interrelations among different realms of reality and their varied manifestations, and to comprehend the earth surface as a whole in its actual arrangement in continents, larger and smaller regions, and places.

GÉHU (2006b) refers to the fact that there is currently a convergence of ideas between biogeography, chorology and geobotany.

According to RIVAS-MARTÍNEZ (2007), biogeography could be called phytogeography, given the importance of species and plant communities in the definition and delimitation of

terrestrial typological units (like territory and landscape). GÉHU and RIVAS-MARTÍNEZ (1981) link the integrated chorology to the biogeography. For them, this science can be considered as the modern culmination of a biogeography with a dimension not only species-specific (at species or population levels) but also at the coenotic and landscape scale (phytoassociation and plant landscape level). For that, integrated chorology is the synthetic expression of classical phytogeography, phytosociology, landscape and ecosystems sciences. For both coauthors, the changes in the combination of plant groupings in geomorphological ensembles from more or less distant territories are at the basis of the vegetation limits (or borders, cuts) in the integrated chorology. As seen, the basic unit of the integrated chorology is the Tessella, considered as the basic cell of the landscape (or plant landscape) and defined by a series of vegetation and Tessellas is useful to describe the territory (DA LAGE & MÉTAILIÉ, 2015). In the disciplinary field of biogeography, GÉHU (1991a) observes that the study of vegetation series and Tessellas, combined with the distribution of taxa and syntaxa, makes it possible to improve the geographical delimitation of basic chorological units (district, phytogeographic sector). Following GÉHU (1977), a few years earlier, the Sigmassociation concept (TÜXEN, 1979) proposed a double (syntaxonomic and chorological) hierarchical system, where synphytosociological units are used as basic units to define the territorial divisions of different size. This is supported by GÉHU's publications, in which he defines the different phytocoenotic assemblages of French salt meadows, cliffs, and dunes (GÉHU, 1976b, 1977, 1978a; GÉHU & FRANCK 1985; GÉHU & GÉHU-FRANCK, 1985 1991), characterized by the repetitiveness of catenal combinations in each particular biogeographic sector of the littoral (GÉHU, 1987, 1991a). To describe the sigmassociations on these three littoral environments, Géhu uses the geosynphytosociological method. On each inventoried site, he carries out geosynrelevés consisting in a list of plant associations present on a geomorphologically homogeneous surface, gathered in a geosynphytosociological table. Each column of the table corresponds to a geoserial type, as each column of a phytosociological table corresponds to a plant association type. This makes possible to underline the structuring and the distribution of the various coastal sigmassociations and to specify the biogeographical limits; in fact, by this approach on the vegetal landscapes of salt meadows and cliffs, GÉHU similarly individualizes different sigmassociations along the Atlantic coastal coasts. Thus, by integrating the different data relating to the geographical distribution of sigmassociations, it becomes possible, thanks to the geosynphytosociological method, to propose new maps and biogeographical subdivisions and the plant organization models (GÉHU, 1976b, 1978a; GÉHU & FRANCK, 1985a; GÉHU & GÉHU-FRANCK, 1985). For all that reasons, according to the CarHAB purposes, and because concerning coastal vegetation types data, in this work we chosen to follow also this approach for our plant landscape study.

2.1.2.2. Small territories

The Terroir is a term used in Agronomy, Ecology and Landscape sciences often with various declinations to define a land portion (TURNER & GARDNER, 1991; FORMAN, 1995; PIGNATTI, 1997; FARINA, 2004; INGEGNOLI, 2011). Terroir concept was commonly consolidated over time to define a combination of homogenous environmental factors (i.e.: geography, exposition, denomination, soil, climate, human influence, human perception, natural dynamics, vegetation, biodiversity...). So not only looking on physical, ecological,

geographical, chemical characteristics; but also taking into account natural, anthropic and historical factors. This causing a huge variation in landscape aspects and in plant landscape.

A Territory, therefore is a more politic definition of a land portion. It is a law defined, geographically or ecologically delimited area that includes portions of soil, air and water, considered usually amenable to an animal, a population, a person, an organization or an institution. That could have a huge variety of ecological and geographical aspects so, in that way, a wide variation in landscape aspects and in plant landscape. Taking into account the work of BRAUN-BLANQUET (1919) we can consider that the Plant landscape is a fundamental part of the Terroir because plants strongly influence the landscape aspect and the soil uses; and vice-versa, following the ecologic characteristic also including the human impact. The "plant landscape" is in fact described by Géhu as the landscape combination of the various elements of natural vegetation or shaped by human activities (GÉHU, 2006b). In some ways, Terroir and Territory could be used as synonyms or not. The plant landscape concept is validly applicable to the Territory or Terroir definition, with any difference in any case. Following the research needs, we can assume Territory and Terroirs as synonyms or almost (considering them case dependent); simplifying this definition context, focusing in any case more on the plant landscape as a part of Territory and Terroir.

SCHMITHÜSEN (1968) define the landscape as a part of the geosphere whose order of magnitude is geographically significant, and the plant landscape corresponds to the vegetal component of a landscape, that is to say to all of its vegetation. THEURILLAT (1992b) specifies that because the vegetation is in the form of mosaics or vegetation complexes, we could also speak of "Plant Landscape complexes". From here, we can highlight the importance of the Synphytosociology to study the plant landscape and the landscape.

2.2 Vegetation mapping of plant complexes

2.2.1 Plant communities between small and large scales

In common language small scale could mean "of limited size or scope" and *vice versa* large scale could mean largest size or scope. We will retain the geographical definition of the scale factor:

In cartography:

- large scale representation represents maps in which the denominator is small (for example, from 1:1 to 1: 10 000) and they represent a small portion of territory and therefore can contain many details;
- small scale representation represent maps in which denominator is large (for example, from 1: 5 000 000 to ∞) and they represent large portions of territory and therefore are less detailed.

We retain the geographical definition of the scale factor.

According to PEDROTTI (2013) geobotanical issues could be represented in different ways, depending not only on the thematic but also depending on the scale factor of the representation. Following the scale of geobotanical studies we can list from the smaller one the different levels.

Smaller surfaces:

- individual plants (sample);
- species populations (species).

At larger surfaces (communities):

- synusiae (syn-unit or coeno-association);
- phytocoenosis (phytoassociation).

At larger surfaces (community complex)

- series;
- geoserries;
- catenas.

Upper categories correspond to the classical biogeographical division proposed by Wallace (GUNNELL, 2013) focusing on Districts, Sectors, Provinces, Regions, Kingdoms; or to Biomes, Biotopes, Habitats, Zones and Belts (PEDROTTI, 2013).

2.2.2 Integrated plant mapping approach

According to PEDROTTI (2013) it is also possible to distinguish subtypes of phytosociological map:

- maps of actual vegetation (i.e.: maps of syntaxonomic units);
- maps of potential vegetation (i.e.: maps of climacic syntaxonomical units);
- integrated maps (i.e. maps of vegetation series or sigmeta or sigmassociations).
In this case the vegetation is integrated in time and space.

Geosynphytosociological maps (i.e.: maps of geosigmeta) are no longer vegetation maps in the strict sense, being maps of complexes of vegetation.

The approach followed in this thesis is between the map of potential vegetation and the integrated one. The cartographic modelling represents the vegetation series or Sigmeta reflecting in potential vegetation and named by potential plant association occurrence. This model is integrated by synphytosociological relevés and tables showing how Sigmeta are composed in actual vegetation. Obtaining an integration of the potential vegetation map by the actual vegetation synrelevés related tables. Particular cases are underlined by symbols or directly in the related notice text attached. The integration with thematic maps is produced and unlimited possible by the GIS elaboration and other computer graphics. In this work QGIS 2.18.14 program was used.

2.2.3 Bio-evaluation, biodiversity and heritage assessment of the vegetation

Bio-assessment is the assessment of the ecological or environmental quality of an environment or ecosystem, based on ecological or biological criteria" (DA LAGE & MÉTAILIÉ, 2015). It brings together all the methods and techniques that allow an evaluation of the different elements of the environment, and which can contribute to a hierarchy of natural heritage and decision support tools (BIORET *et al.*, 2009).

We can divide bio-assessment following the natural-cultural heritage value, the productivity and products of an agro-ecosystem, the anthropization/wilderness, or just the quality in terms of pollution, species or community's presence.... The assessment type and monitoring depends a lot to what is the level of reference (i.e.: ecosystem, landscape, species and plant community of reference). Within any level the bio-evaluation depends also on the environmental values choice and to the reference choices (number of species per unit area; number of communities per unit area; number of genotypes per unit area; wilderness; productivity; pollution; urbanization; flowering or other aesthetic factors; cultural-historical

issues; perception or affection...). The environmental quality of a plant landscape can be assessed by using one or more criteria such as naturalness (or conversely, artificialization), resilience, threats, rarity, diversity...).

The same land could have a positive and negative feedback at the same time depending on evaluation choices and observer subjectivity. For that ways the bio-assessment techniques had some critics and evolution during the time, leading to the proposal of new indices or evaluation scales: trying to establish more objective criteria and status of references (LUCAS, 1973; GÉHU 1987, 1979a,d, 1988, 1991b, 1992a; GÉHU & GÉHU, 1979; ARNÁIZ 1981; GÉHU & GÉHU-FRANCK, 1982, 1991; GÉHU *et al.*, 1983; COSTA *et al.*, 1988, FERRERAS CHASCO 1988; MARTIN OSORIO & ASENSI MARFIL, 1988; ASENSI, 1990; ASENSI *et al.* 1991, 2000; BARNAUD, 1991; LOIDI 1994, DÍAZ GONZÁLEZ & FERNÁNDEZ PRIETO, 2000; CANO *et al.* 1994; BARDAT *et al.*, 1997; GAFTA & PEDROTTI, 1997; CADIÑANOS & MEAZA, 1998; IZCO, 1998; BIONDI *et al.*, 2005; BIONDI & COLOSI, 2005; PEÑAS *et al.*, 2005, 2010; MUÑOZ RODRÍGUEZ *et al.*, 2009; GONZÁLEZ DE PAZ, 2012; BIRET & GLEMAREC, 2014).

Following the previous authors, we can assume that in the field of plant landscape bio-assessment, the dynamico-catenal phytosociology proves to be a useful tool to bring essential information to the territory planning and allowing the implementation of land plans, conservation and management, programs thanks to its predictive nature based on phytoassociation and series (LOIDI, 2008).

According to GÄRDENFORS *et al.* (2001) and IUCN species redlists, generally the vegetation biodiversity assessment mainly focuses on rare species presence. In any case, the species related criteria (scarcity, threats, uses, appearance...) could also be applied to higher levels of plant organization, for the elaboration of red lists of plant communities at many levels. From plant communities (RODWELL & COOCH 1998), including phyto-associations (GÉHU, 1991c; BIRET *et al.*, 2011; LAZARE, 2013b), synusiae to biotopes and complexes of biotopes (BLAB, *et al.*, 1995; HELCOM, 1998).

Following the European Habitat directive (Natura 2000), and based on the species-community's presence, the application of the International Union for Conservation of Nature (IUCN) criteria in France, allowed to the production of lists or "pre-lists" of habitat of interest for vegetation at regional or local scales (DELASSUS & ZAMBETTAKIS, 2010; DUHAMEL & CATTEAU, 2014; PREY & CATTEAU, 2014; SAVIO & GAUDILLAT, 2015).

Always in this direction, since 2008, a global red list of terrestrial, freshwater and marine ecosystems have been developed (RODRÍGUEZ *et al.*, 2011; SAVIO & GAUDILLAT, 2015), with the objective to assess the vulnerability of ecosystems at the global level. The criteria and the methodology for this red list of ecosystems have been the subject of several publications (RODRÍGUEZ *et al.* 2011, 2015; CARRÉ 2012; KEITH *et al.*, 2013; BLAND *et al.*, 2016). In this context, LAZARE (2014) proposed to consider a "Plant Series Directive" and some criteria for an eventual Plant series of EU Community interest.

2.3 Principles of geography, morphology and other ecological aspects of Estuaries

2.3.1 Main geographical and abiotic aspects

A river mouth is the part of a river that flows into a water body (another river, a lake, reservoir, sea, ocean...). At the river mouth the water characteristic changes in some way. The

main changes are on water flow conditions, causing changes in currents and related physical, chemical and biological characteristics, together with the erosion and sediment deposition dynamic. In common language, the “river mouth” word can be generically used to denote any geomorphologic type of estuary i.e.: «Bouches du Rhône» – where the Rhone river final portion is from delta type; and «Embouchures de la Loire» – where the Loire river final portion is from Real Estuary type.

An estuary corresponds to the river portion where the effect of the sea (or ocean) in which it flows is more noticeable (Fig. 1). It concerns the entire portion of the river where the water is salty and brackish. As previously described, the river portion flowing in to the sea and influenced by the sea is called Estuary in a broader sense, and the river mouth is the last part, the part of the estuary most in contact with the sea or the ocean. Ocean and Sea are here used as synonyms.

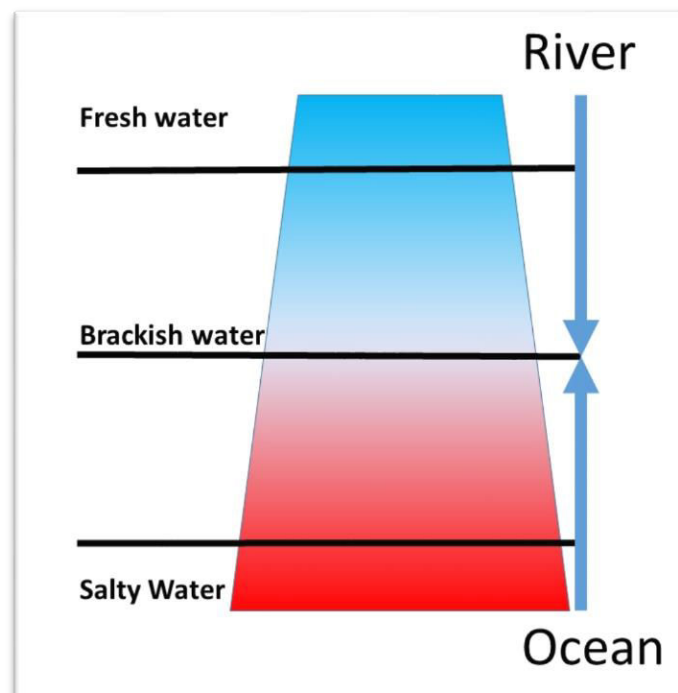


Figure 1. - The general salt-freshwater gradient in estuaries follows this cline, between Ocean and River conditions.

In 1967 Donald W. Pritchard, considered great specialist in estuaries (ROMAÑA, 1994) proposed a definition of them based on scientific considerations: an estuary is a confined body of water with a free connection to the open sea and which seawater is measurably diluted with fresh waters drained in the watershed.

It is interesting to note that the word "tide" was not mentioned because some estuaries are not under the influence of tide cycles. Tides determine the tidal estuaries, being them the main dynamic factor of the estuarine cycles and related variations. For that, tidal estuaries are more variable in time and space systems. Estuaries body of water are in any case transversally confined in the estuarine bad and longitudinally confined in the area of where the upriver waters are influenced by the sea waters (Fig. 2).

Tidal estuaries are in general characterized by: longer surfaces, following the highest tide level, and because in the upper side the freshwater front is influenced by the seawaters following the

tide level. This estuarine freshwater portion is also commonly known “dynamical tide portion”, while the other downstream portion is commonly known as “salty tide portion”.

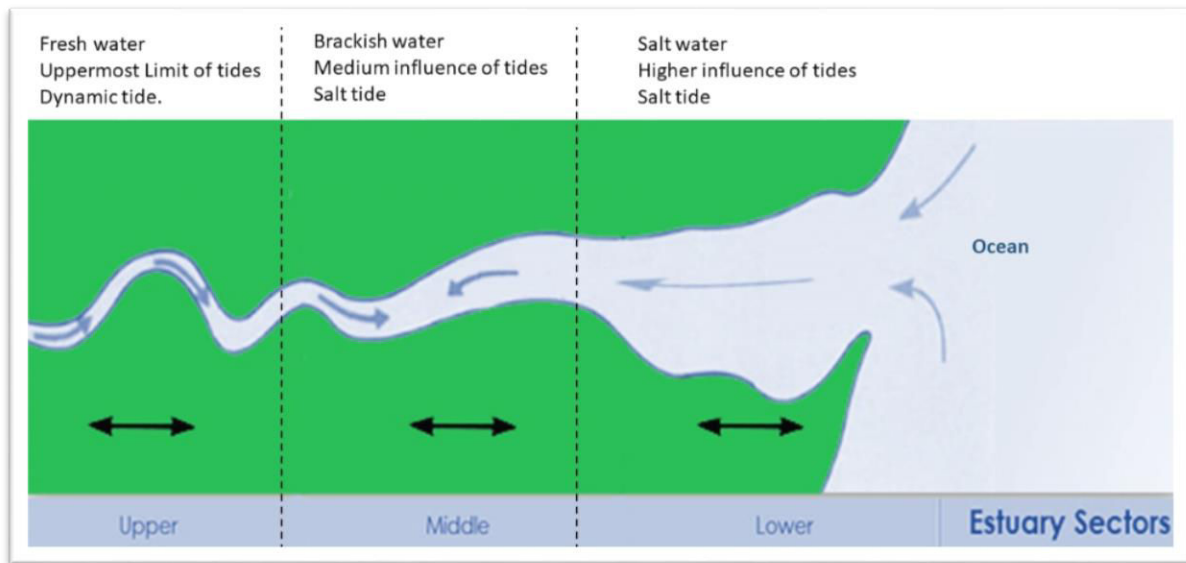


Figure 2. - Tidal estuary sectors and water dynamic. Upper estuary is fresh water dominant, but subject to tidal influence. In middle estuary, salt water and freshwater are mixing. In lower estuary, the influence of salt water is dominant. Related estuary sectors boundaries are mobile (dotted lines); the shift is subject to tidal cycle, seasonal and occasional floods.

Following ROMAÑA (1994), the tidal estuaries are classifiable reflecting the distances reached by the tide influence (between 100 and 200 km in the large French estuaries, and few tens of kilometers for the small ones). In tidal estuaries, the dispersion introduced by the periodic movement of water (estuarine swing) upstream and downstream makes sea and river waters diluted following a salinity gradient. For that, we can distinguish estuaries in:

- big estuaries (from around 100km longer);
- small estuaries (under 100km);
- very small estuaries (few meters). In that case we could have a very balanced flux swing between sea and river waters (i.e.: in Lagoon and brackish marshes) or a dominant sea condition like in Bay, with a weak river influence (i.e.: torrents, rivulets, ria), or a mixed condition.

In tidal estuaries, the inner portion consists in the point where the water table level is still influenced by the tidal dynamic but remaining always in freshwater condition. In any case, estuarine dynamics are influenced up-to-downstream also by the full and lean seasonal cycles of rivers. In all types of estuaries, the bed, meanders, banks and terraces are constantly reshaped by the water flows cycles; by continued or alternative filling/erosion of materials; by suspensions coming from river or from the sea flows, creating a “permanently unstable” environment under recurrent perturbation or just occasional perturbation influencing the biological expression. In any case, estuaries represent a geography and geomorphology gradient between coast and inland. According to VALLE-LEVINSON (2010) the most widely accepted definition of an estuary was proposed by CAMERON & PRITCHARD (1963) “a semi enclosed coastal body of water, with free communication to the ocean, and which ocean water is diluted by freshwater derived from the inner land”. Always according to both previous authors, the temperate estuary type is generally considered as the classical estuarine system. Arid, tropical and subtropical basins could make exceptions because their related basins could easily exhibit

different hydrodynamics. In this way, the estuarine water system could be quite different also if the geography and geomorphology aspect are similar or the same.

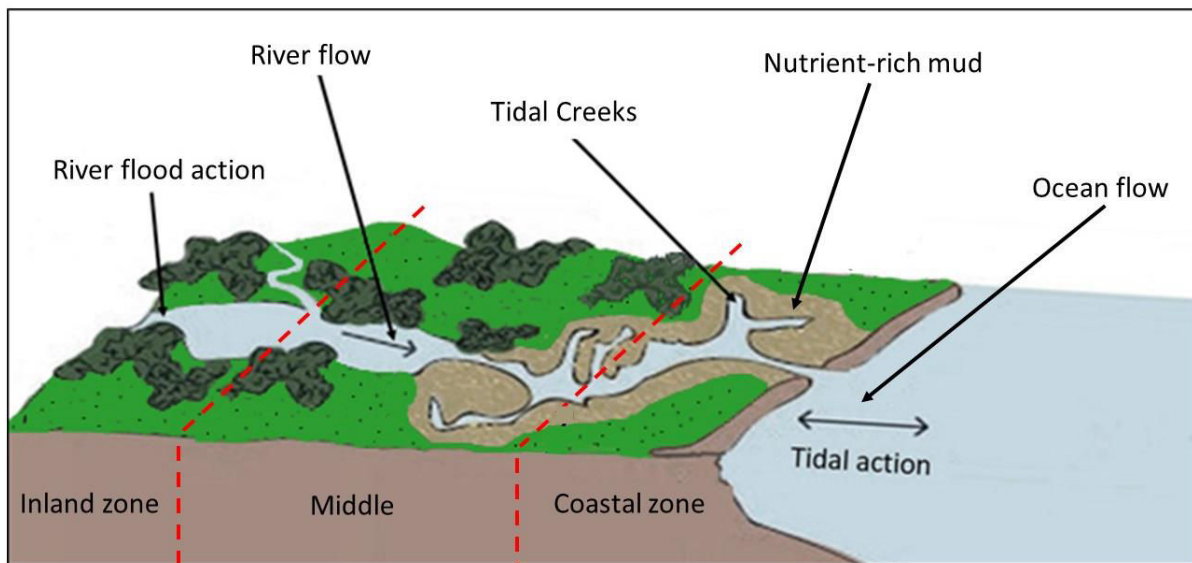


Figure 3. - General geomorphologic variation between inner and coastal estuary portions.

According to VALLE-LEVINSON (2010), the water salinity gradient is following the coastal-inland gradient (Fig. 3). The saltiest waters are in the estuary river mouth, brackish water in the middle, while in the inner estuarine zone, there are only freshwaters. In temperate estuaries, as it is for our study, the freshwater entering the estuarine bed establishes longitudinal and transversal density gradients that results in a long-term surface outflow and inflow (Fig. 4). Here the freshwater input is the main driver of the long-term (order of months) circulation through the difference on waters density. The estuarine system could be subdivided in salinity portions following the average water salinity concentration – following the international thalassic series of the “World Ocean Atlas 2009”⁶, from the downstream to upstream.

Salty water domain:

- Euhaline (mixoeuhaline) zone – more than 30 psu;
- Polyhaline zone – between 30 and 18 psu.

Brackish water domain:

- Mesohaline zone – between 18 and 5 psu;
- Oligohaline zone – between 5 and 0.5 psu.

Freshwater domain:

- under 0.5 psu.

⁶ https://www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html

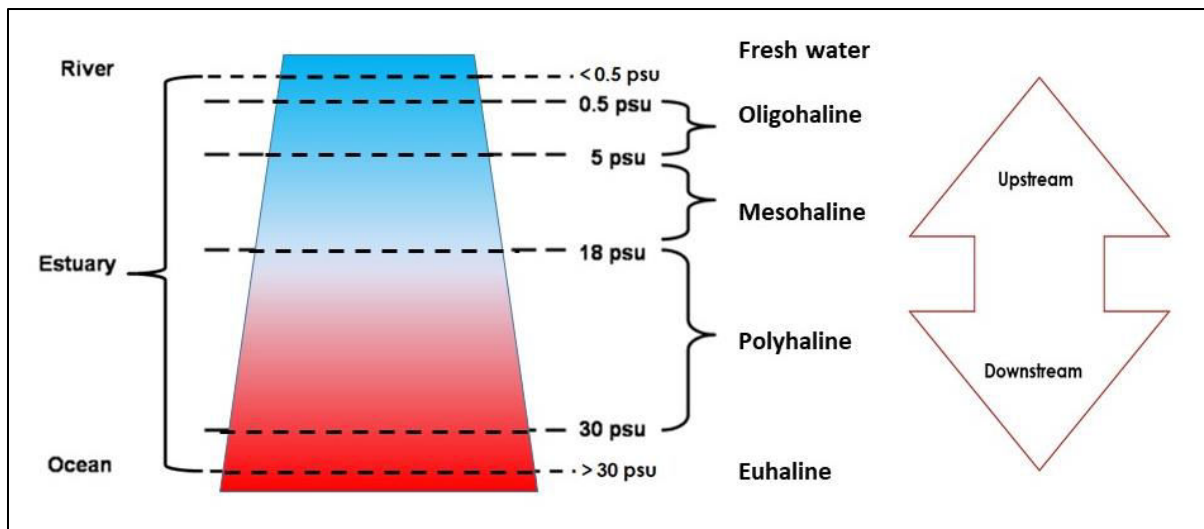


Figure 4. - Estuarine up-down stream salinity gradient and related ecological sectors. Psu corresponds to one part of NaCl per thousand parts of water.

“Psu (practical salinity unit)” is the salinity measure units. One psu corresponds to one gram of salt (NaCl) per kg (or liter) of water. Psu can also be equivalently expressed as “ppt (part per thousand)” or in “g/kg”. Often the salinity measures simply these equivalent units, using dimensionless numbers or just followed by the “‰” or by word “salinity (s)”. By comparison, generally the average ocean salinity is around 35 psu. The limit on agriculture irrigation is normally fixed on 2 psu and the limit for drinking waters commonly is 0.1 psu.

Tides cycles influence salinity zones extension and could shift them along the riverbed. Salty tides are located where the effect of the sea in estuaries is strongest. In the inner estuarine zone, the effect of sea is lesser, only freshwater is present but still under tides influence: the dynamic tides. Estuarine systems could be classified following the tidal dynamics in:

- Macrotidal - undergoing significant tidal ranges (over 4 to 5 m);
- Microtidal - undergoing lesser tidal ranges;
- Non tidal - are not influenced or under negligible tidal influence.

About surfaces, estuaries can be distinguished in large and small ones.

Large estuaries are generically longer and wider, and the river influence is stronger due to the river flow. Others important physical factors that could influence the estuarine longitudinal gradient are the substrate granulometry and the sea winds (Fig. 5). In estuaries, the geography and morphology gradients are not only longitudinal, but also transversal, occurring in riverbed from the minor (lower) bed to the major bed. From minor to major riverbed the transversal gradients are similar to the longitudinal ones, the salt and tides influence trends to be lesser and the phreatic and precipitation waters increase their print importance.

Each estuary is a unique geographic and ecological dynamic system, according to the nature of the geological setting, watershed, climate and winds, combined to the actual and the historical human pressure (anthropization, land use, global changes). All this shows how estuarine gradients are variable and multidirectional, reflecting the complexity of each of these systems.

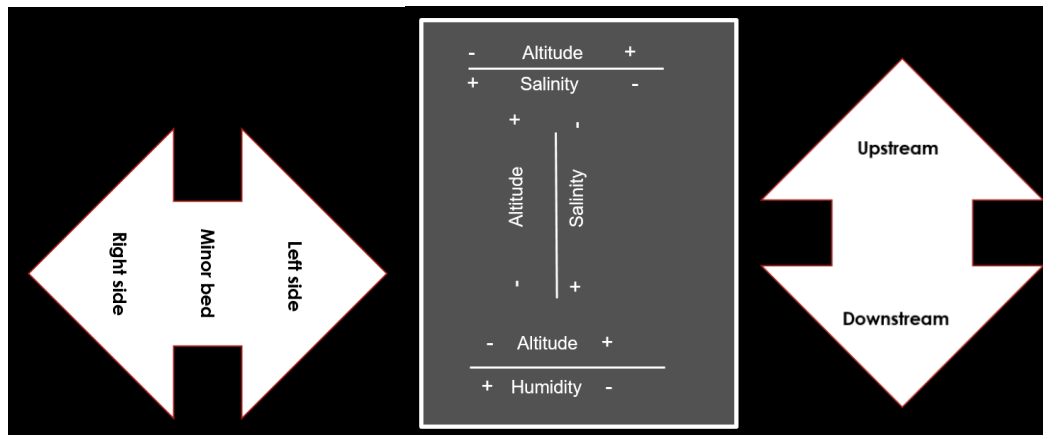


Figure 5. - Schematization of estuarine physical gradients and directions

2.3.2 Morphological types

The behavior of an estuary changes a lot depending on seasonal time, geography location, tide forcing, river flow, and even winds and offshore wave regime. Following DYER (1973) estuaries can be classified by geomorphologic characteristics looking on the average long-time stable characteristics - since in any case most of the physical features and therefore of the classifications are variable in the estuaries depending on the variation of the various factors examined.

A river mouth can be prolonged in the sea, in case of sedimentation zone occurs, by submarine canyons or if the tides flow is less important if compared to the river flow. This could occur more generically in seas where tidal dynamics are reduced or absent.

The estuarine water flows and winds can generate a wide variety of landforms:

- Channel (or Estuary, in the strict sense) with generally only one river mouth to the sea;
- Delta - alias an estuary with some river mouths (and related channels) to the sea;
- Fjord or fiord – is a long, narrow inlet (indentation of a shoreline) with steep sides or cliffs, created by a glacier (JIA-LIN, 2015; SWART, 2009);
- Inlet – an indentation of a shoreline, usually long and narrow, that often leads to an enclosed body of salt water of some definitions (i.e.: bay, arm, sound, creek, bay, lagoon, or marsh...) and that could develop in different salt level depending on the inner estuarine position (DAVIS *et al.*, 1994; KJERFVE, 1994);
- Spit or bar – is a deposition landform off coasts that develops by the process of longshore drift by longshore currents (DUANE & JAMES, 1980; EVANS, 1942) according to previous authors we can have some similar or derivate forms like: Tombolo, Barrier-River-Estuary islands (depending in the inner estuarine position), Isthmus, Wadden, Velme, Sillon, Cordon de gallets, Sand bar...;
- Tie channel – is a more inland formation that connect rivers to floodplains or lakes on many lowland rivers (ROWLAND *et al.*, 2009) and thereby play a central role in floodplain sedimentology and ecology at estuarine level (ROWLAND, 2009).

According to DUCROTOY (2010), the sedimentary phenomena happens with particles of various sizes, even remarkably larger, depending on the strength of the water flows. More the particles are larger and heavier and more they sediment easily, and consequently they are moved only by the less recurrent flows. The particles of mud are so thin and light that they do not easily sediment because always moved by the constant quotidian flows.

This is fundamental to have another typical and estuarine landform: the Silt plug. According to KIRBY (1988), WOLANSKI *et al.*, (1989) and WINTERWERP *et al.* (2001) in Estuaries the mud is blocked by the two flows (river and sea) encounter: mud concentrate here to the point of the greater forces balance. For this, estuaries have easily and commonly turbid waters. Mud is the result from the watershed soil erosion from the river, and the sediments carried by the sea flows into the estuary bed. The liquid mud consists in a mobile front that represents an important natural phenomenon, typical of tidal estuaries. The point of the Estuary where the suspended fine sediments are highly concentrated is known as "maximum turbidity zone", creating a Silt plug. More the mud particles concentrate and agglomerate, and more their weight increases, favoring their decantation. For that reason, the estuarine portions from the lower to the higher river bed that corresponding to Silt plug area, and paleo silt plug zones are recognizable in general by the siltier and more argillaceous substrate. Clay, silt and organic portions form mud. The Silt plug is therefore mobile, as it moves following the water flow cycles, the changing currents and related forces involved. The Silt plug (maximum turbidity zone) is a very special system. According to ROMAÑA, (1994) its suspended solids levels could be from 100 to 500 times higher than those typical of most rivers or marine water; alias up to 300g of suspended matter per liter (organic portion with bacteria and plankton included). This mud cream at this point is thickest and denser during the lowest tides periods, with a coefficient less than 70.

Following ROMAÑA (1994), as French selected examples of the estimated average weight of silt plug sediment from three large estuaries could be:

- Seine: 20 000 to 400 000 t/l;
- Loire: 800 000 to 1 000 000 t/l;
- Gironde: 4 000 000 to 5 000 000 t/l.

Considering these mass as tons (t) per liter (l) equivalent of one to three years of sediments inflow by their river.

Estuarine water cycles depending on water flows that can change from:

- hour by hour (due to the daily tides);
- day by day (due to monthly tides);
- month by month (by seasonal changes);
- year by year (by yearly evolution);
- exceptional events (more than one-year evolution).

These recurrent cycles influence the estuarine landforms and habitat, but the water level because from daily to exceptional events the flooding level increase or decrease notably; from few millimeters until some meters - depending on river and sea flows regime.

Following CHANSON (2011), the tidal bore (often simply bore) represents another characteristic tidal phenomenon, especially for macrotidal estuaries. In this context, the leading edge of the incoming tide forms a wave (or waves) of water that travels up an estuary (along its riverbed or its narrow bay) against the direction of the river's current. In this context, a tidal bore (often simply given as bore) is the phenomenon in which the leading edge of the incoming tide forms a wave (or waves) of water that travels up a river or narrow bay against the direction of the river or bay's current. Bores occur in relatively few locations worldwide, usually in areas with a large tidal range (typically more than 6 meters, between high and low water) and where incoming tides are funneled into a shallow, narrowing river or lake via a broad bay. The funnel-like shape not only increases the tidal range, but it can also decrease the duration of the flood tide, down to a point where the flood appears as a sudden increase in the water level. A tidal bore takes place during the flood tide and never during the ebb tide. A tidal bore may appear under various forms (BARTSCH-WINKLER & LYNCH, 1988), ranging from a single breaking wave to a sequence of secondary smaller waves known as whelps. The tidal bore induces a strong turbulent mixing in the estuarine zone, and the effects may be felt along considerable

distances; influencing estuarine banks, water salinity mixing, the water oxygenation rate, the sediment/erosion dynamic. Aeration induced by the tidal bore is very remarkable in an environment with a high anoxic tendency. Tidal bores also provide opportunity for recreational purposes (i.e.: surfing), also if they may be dangerous. Many bores have had a bad reputation like in Seine estuary or in Garonne estuary, where they are considered as being extremely dangerous.

Estuaries can be classified based on their water balance, geomorphology, vertical structure of salinity, and hydrodynamics (VALLE-LEVINSON, 2010).

About the water balance, we can distinguish three types:

- positive estuaries are those in which freshwater additions from river discharge, rain and ice melting exceed freshwater losses from evaporation or freezing and establish a longitudinal density gradient. The circulation induced by the volume of fresh water added to the basin is widely known as “estuarine” or “gravitational” circulation;
- inverse estuaries are typically found in arid regions where freshwater losses from evaporation exceed freshwater additions from precipitation;
- low-inflow estuaries occur in regions of high evaporation rates but with a small influence from river. During the dry and hot season, evaporation processes may cause a salinity maximum zone referred to as a “salt plug”.

Geomorphologically, estuaries may be classified following PRITCHARD (1952):

- coastal plain estuaries, also called drowned river valleys. Originally, rivers, these estuaries formed during flooding over time by rising sea levels. They formed because of the Pleistocene sea increase (more or less 15000 years ago). Their shape resembles that of normal river, although much wider (with large width/depth ratio);
- fiords are associated with high latitudes with intense glacial activity; they are characterized by an elongated, deep channel with a sill related to glacial activity (actual or former);
- bar-built estuaries, originally embayment, became semi enclosed because of littoral drift causing the formation of a sand bar or spit between the coast and the ocean. Some of these bars could be joined to one of the headlands of a former embayment and display one small inlet approximately a few hundred meters, where the estuary communicates with the ocean. Some other sand bars may be detached from the coast and represent islands that result in two or more inlets that allow communication between the estuary and the ocean. In some additional cases, sand bars could be formed by rising sea level.

About the vertical structure of salinity, estuaries may be classified according to the water column stratification or the salinity vertical structure, as: salt wedge, strongly stratified, weakly stratified or vertically mixed (PRITCHARD, 1955; CAMERON & PRITCHARD, 1963). Mixing from tidal forcing is proportional to the tidal prism: the volume of oceanic water entering the estuary during every tidal cycle (VALLE-LEVINSON, 2010).

A moderate to large river discharge and weak tidal forcing, result in strongly stratified estuaries. Typical tidally averaged salinity profiles exhibit a sharp pycnocline (or halocline), with mean flows dominated by outflow throughout most of the water column and weak inflow in a near-bottom layer. Large river discharge and weak tidal forcing results in salt wedge estuaries. These systems are strongly stratified during flood tides, when the ocean water intrudes in a wedge shape. For that reason, these systems could lose their salt wedge during dry periods. These estuaries have similar stratification to salt wedge estuaries, but the stratification remains strong throughout the tidal cycle. The tidally averaged salinity profiles have a well-developed pycnocline with weak vertical variations above and below the pycnocline. The mean flow exhibits well-established outflows and inflows, but the inflows are weak because of weak mixing with freshwater and weak horizontal density gradients. Weakly stratified or partially mixed estuaries result from moderate to strong tidal forcing and weak to moderate river

discharge. The mean exchange flow is most vigorous (when compared to other types of estuaries) because of the mixing between riverine and oceanic waters. Strong tidal forcing and weak river discharge result in vertically mixed estuaries. Mean salinity profiles in mixed estuaries are practically uniform and mean flows are unidirectional with depth. In wide (and shallow) estuaries, inflows may develop on one side across the estuary and outflow on the other side, especially during the dry season. In narrow well-mixed estuaries, inflow of salinity may only occur during the flood tide because the mean flow will be seaward. Examples of this type of estuary are scarce because, under well-mixed conditions, the mean (as in the tidally averaged sense) flow will most likely be driven by wind or tidal forcing. The estuaries water column and the related vertical structure of salinity, may be variable, following the local tidal cycles, changing from one type to another.

The pycnocline is the lines in an area with a density gradient that separate the water layers with different densities (GNANADESIKAN, 1999). Density variations can be linked to changes in salinity or water temperature. The study of the pycnocline assumes a considerable importance in oceanography, as one or more pycnoclines separate masses of water with very different and immiscible characteristics; these layers flows on each other giving rise to a water circulation (thermohaline circulation) with great influence on the global climate and in water systems. River and sea forces influence the pycnoclines and the miscibility of different pycnoclines. Below the pycnocline, the different density hinders the mixing of water and the consequent diffusion of heat, salinity, oxygen content and nutrients (MANN *et al.*, 2013). This separation has important biological effects on the life of marine or aquatic animals. However, with time, however, a vertical mixing of the water occurs due to turbulence phenomena (FERNANDO, 1991), and this mixing plays an important role in the transport of nutrients (STRANG & FERNANDO, 2001).

About the hydrodynamics, estuaries may be classified according to HANSEN & RATTRAY (1966) following two non-dimensional parameters: the circulation, and the stratification. We can consequently distinguish four hydrodynamic types of estuaries:

- 1 –no vertical structure in net flows;
- 2 – the net flows reverse with depth;
- 3 – exhibit strong gravitational circulation;
- 4 –salt wedge

The two considered parameters refer to tidally averaged and cross-sectional averaged variables according VALLE-LEVINSON (2010).

Following GUILCHER *et al.* (1982), we can distinguish three groups of estuaries depending on sedimentation granulometry:

- prevalently pelitic type, consisting in muddy, pelitic consistence
- prevalently sandy type, in which sand flats (generally of marine origin) usually cover the outer estuary, and unusually the inner portions;
- bay to bight type, in which the outer marine forces are stronger, with midbay spits consisting sometimes of pebbles.

In estuaries from the first type Schorre, slikke and minor riverbed can be easily distinguishable. The banks are formed by cliffs in form of rocky outcrops, or covered by embankments consisting in mudflats with very strong pelitic fraction, subdivided into slikke (the upper part of the mudflats covered only at high seas) and in Schorre (the lower part of the mudflats covered with each tide). The minor riverbed is the main channel always underwater (or exceptionally dry during the driest seasons. Sandy, gravelly or bigger size sediments could occupy only the minor riverbed and not the lateral banks, which are always muddy or prevalently. The Schorre is especially represented upstream and in diverticula (portion under slow water flows) and they tend to disappear downstream. Except for very steep points, the cliff foot of the banks is

preceded by the cliff debris. The essential banks (slikkes and Schorres) sedimentary stock is muddy. The second type is less classical than the first. Unlike the previous one, the middle part of the estuary is covered by sand or thickest sediments (from the minor riverbed to the higher banks). However, going to the inner part, or between the small diverticula, we could usually see more or less muddy sedimentation. The sand and thickest sediments generally comes, directly from the sea; the estuary basin, or from outside in the sea or from the contact of dunes. In the third type, the water flow is prevalently from sea, resulting in sediments of different granulometry. In addition, mid-bay bars more frequently occur even in rather coarse sediments. However, the existence of mid-bay arrows cannot be evaluated alone; in fact, this must not necessarily lead to classify estuaries in the third type. Generally, out of the Armorican peninsula the muddy and pelitic estuaries are certainly more frequent, as is the case for the large estuaries of the North Sea. GUILCHER *et al.* (1982) describes also a periglacial « Kastental » micro-ria type, where the sea water flux are only remarkable forces in action. Taking into account the already cited literature and field personal observations, and following the “Centre régional de documentation pédagogique de Bretagne” dictionary⁷ and the studied bibliography - we can distinguish from different geographical local estuarine forms typical of the Atlantic French coast:

- Aber (from Celtic, meaning estuary) design an estuary. This word is traditionally used in Scotland, Ireland, Wales and Brittany. Often likened to Ria; it is commonly distinguished by a larger embankment alluvium (alluvial bed);
- Hâvre is a creek overlooking the sea and an excellent natural shelter for ships. Consequently, it is also a port, whose characteristic is often to be often discovered at low tide. Word used more traditionally for the Northern France;
- Ria is a word typically used in Brittany and others countries to design small rivers, otherwise meaning also the related downstream (estuarine) river valley portion deeply penetrated by the sea following a marine transgression (tides).

According to COTTON (1956) and BIRD (2008), a Ría is defined in geomorphology as a narrow, elongated and relatively deep bay formed by the lower part of the valley of an invaded coastal river, in part or in whole, by sea. International geography uses the word Ria, as the word Aber is also used. In any case these types represent the furrow, much deeper and with steeper slopes estuaries. The Ria sometimes encompasses islands that correspond to the peaks of the partially submerged ridges. A Ria refers to the non-glacial valley of a coastal river flooded by sea-level rise (tectonic flooding, Flemish transgression...). Sometimes locally, an Aber is more specifically used to distinguish a funnel in a wide open sea, or a Ria type - characterized by a larger embankment alluvium. In a Rias coast (a coastline with parallel rias separated by ridges), topography could be morphologically regularized by the sediment filling (DERRUAU, 2010), from the sea or from the inland cliff erosion combined otherwise by the river flow.

The riverbed or river channel is a type of landform referring to the site where water flows between identifiable banks. Natural riverbed are formed by water cycle processes. A river channel is the physical confine of a river (or estuary), consisting of a bed and related stream banks. The nature of any riverbed is always in function of the water flow dynamics and the local geologic materials, influenced by the land uses history. The nature of the river channel is responsive to the conditions of the precipitation runoff. The stream bed is very complex in terms of erosion-deposition phenomena; the sediments are transported, eroded and deposited along the riverbed. Where natural conditions of either grassland or forest ameliorate peak flows,

⁷ http://www.cndp.fr/crdp-rennes/crdp/crdp_dossiers/dossiers/rance_patrimoine/lexique.htm

streambeds are more stable. Channel type can be distinguished between low gradient streams (slightly sloped) and high gradient streams (steeply sloped). High gradient river channels could be divided into riffle-pool, rapid-plane bed, step-pool and cascade unit morphologies (GARCIA and PARKER, 1991; HAUER and LAMBERTI, 2007; DI FIDIO and GANDOLFI, 2013). Riffle-pool sequence channels are composed of migrating pools and transverse bars called riffles and occur on gradients less than 1-2 percent. Rapids (also called plane bed, but not to be confused with the plane beds described in sand bed rivers) lack distinct pools and bars but commonly have stone cells or clusters. Step-pools are composed of channel-spanning pools and boulder or cobble steps that cause subcritical flow in the pool and supercritical flow over the steps. Cascade units exist at steeper gradients where boulders and cobbles dominate the riverbed; and channel-spanning pools do not exist, but pocket pools are common.

Generally, the High gradient slightly sloped channel is the typical river form of the lower valleys, like in estuaries. They are influenced by deposits from the water flows distinguishing as example: braided rivers, wandering rivers, meandering, and anastomosing rivers. During floods, water flow may exceed the capacity of the channel and flood waters will spill out of the channel and across the valley bottom, floodplain. Following the topographic levels, we can distinguish the channel into three portions: minor, ordinary and major riverbed. The minor riverbed represents the greater river depth, the lowest channel portion in which the minimal water flows. It is also known as minor flow channel, minor streambed or smaller riverbed; alias the channel bottom of a waterbody with the lowest water levels flow. Its margins are known as the stream banks or riverbanks.

The ordinary riverbed represent an upper portion, where the waters of ordinary floods cycle can flows. This limit is raised and larger than the minor bed.

The major riverbed or flood bed, represent the uppermost portion of the channel, the maximum surface that can be flooded by the river during largest floods. This limit is raised and larger than the ordinary bed.

About estuary riverbed geomorphology, hydrology and limnology, the major river bed is the most floodable surface from the estuary, even during exceptional recurrent or extreme events. "Major riverbed", "flood bed", "alluvial bed", "alluvial plain", or "flood plain" consists of the maximum floodable surface from the river (or estuaries). It is raised and larger than the ordinary (minor) riverbed. As it is for the minor bed and banks, also the flood bed is characterized by the presence of sediments and coarse material deposited. The granulometric size of deposits depends in any case by the water flows. The minor and the major bed could be subdivided in some ways depending the geomorphology in terraces (or alluvial plains), ditches and even tranches (i.e.: in case of abandoned meanders). Depression here often cause the presence of natural ponds, pools, lakes or marshes (also of temporal or seasonal type). In some case we can observe also some secondary rivers or rivulets that run in parallel to the main stream. Dry and abandoned streambeds are subject to burial, or to became water pockets and flooding by heavy rains, river flooding and water rising from the ground and may sometimes be part of the rejuvenation of the stream. The nature of the streambed is strongly responsive to conditions of precipitation runoff. More precisely the large riverbed includes geomorphologic surfaces external to the minor riverbed (main river channel, geul or alveo). In that way, we can find an alluvial plain: indicating a more or less flat surface, adjacent to the watercourse and consisting of alluvial sediments (floods) deposited by the same watercourse. The alluvial plain could be also in a lower topographic level if compared to the small riverbed and delimited by a natural levee (dyke, embankment or flood-bank). When the floodplain is more elevated to the river bed, it can then be eroded by the river, creating slopes or terraces, alias: sub-horizontal

(more or less flat, even in gentle slope) topographic surface that represents the ancient levels of the alluvial plain of a watercourse, deriving from the fact that the river has carved the plain. If these terraces level is still floodable from the river, it belongs to the alluvial bed (major riverbed). For that reason, the floodplain and terrace often could be generalized and considered as synonyms in large sense, together with larger riverbed as is in our case, due to the fact that we consider only the floodable surfaces. The largest riverbed vegetation evidences consist in a wide covering vegetation (RAMEAU, 1996; BENSETTITI *et al.*, 2001, 2004), with significant actual (or potential) presence of arboreal vegetation; together with the presence of high amount of necromass (VALLAURI, 2005) from endogenous and exogenous provenance. The endogenous biomass is produced by the fallout of the local vegetation, while the exogenous is transported up-to-downstream by the river flow and down-up-stream by tidal flows: marking at the same time the level reached by recent floods. Generally, in our latitudes and in any case in our study area, in the major riverbed level (more floodable surfaces) the softwood hygrophytes cover is dominant; while in highest levels (the less floodable surfaces) we found mesophytic vegetation and hard wood species (WILSON & WHITE, 1986; RAMEAU *et al.*, 1989; SCHNITZLER-LENOBLE, 2007; BASTIEN & GAUBERVILLE, 2011).

With global warming there is a fear that the size and shape of riverbeds will change due to increased flood magnitude and frequency but maybe these systems could buffer it by its ecosystem services and resistance from biotic and abiotic components (PHILLIPS & JEROLMACK, 2016) increasing the importance to not only study these actual systems, but also the potential vegetation, models, dynamics and previsions (TURITTO *et al.*, 2008; SAWTSCHUK & BIORET, 2012; JIA-LIN *et al.*, 2015; CIANFAGLIONE & BIORET, 2017; LE DEZ *et al.*, 2017b; SENDER *et al.*, 2017). Where natural conditions of either grassland or forest ameliorate the water and sediment peak flows (TABBACHI, 1992): the stream beds are more stable, generally more rich in biodiversity (DUFOUR & PIÉGAY, 2006), biomass (even necromass) and in functionality and consequently these streams support a rich biota (VALLAURI, 2005; DAJOZ, 2007).

Under certain conditions a river can branch from one stream bed to multiple stream beds (GUILCHER *et al.*, 1982; JEROLMACK & MOHRIG, 2007). A flood occurs when a stream overflows its banks onto its flood plain. As a general rule, the bed is the part of the channel up to the normal water line, and the banks are that part above the normal water line. However, because water flow could vary for some reasons, this differentiation is also subject to variation: as it is for tidal estuaries. Especially for tidal estuaries, the word “Geul” is more useful to represent the lowest part of the river bed. In fact, slikke and Schorre are also part of the minor river bed – depending on tides, as seen in paragraph 2. For that reason, slikke and Schorre represent the tract of union between minor riverbed and banks; where the lower slikke is closer to the high Schorre is closer to the riverbanks.

The estuarine riverbed geomorphology can be synthetically defined as the study of the processes of production, flow and storage of sediments in the basin and in the riverbed in the short, medium and long time scale, and the resulting forms in the riverbed and in the floodplain (SEAR and NEWSON, 2003). The streambed (in large sense) is very complex in terms of erosion/sedimentation processes, and sediments are continuously transported, eroded and deposited reshaping the landforms (SCHUMM & KAHN, 1972; HICKIN & SICHINGABULA, 1988; GARCIA & PARKER, 1991; MÜLLER, 1995; SEAR & NEWSON, 2003; TURITTO *at al.*, 2008). The geomorphological nature of any streambed is variable in function of the geo-hydro-morphology and its nomenclature is variable following local variations and local cultural custom (DI FIDIO & GANDOLFI, 2013). In any case, the geomorphology is always in function of the flow dynamics and the local geologic materials, influenced by the water flows (GARCIA & PARKER, 1991) and

creating some land forms as follows. As we noted, riverbed (in the largest sense) characteristics are crucial to understand vegetation patterns. The classification of riverbeds varies according to the considered section and inclination. In estuaries, the up-downstream riverbed inclination is small; the division of the estuarine system into zones and dominant processes reflects other physical characteristics of watercourses, such as lateral confinement (direct contact with elements that prevent the lateral mobility of water in the riverbed) and riverbed dimensions. The inclination influences the length of estuaries.

According to FRYIRS *et al.* (2015) valley setting and confinement are primary controls on river character and behavior. Confinement is the degree to which waterbodies are limited (confined) in their ability to move laterally. According to the previously cited authors, we can describe and distinguish confinement as follows. Confinement can result from bedrock walls (canyons), closely spaced hillslopes, or by entrenchment into a floodplain. Valley confinement is the degree to which topographic features, such as hillslopes, alluvial fans, glacial moraines, and river terraces, limit the lateral extent of the valley floor and the floodplain along a river. Based on the confinement degree we can distinguished three cases:

1. confined riverbed segments: over 90% of the banks are constrained, directly in contact with non-floodable surfaces (slopes, cliffs or paleo-terraces). Eventually the flood plain is restricted only to small or isolated points (in total less than the 10% of the length of the stretch);
2. unconfined riverbed segments: the plain is continuous and unconstrained. Less than 10% of the riverbed margins are in contact with non-floodable (from the river) surfaces. The shores are therefore completely deformable by water flows, and in such a way the riverbed is completely free model and reshape freely its external limits;
3. semi-confined (or partially confined) riverbed: the plain is discontinuous. It is an intermediate situation from the previous two points. The river banks are in contact with the floodplain for a length between 10 and 90% of the length of the stretch.

Human structures (i.e.: urbanization, channeling and artificial embankments) and infrastructures (i.e.: roads and railroads) are recognized as confining features with potentially large environmental impacts (BLANTON & MARCUS, 2013; CZUBA *et al.*, 2018) producing unnatural levels of runoff, the stream beds will exhibit a greater amount of scour, often down to bedrock and banks may be undercut; greatly increasing the basin erosion and results in thinner soils, upslope from the stream bed: as the channel adjusts to the increase in flow.

In condition of confining or near them, we can find “Armor”. In hydrology and geography, the armor is the association of surface pebbles, rocks or boulders with streambeds or beaches. Most commonly hydrological armor occurs naturally; however, a man-made form is usually called riprap, when shorelines or stream banks are fortified for erosion protection with large boulders or sizable manufactured concrete objects. When armor is associated with beaches in the form of pebbles to medium-sized stones, grading from two to 200 millimeters across, the resulting landform is often termed a shingle beach. Hydrological modeling indicates that stream armor typically persists in a flood stage environment (WILCOCK & DE TEMPLE, 2005).

CHURCH (1992) summarized the sediment and channel dynamics of rivers subdividing the riverbeds according to the width, with respect to the average diameter of the sediments on the bottom:

- (1) small waterways (small channels): width between 1 and 10 times the particles on the bottom;

(2) intermediate waterways (intermediate channels): the width of the riverbed is more than 10 times the particles present on the bottom (generally > 20 - 30 m);

(3) large waterways (large channels): width of large long superior (several orders of magnitude) compared to granulometric size of sediments.

Another important geomorphologic characteristic is the continuity in longitudinal, lateral and vertical directions. The continuity represent the natural functioning of the sediments transfer processes towards the valley, and depends on the connectivity between the different riverbed units:

- longitudinal continuity: sediments move downstream without significant interruptions (even if same natural obstacles are possible like: as landslides or rocky outcrops);
- lateral continuity is determined by the existence of a lateral riverbed belt of in which periodically the flooding processes allows the lateral mobility of the waterway;
- vertical continuity is determined by the continuous water exchange between the underground water and the watercourse within the hyporheic zone, which is always present when the bottom of the bed is made up of permeable sediments.

The estuarine minor riverbed could have some land forms (Fig. 6) or morphologic units (MONTGOMERY & BUFFINGTON, 1997; HALWAS & CHURCH, 2002) as:

Pool - Morphological depressions;

Dune ripple - forms in riverbeds with sandy bottom;

Riffle - Relatively less coarse sediments (gravel, pebbles), mostly submerged. Non-breaking waves (unbroken standing waves) but also possibly breakers (almost partially);

Glide (or run) - Heterogeneous sediments, even coarse, mostly submerged (possible local emerged boulders). Mostly rippled flow (if not around emerged boulders);

Bar - depositional body (lateral) emerged. Typically associated with pool and riffle (sometimes even with rapids and glides).

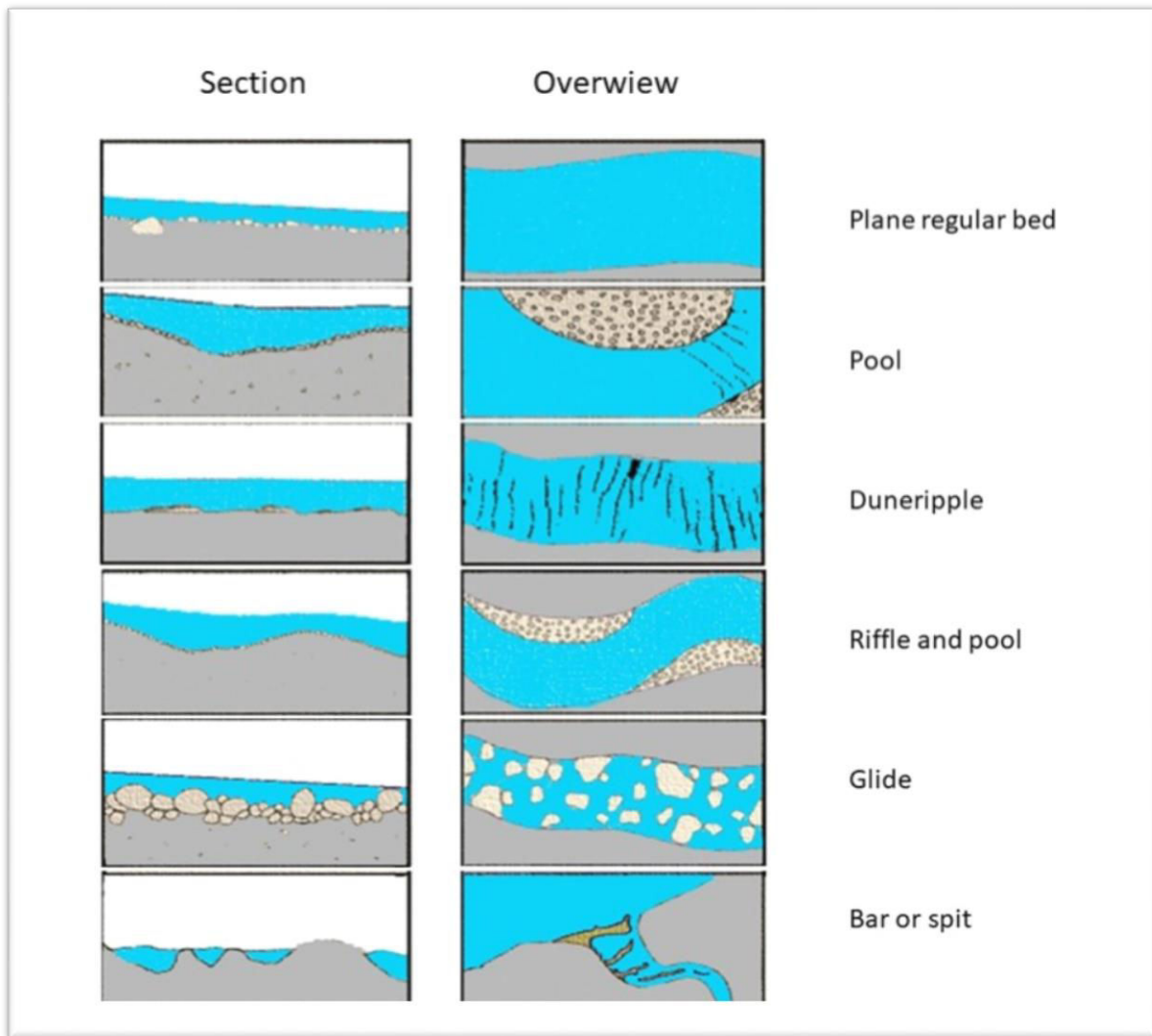


Figure 6. - Schematic of estuarine and riverland-forms (geomorphology), following MONTGOMERY & BUFFINGTON (1997) and HALWAS & CHURCH (2002).

2.3.3 General ecological and synecological aspects

Estuaries are important areas for biodiversity. They are usually an ecological hot spots for their high heterogeneity of abiotic characteristic; they are rich in biomass productivity and they consist in an important sources of ecosystem services (MUCHIUT *et al.*, 2008). They provide a vital nesting and feeding habitats for many water birds, fishes and others animals, and they provide goods and services that are economically and ecologically indispensable – for that often they are so-called “the nurseries of the sea”⁸. For the same reasons they represent sometimes a cultural and natural important heritages, like: Nile delta (Egypt); Rhone delta (Camargue, France); Gironde Estuary (France); Po delta (Italy); Venetian Lagoon (Estuary complex of some rivers, from Piave to the North, Sile, and Brenta to the south - Italy); Ganges-Brahmaputra delta (Bangladesh); Okavango delta (Botswana); Orinoco delta (Venezuela); Danube delta (Romania

⁸ <http://omp.gso.uri.edu/ompweb/doe/science/descript/whats.htm>

and Ukraine); Niger delta (Nigeria)... (CALLEGARI, 2003; HOWARD & PINDER, 2003; VALLEGA, 2003; ROSATO *et al.*, 2011),

They are places where some ecosystem mixing or overlapping; and where we can find very different ecological conditions in small surfaces, mainly following the water composition (temperature, flows, deposit, salinity...), nutrients and sediments carried by the river and sea flows resulting in an “ecosystem of ecosystems”. Estuaries can be defined at the same time as ecosystems, and as ecosystem complexes, characterized by “fluid ecotones”, whose boundaries are feeble, uncertain and mobile (in time and in space). This reflects on variable characteristics depending on water flows cycles. For that reason, limits are here only on average, usually underlined by long analysis of fresh and salty water masses movement to and from the sea, based on the main stream.

This allows the expression of multiple habitats, from marine, brackish to fresh waters ones, all them affected by salinity, humidity, tides, river floods, bank type (slope and shape), and sedimentation changes, as well as from the winds, their direction, atmospheric humidity, air temperature and the aerosol spray.

This is the place, not only of particular habitats and special dynamics, but also of endemic and typical species. Here, the estuarine Biodiversity expression is complicated by the presence of apparently conflicting characteristics coexistence (like salty and fresh waters or by dry and aquatic conditions), expressed at different time and scale. The meeting of that different ecological conditions, induces variable biotopes (alternatively in freshwater/salty or dry/flooded conditions, and combinations of them). In other hand, the meeting of these apparently conflicting characteristics at space level can make some specific combinations with more or less brackish water, with a mobile front tides depending; and more or less mesic areas (salty, brackish or fresh) depending to the average level of both groundwater and river waters. All that can happen in small on very large surfaces. The main ecological constraints conditioning the estuarine ecology are salinity, sedimentation, slopes, floods, natural disturbances and anthropogenic uses (Fig. 7).

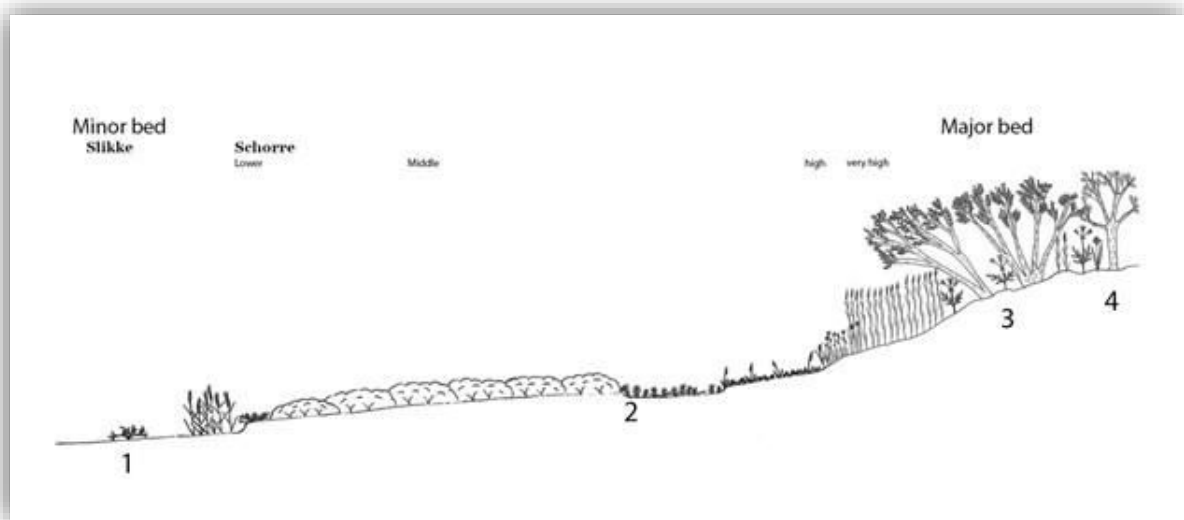


Figure 7. - An example of complete phanerophyte gradient per geomorphological position, in salty estuarine portion. Vegetation is divided as expected from literature: from 1 to 2 non woody (permaseries) vegetation; to 3 to 4 woody vegetation (holoseries).

The estuarine plant communities are characterized and distributed in a precise dynamico-catenal context: individuals of holoserries, curtaserries, and permaserries which, placed at the scale of the landscape constitute typical estuarine catena. The organization of estuarine communities and plant landscape is influenced by a mix of natural and human dynamics (land use and land conversion). The expression of the vegetation is here distributed mainly by series, according to two types of gradients: longitudinal (up-to-down) and transverse (minor to major riverbed); mainly influenced by salinity, humidity and the type of bank. Influential factors are sea winds, substrate and granulometry. These concepts are applied to understand and analyze the estuarine systems (from the sea to the dynamic tidal zone) of the French Atlantic seaboard, with ecological and biogeographical applications, with a view to understanding biodiversity and phytodynamics, applicable to the planning and natural resources. The different series and catenas are described by integrating the dynamics of the secondary succession, in order to specify the spatial organization of the communities along these gradients. An increase in biomass and vegetation structure is observed, towards the least saline and most mesophilic portions.



Figure 8 - Laïta estuary middle portion. From minor to major riverbed: the roselière community (in large sense); *Salix atrocinerea* marshy forests; and *Fraxinus excelsior* forests Upper, the zonal forests of *Fagus sylvatica*, out the estuary.



Figure 9 - Aulne estuary lower portion. The salt mud and meadows community, from glasswort, up to *Halimione portulacoides* coenoses, on salt mud tidal creeks.



Figure 10 - Laïta estuary, St. Maurice. The contact between salt mud and meadows community (*Elymus repens* and *E. athericus* grasslands) and mesic forests community (*Fraxinus excelsior* and *Quercus robur*); on sandy-mud salt tidal creeks. At the bottom, the estuarine macroalgal tidal community.

2.3.3 Global environmental risks, natural resources, human ecology, land uses, and threats

Estuarine ecosystems are degraded almost everywhere in the World (LOTZE *et al.*, 2006). The estuary is the place where the force of the river is slowed, because the tides are braking on fluvial water flow; and the river flow is broken by the tides flow. Silt plug, nutrients and organic matter concentrate here for this reason, but also the pollutants may preferentially concentrate here for the same reason. Most estuaries around the world are constantly traversed by waters contaminated by various pollutants from micro to macro types (BROWNE *et al.*, 2010). Locally and to a certain extent, also the (motor) ships and the wind can influence the composition and behavior of the silt plug (VERNEY *et al.*, 2007). River and estuaries artificial regimentation of water flows, channeling, agriculture and deforestation affect the formation and movement of the silt plug. Often causing environmental problems as a result of abnormal deposits, or out of place sedimentation.

According to DUCROTOY (2010), during years, centuries and millennia, the man made some changes in the estuaries, for business, military, marine, agricultural, fishery or human safe needs. Ports, channels, barrages, reclamation, polderization, canals, channeling, vegetation clearing, deforestation, pastures, fires, fillings, logging, urbanization, facilities, stabilization, drainage and drying, or alluvial deposition exploitation have changed volumes, surfaces, sections, flows, salinity, dynamics, characteristics, course, biodiversity and length of estuaries. Man has tried to control estuaries by fixing the banks and channeling them, making expensive dams, or reclamation activities. Making fresh the previous salty areas and vice versa; or making dry the previous flooded areas and vice versa; or diverting estuarine portions. Today, for that reason, some estuarine portions are not yet submitted to estuarine dynamics; or are they submitted to not natural (controlled) estuarine dynamics. To do this, Man mobilized natural sciences and engineering. Only in recent decades ecology, biodiversity conservation, sustainability, and social and economic sciences skills were also used trying to limit the human impact and to resolve the use conflicts derived from human activities and interests – frequently contrasting (hunting, fishing, hiking, urbanization, agriculture, biodiversity, re-wilding, habitats restoration, species reintroductions/extinctions, management, human health and wellness, farming, scientific investigation, recreation, quarries, conservation, exploitation, commerce, industries, social, cultural, infrastructures...). Not only works in rivers mouth, but also from downstream and upstream may have a big (also if delayed) impact in space and in time to the flows, biodiversity, productivity, landscape, land uses, sedimentation, functioning, and human safety. Not only biodiversity hot spot, estuaries are the most productive places of the world in terms of biomass, and plankton (CLOERN *et al.*, 2014) if pollution and man uses not mine it. For this reason, estuaries give origins to many food chains, and they are considered important feeding and reproduction sites for many species.

3. STUDY AREA

3.1. Atlantic French Estuaries

3.1.1. General description

3.1.1.1. Location and distribution

The study area correspond to the Atlantic Ocean coastline of France, located between the French Basque country to the south west (Spain-France border) and the French Flanders to the northeast (Belgium-France border). The study area, from south to north, belong in the Atlantic Ocean to the North Sea coastal zone; throw the Biscay Sea, the Iroise Sea, the Celtic sea, the Manche-English channel Sea.

This first part of our work consisted to provide a preliminary selection of study sites (Fig. 11, 12, 13) considered as being biogeographically and morphologically representative of the French Atlantic estuaries, in order to precise the typology, mapping of their vegetation and for testing the processed models of the French Atlantic estuaries plant landscape.

Thirty-six estuaries were considered in a preliminary study, distributed along a latitudinal gradient from southwest to northeast:



- 1- Gironde;
- 2- Loire;
- 3- Seine;
- 4- Basse-Normandie estuaries (hâvres):
 - 4a- Vanlée;
 - 4b- Regnéville;
 - 4c- Blainville;
 - 4d- Geffosses;
 - 4e- Surville;
 - 4f- Saint-Germain-Sur-Ay;
 - 4g- PortBail;
 - 4h- Carteret;
- 5- Picardie and “Nord-Pas-de-Calais” estuaries:
 - 5a- Somme;
 - 5b- Authie;
 - 5c- Canche;
 - 5d- Liane;
 - 5e- Wimmereux;

Figure 11. - The main estuaries sectors of study

- 5f- Slack;
- 5g- Calais;
- 5h- Aa;
- 5i- Dunkerque Port;
- 6- Charente;
- 7- Autres estuaires de Aquitaine:
 - 7a- Adour;



Figure 12. - The Manche sub-sector estuaries

Penfeld River, “Ruisseau de la Baie des Trépassés” river, and “Ruisseau du Caro” river estuaries were also studied to test observations and models, looking for any possible differences in very small estuaries

- 7b- Courant de Mimizan;
- 7c- Nivelles;
- 7d- Bidasoa;
- 8- Estuaires de Bretagne:
- 8a- Rance;
- 8b- Blavet and Scorff;
- 8c- Laïta;
- 8d- Abers (I -Vrac’h; II- Benoît; III- Ildut);
- 8e- Elorn;
- 8f- Aulne;
- 8g- Vilaine;
- 8h- Ria d’Étel.



Figure 13. - Brittany sub-sector estuaries

3.1.3 Principles and State of knowledge on vegetation

The description of the sigmeta and geosigmeta units of the landscape requires a preliminary good knowledge of the plant associations, that represent the fundamental units composing the territory (BÉGUIN & HEGG, 1975, BÉGUIN *et al.* 1979, GÉHU 1987, 1993, BÉGUIN 1998, 2003).

A recent wide review of phytosociological and plant landscape works carried out on French Atlantic coasts was done by DEMARTINI (2016). Her work has been used as a basis for the coastal vegetation overview, for the interpretation of the actual knowledge on coastline vegetation. We integrated a bibliographic review on French Atlantic estuaries and rivers literature, according to the coastline-inner land geographic gradient in estuaries.

Beyond the most strictly coastline bibliography applicable to estuaries already dealt with in DEMARTINI (2016), references and publications has been analyzed to precise the state of knowledge, about vegetation description, distribution and dynamics in our study area, following the interest in plant community issues along the geographical gradient towards the innermost estuarine territories systems... Thematic works can involve sometimes more than one estuary. Only few works were carried out to describe single estuaries, or mainly portions of them: not

always using phytoassociations. More generally papers deals on punctual or thematic studies, linked to species, associations, habitats or on limited geographic portions of estuary systems. Other papers concerned on flora or vegetation, studying species, biodiversity or human impact, focusing on species presence, macrophytes, habitats (*sensu* Natura 2000), or on a too generic or just physiognomic plant landscape (i.e.: marshes, fen, roselière, megaphorbs, meadows, salty, shrubland, woodland, synantropic environments).

We can group the studied papers per largest estuarine system: “Seine estuary”, “Loire estuary”, “Gironde estuary” and “Others” types. “Others” not only refers to the works carried on others smaller estuaries (or almost a portion of them), but also on thematic studies of interest for estuaries, or papers concerning at list one portion of more than one estuary.

Seine estuary

FRILEUX, 1978; LE NEUVEU, 1984; FRILEUX *et al.*, 1989; CHABRERIE *et al.*, 2001; MOUSSARD *et al.*, 2008; GIP SEINE-AVAL, 2011, 2014; LEVY *et al.*, 2012; LAVABRE and FISSON, 2013

Loire estuary

DEMAURE, 1979; CORILLION, 1981, 1989, 1991, 1992a,b; GRAS, 1981; DUPONT, 1981, 1986, 1990; DUPONT *et al.*, 1983; BECKELINCK, 1986; VOELTZEL, 1987; LEROY, 1989; BARREAU, 1996a,b; MAGNANON, 1991; MAGNANON *et al.*, 1998; LEBRET, 2001; CORNIER, 2002, 2003; CHADENAS *et al.*, 2009; SAWTSCHUK and BIRET, 2012; MOATAR and DUPONT, 2016; LE DEZ *et al.*, 2017a;

Gironde estuary

LAHONDÈRE, 1996, 2005

Somme

GÉHU *et al.*, 1976; GÉHU & GÉHU-FRANK, 1979; GÉHU & MÉRIAUX, 1979; MOREAU, 1992; DUCROTOY and KALAORA, 2009; DUCROTOY and KALAORA, 2009; GÉHU & DELAPORTE, 2008; GÉHU, 2009a,b; MEIRLAND *et al.*, 2013; MEIRLAND, 2015;

Others

HOCQUETTE *et al.*, 1965; GÉHU & GÉHU-FRANCK, 1972, 1982, 1985a,b; GÉHU & GÉHU, 1976, 1978; GÉHU, 1979, 1991, 1994, 1995, 1998, 1999, 2006b, 2007, 2012; MUCINA & POPMA, 1982; DE FOUCAULT, 1984, 1994, 2011; RAMEAU *et al.*, 1989; GÉHU & BIRET, 1992; BIRET *et al.*, 1993, 1995; LAHONDÈRE & BIRET, 1997; BOURNÉRIAS *et al.*, 1999; LEFEUVRE *et al.*, 2000; BOUGAULT *et al.*, 2001, 2003, 2004, 2005; BIRET, 2002; FAY *et al.*, 2003; LOUCOUGARAY *et al.*, 2004; BARDAT *et al.*, 2004; DUPONT, 2005; VERGER, 2005; DUCROTOY, 2007, 2010; CATTEAU *et al.*, 2008; DUCROTOY & DAUVIN., 2008; DAUVIN & RUELLET, 2009; BONNOT-COURTOIS & LEVASSEUR, 2012; DE FOUCAULT & CATTEAU, 2012; DE FOUCAULT *et al.*, 2012;; DESMOTS *et al.*, 2015; FERNEZ & CAUSSE, 2015; CIANFAGLIONE & BIRET, 2018; DELCOIGNE & THÉBAUD, 2018.

The bibliography was analyzed to make a review, to synthesize the state of knowledge on estuaries vegetation, to define a first idea before the successive fieldworks step, and to

understand how estuarine plant associations could be distributed (and vary) along the estuarine gradients.

A first bibliographic analysis shows that if compared to the most coastline portion, less is known about the complete estuarine vegetation set and distribution. This bibliographic research underlined also how the research result could be easily affected by the inaccessibility of references (i.e.: grey literature, unpublished works...).

Following DEMARTINI (2016), the dynamic-catenal phytosociology, by its capacity to understand the complexity of the vegetal landscapes by integrating various scales of analysis without loss of information, appears relevant to answer our objectives of typification and cartography of the littoral systems. By highlighting the syntaxa richness of estuaries (within the β -biodiversity), this bibliographic study shows a good basic knowledge on this environment; but rather linked to portions of estuarine territories or on precise themes. It also pointed out a lack of studies on the most complete vegetation set assembly (distribution and variations) along estuarine gradients.

3.1.4 Human impact, modification of land forms, and historical uses

Over centuries, the French Atlantic littoral space inspired a feeling of repulsion, of attraction, or both at the same time – depending on the historical period, and cases. This was not without consequence on the natural environments (BOUSQUET, 1970; RENARD, 1970, 1974, 1977; REGRAIN, 1977; LEFEUVRE, 1983; HALLÉGOUËT *et al.*, 1986; MIOSSEC, 1987, 2004; OTTMAN, 1987; PETIT-BERGHEM, 1996, 1999; ELLIOTT *et al.*, 2007).

In the past, the estuaries were subject to intense deforestation and clearing for livestock or crops; and more recently they experienced more or less significantly urban, industrial, navigation and touristic development, depending on the region (PERRIN, 1928; HINSCHBERGER & CLARY, 1979; LEFEUVRE, 1983; MIGNOT & LE HIR, 1997; PRAT & SALOMON 1997; DUCROTOY *et al.*, 2000; PETIT-BERGHEM, 2004; MEUR-FÉREC, 2006, 2007; GEFFRAY & KAUPE, 2012; LE BAIL & LACROIX 2005; DUCROTOY J.-P., 2018). Dam, embankment, filling, polderization modified strongly the estuarine systems for navigation, agriculture, urban and touristic purposes. This not only created an anthropized environment that reflect the modification of the landform and the expression of vegetation, with serious upheavals for human use, such changing in water flows causing critical erosion, excessive mud-silt deposits, and the salty water up-shift, (LE RHUN & PRIOUL, 1983; LEFEUVRE & LE DÉMÉZET, 1984; TERRISSE & CHAMPION, 2008; DUCROTOY & DAUVIN, 2008; DUCROTOY, 2010). The changes in agriculture also led to other new impacts with the establishment of intensive forage crops, barrages, and the cadastral particles reassembly with the related disappearance of traditional Bocages (hedgerows), groves and bosks (RENARD, 1973; CROIX, 1978; COLLINEAU, 1978).

This led to a high modification of the vegetation expression (DAUVIN & RUELLET, 2009), enhancing the difficulty of detecting anthropogenic stress in naturally stressed areas (ELLIOTT & QUINTINO, 2007). The vegetation changes led to the point of creating various secondary formations and in some cases even to lose the traces of the potential vegetation in plant series individuals, increasing the problem on vegetation interpretation and vegetation communities potential understanding: according to PERRIN *et al.*, (2018) even affecting the natural biological potential (architecture) development of plants (i.e.: trimmed trees; trees known as shrubs; forests as Bocages...).

Since the Middle Age to actually as marshes and rivers were transformed for agricultural purposes, estuarine flow started to be regulated for these purposes (REGRAIN R., 1977; RENARD J. 1977; LEFEUVRE & LE DÉMÉZET, 1984; DUCRTOTOY, 2018; OTTMAN F., 1987). The industrial revolution and the related urbanization has amplified the urban-industrial-port vocation of the main estuaries of the French Atlantic coast (OTTMAN F., 1987; CROIX N., 1972; VIGARIÉ A., 1977; HÉDELIN M. 1984; DOODY, 2001; BEAUMAIS & LAROUTIS, 2007). This led to further management, impacts and land forms change. Also the wastewaters have a strong influence from productive industrial system, agriculture-livestock activities and urban areas. In estuaries, it is possible to find important traces even of human pharmaceutical compounds accumulation (THOMAS *et al.*, 2004).

In general, larger the estuaries are, and more likely they have been profoundly modified for navigation purposes because some cities and ports were developed along the estuaries.

Small estuaries are often appearing closer to a more natural aspect; almost more than the largest ones (GUILCHER *et al.*, 1982), even undergoing human modifications (deforestation, pastures, pollution, barrages, canalization, reclamation, and others land form adjustment). Small estuaries were more subject to barrages and dams. After the 80s, they undergone further impacts following the strong development of small ports, especially Harbors and Marina for recreational (MAUVAIS *et al.*, 1991; SONNIC, 2005).

3.2 General description per Estuary

In this section, for the hydrologic and geomorphologic description of estuaries (unless otherwise indicated) we basically makes reference to: IGN Geoportail database (<https://www.geoportail.gouv.fr/>), SANDRE database (Service d'administration nationale des données et référentiels sur l'eau)⁹, and the French technical reference system of the water information system (SIE); in accordance with the Decree N° 2009-1543 of 11 December 2009. For the geographic, geologic and geomorphologic features unless otherwise indicated we makes reference to Geoportail database and IGN.

For the land use, topographic issues and others environmental factors, unless otherwise indicated we makes reference to IGN topographic maps 1:25 000, IGN aerial photos and field relevés.

According to the main estuaries subdivision in big and small estuaries followed in this work, between Macrotidal estuaries we can analyze the problems and environmental characteristics of the study estuaries as follows.

3.2.1 Largest estuaries

3.2.1.1 Gironde

Is the biggest (largest and longest) macrotidal estuary of our study area. It is a double estuary (with one common river mouth to the sea) formed from by Dordogne and Garonne rivers, meeting together just downstream of the Bordeaux City. The Gironde estuary is almost

⁹ <http://www.sandre.eaufrance.fr/missions-et-organisation-du-sandre>

80 km long and its wide range from 3 to 11 km. Covering around 635 km² it is the largest estuary in western Europe.

Located in southwest France, the Gironde is a navigable estuary. It is subject to strong tidal currents and great care is needed when navigating the estuary, especially because of strong tidal bore possibility. The Gironde watershed is very large, covering more or less 80 000 km². The Garonne river is the biggest river flowing in the estuary; with an average flow of 650 m³/s (Bec d'Ambès, Gironde); the Dordogne river is the second; with an average flow of 380 m³/s (Ambès). The estuarine watershed portion is relatively sparsely populated and unindustrialized, if compared to others French estuaries; maintaining a relatively natural balance manifested in a well-established geomorphological stability and low pollution rates. The main sources of pollution (ROUX, 1992) or risk and the related warming of the water due to the cooling of the nuclear power plant. Navigation purposes that resulting from dredging and channelization of port accesses. The reception of pollutant in estuary it is the result of human (industrial and agricultural) activities on the whole of its watershed (ROUX, 1992).

Land use is predominantly agricultural (crops, aquaculture and pastures). The landscapes between the left bank and the right bank are very different (REUNGOAT *et al.*, 2014). On the left bank (Macau to the Pointe de Grave), an alluvial plain is developed, fed by gravel from the Pyrenees. Here vineyards landscape is dominating. Near the sea, the vineyards give place to dunes and some marshes. On the right bank, the landscape is less gentle; with some cliffs and hills. Vineyards are less present (if not on terraces). To the north, large swamps areas extend.

3.2.1.2 Seine

Seine estuary catchment basin is average 79000 km², where are living 30% of the French population including the agglomeration of Paris, where 40% of the national industrial activity is installed. A small channeled affluent, the Risle river, insists in the Seine estuary. The urbanization surface of this estuary mainly corresponds to the “Le Havre” and Rouen conurbations, functioning also as ports of Paris. Following ROMAÑA (1992) and GOUJON (1992), as a result, for many years, this estuary has been under serious pollution problems. In addition, the importance of its infrastructure role as navigation channel has been the cause of innumerable transformations. The Seine river average flow is of 563 m³/s (Le Havre). The channeling of the Seine in favor of the port of Rouen induces a modification of the natural environment. The embankments make the wetlands disappear for the benefit of the industrial sites managed by the port of Le Havre. Mudflats disappear following the modifications upstream and cannot replenish downstream. Major works on the riverbed contribute to amplify the natural filling phenomena. The Seine estuary has been completely directly and indirectly reshaped by man, mainly during the two last centuries (NICHOLS & ALLEN, 1981).

3.2.1.3 Loire

Loire river drains a wide watershed (average 117 356 km²). It is the main river flowing in the estuary with a flow of 931 m³/s at Saint-Nazaire. Two small rivers are connected to the estuary (Sèvre Nantaise - 24,7 m³/s; and Erdre - 2,5 m³/s, both measured in Nantes). More downstream near Saint-Nazaire, the Brivet river flows into the main estuary. This small river is channeled, with locks. Its flow is unknown also for these reason, but it is not remarkable.

At the beginning of the XXth century, the Erdre river also underwent modifications so that its last 500 meters were filled up and became one of the main road axes of Nantes. The

Erdre now passes through the Saint-Félix canal-tunnel under the City up to the Loire (CROIX, 1972). There are two barrages, Pont-Rousseau dam and Vertou lock. Built in 1995 to replace the oldest dam carried by the flood in 1962, the dam Pont Rousseau maintains a more or less constant water level upstream, to limit the effect of tides; it is passable at high tide levels (DUPONT, 1981, 1989c; LEBOT, 2006)

As happened in general in all the French estuaries, during the time also the Loire estuary has undergone significant changes linked to the development of human activities (embankments, deepening of the river bed...) (DEMAURE, 1979; OTTMAN, 1987; CROIX 1972, 1978; COLLINEAU, 1978; CHAUVET, 1984). These developments have resulted in the gradual filling of the secondary branches of the river, the attachment of many islands to the shore, and a rise of the salinity front upstream (VERGER, 2005). Following LEROY and FERA (1992), the last fifty years have seen the maritime vocation of the estuary favored with the deepening of the navigation channel from Saint-Nazaire to Nantes and the development of large areas of urban-port-industrial activities along the river (HÉDELIN, 1984). At the same time, large sand extractions were allowed in the estuarine bed to respond to this development, with major consequences on the hydro-sedimentary functioning of the estuary (MIGNOT & LE HIR, 1997; MAGNANON *et al.*, 1998; LE BAIL & LACROIX, 2005; GEFFRAY & KAUPE, 2012).

Various effects occurred as a result of all this listed activities:

- the estuary rise, nearly to 25 km upstream of Nantes, with an upstream penetration of salty and brackish waters;
- the lowering of the low-flow water line, of several meters;
- an increase in currents and a significant erosion of the banks;
- an extension of the muddy plug, with an over deposition of sediments, as well as the mud filling of the secondary associated hydraulic systems (canals, docks, marshes...);
- the reduction of lateral hydraulic exchanges.

These phenomena have reduced the natural system functioning while discharges of industrial and urban wastewater have increased. This reflect on strongly changes endangering or destroying the wetland complex linked to the Loire estuary (LE DEZ *et al.*, 2017b; CIANFAGLIONE & BIORET, 2017), often also causing a huge die-back process on plants. The lateral hydraulic diminution affected also the slikke and Schorre surface reduction (GIP LOIRE ESTUAIRE, 2014) and the plant and vegetation trends; the riverbed was completely channeled and almost reshaped (including the river islands), some places were filled or reclaimed and some barrages were installed to regulate water flows (VERGER, 2005). The human modifications caused an upshift of the salty portion, together with a simplification of the wetland geomorphologic complexity, and reducing the habitat connectivity (CIANFAGLIONE & BIORET, 2017). Various wetlands once connected to the estuary and tides are now disconnected or limited. The largest urbanized surfaces consist in Saint-Nazaire, Nantes, Angers and Ancenis conurbations. The main soil use is pastures and meadow. Farming-linked activities occupies important surfaces; crop surfaces are increasing by climbing the river up to Nantes.

3.2.1.4 Somme

Following MOREAU (1992), the “Baie de Somme” Bay is the largest of the estuarine macrotidal complexes of the northern France. Its area is 7200 hectares and is located in a seaside transitional landscapes where the estuarine dynamics influenced the land forms. To the south, the steep cliffs on the sea extend the coast of Haute-Normandie and give birth to a shoreline of

pebbles. In the North, the sedimentary coastline is characterized by large dunes and sandy beaches. The hydrographic network complex of the bay is divided into four main units:

- the Somme and its “Contre-Canal” channel (32 m³/s);
- the network of “Marquenterre South”, grouping in the “Canal de la Maye” (1,5 m³/s);
- the network of “Bas-Champs de Cayeux”, resulting in the “Courant à poisons” (0,6 m³/s);
- the Maye (0,3 m³/s).

Following MOREAU (1992), the “Baie de Somme” estuary is divided into three geomorphologic sectors:

- a sandy underwater delta;
- an average bay with sandy bottoms covered by many channels, and divulging courses rivulets (Slikke);
- an often emerged area, except at the time of high water tides, characterized by dense herbaceous vegetation (Schorre).

MOREAU (1992) underlines how that the “Baie de Somme” is threatened by eutrophication and silting, phenomena aggravated by a low sanitary quality that limits swimming and the development of shellfish farming. From 1988, the first water quality results of the Bay confirmed the pressure of the continental inputs for bacterial pollution, nitrates and nitrites. The mass mortality phenomena of the benthic fauna, observed in 1989 and 1990, is a consequence of this eutrophication (MOREAU, 1992).

3.2.1.5 Charente

If compared to the other big estuaries with large rivers, the Charente watershed is relatively small, with a surface of average 10500 km²; and an average water flow of 40 m³/s. The Charente river is a relatively short river (360 km long); and it has a small difference in elevation since its source and the estuary of only 300 meters. We integrated the geomorphology and hydrogeology characteristics following the project of water management of the Charente watershed (EPTB CHARENTE, 2009) info. The watershed basin is influenced by important groundwater resources due to sedimentary formations to numerous shallow depths aquifers. These resources are particularly vulnerable to climatic hazards and pollution. In addition, the rather warm climate generates a strong evapotranspiration explaining the absence of recharging groundwater in summer and salinification of soils in dry periods in estuarine position. On the other hand, heavy autumn rainfall is absorbed by the permeable karst-type corresponding to a large part of the basin. The risk of flooding then appears only when the superficial aquifers are saturated. The watercourses of the basin, although fed by rainwater, have their flow strongly supported by groundwater. The low river water period is generally from June to September. Low water levels are particularly severe and are related to the nature of the limestone substrate of the aquifers, combined with the absence of rain during the summer season. This problem is accentuated by anthropogenic impact, mainly from agriculture (57%) or for drinking water (34%) withdrawals, which cause an acceleration of the dry-up phenomenon as well as its prolongation over time. Depending on the occasion, water taking could reach between 50 and 100% of the low water volume.

The Charente estuary littoral marsh sub-basin undergone various changes and human impact (REGRAIN, 1977); in any case it results less affected by the watershed average drying-up in year, because more rich in water and because the waters taken upstream of Saint-Savinien are released after the uses. Floods of the Charente, in other hand occurs in winter (December to

February), they can reach 800 m³/s downstream of the basin. The peculiar physiognomy of the Charente, with a small bed of small section with limited flow capacity and a very flat bed, favors slow flooding that spreads over large surfaces and at a low height, with a very slow recession. Finally, most rivers have been subject of many modifications, such canalization, dams, mills, recalibrations that have changed the general hydro morphology of the Charente and its tributaries.

The estuary of the Charente is a macrotidal estuary, 3 km wide at its mouth and with many lateral well developed slikkes areas are discovered at low tides (TESSON, 1973). The tidal range is 7m for the highest coefficients (> 100).

BOEUF (1949) and SALVADOR (1976) described the clash of marine and freshwater in the inner estuary. Water fluxes were studied by PINARD (1965); LE MOINE *et al.* (2012); LE MOINE & GEAIRON (2013). RAVAIL-LEGRAND (1993) and MODÉРАН (2010) studied the areas of influence of estuarine waters on the basin and their consequences in the water ecological system. The limit of the penetration of the dynamic tide in the estuary is 82 km from its mouth but it was modified by the construction of a dam at Saint-Savinien, 50 km upstream from the estuary mouth (SCHMIDT *et al.*, 2010). However, this dam does not run when the tidal coefficients exceed 70 to avoid excessive flooding downstream areas. Tidal penetration in the estuary is lagging, depending on the coefficient and river discharge. The brackish water extends approximately 30km (from the mouth): the estuary is partially mixed during the flood periods and well mixed during the low water periods. The suspended matter concentrations during a tidal cycle can exceed several grams of dry matter per liter at the surface at the upstream limit of the saline intrusion, forming a dense muddy plug (PROUST, 2004; TOUBLANC *et al.*, 2014). As in the Gironde estuary, this is mainly influenced by the tidal bore and related asymmetrical tidal wave (SOTTOLICHIO & CASTAING, 1999), migrating longitudinally according to river flow and tidal cycles, moving between Rochefort and Port des Barques.

3.2.2. Smaller estuaries

3.2.2.1. Brittany estuaries

Aulne estuary complex

The Aulne estuary complex is the biggest estuary of the Brittany in the Département of Finistère (25 km). This estuary is composed by several rivers, marshes, bight and bay - generally related to a torrent or rivulet. Some pebble bars exist in this estuarine system, like the: “Loc’h” bar, “Sillon des Anglais”, “Pal”, “île d’Arun” bar, “île de Tibidy” bar, “île de Térénez” bar. The main rivers flowing in the Aulne Estuary are: “Châteaulin river, also known as Aulne or Aon river, Faou river, Keroullé river, and Camfrou river.

The Aulne river is the main river flowing in the estuary. Its name derives from the word “Aon” coming from ancient Celtic language meaning “River”. At the left side of the Estuary mouth, is a small rivulet called “Loc’h River”. In Breton language, the word “Loc’h” means an arm of the sea, an estuary or a coastal pond in Breton language. This toponymal is exactly reflecting the original meaning. The Loc’h sub-estuary it is a very particular formation because it corresponds to a complete estuary in miniature, reflecting in a complete vegetation distribution cline and a complete sedimentation gradient from pebble and shells bars to the inner sandy muddy surfaces. Here an example of vegetation exception, consisting in a *Prunus spinosa*

and *Ulex europaeus* as a head series (a truncated series due to substrate conditions and natural environment rise) was observed, as it is for the close “Sillon des Anglais” a pebble to mud, and shells bar observed during field works. The double pebbles arrow ‘bar’ of “Loc’h” between the marshy portion and the sea, has undergone significant changes in recent years by marine exceptional erosion events (storms), being increasingly exposed to the sea waves (STEPHAN *et al.*, 2005). “Le Sillon des Anglais” is changing too, observing a decline of the vegetated ridge especially in a few specific points. These field observations indicate an erosion of sites by the sea and their vulnerability to marine submersion. In any case these bars and related systems are fragile and instable, due to their nature (STEPHAN *et al.*, 2005)

The uppermost important affluent is “Douffine” river, with some other minor rivulets like: “Folgoat”, “Roskoat”, “Neizig”, “Garvan”, “Roudou Hir”, “Cabeuric”, “Rozarnou”, “Stang”. And related bay or marshes. All this geomorphologic forms combination makes the Aulne estuary a very branchy and complex system.

In the Aulne, the granulometric differentiation between the main axial channel (geul) and the slikke is clearly evident almost in the two-thirds downstream; however, the granulometry considerably decreases in the minor riverbed, in the upstream third position near Logonna-Guimerc'h, especially upstream of Lanvian, and even, in the downstream part of the concave bank of the Trégarvan meander (GUILCHER *et al.*, 1982).

Faou

The Faou river affluent is 4.5 km long and widely opened (750 m) on the eastern end of the Brest harbor, yet barred at halfway by a mid-bay bar (GUILCHER *et al.*, 1957) that an exceptional storm of January 1974 strongly jostled: as a confirmation of the fact that these formations cannot be considered as stable in nature. Following GUILCHER *et al.* (1982), the Faou estuarine branch is a typical case of fine-grained (muddy) estuary in all its parts, in which the distinction between slikke, Schorre and minor riverbed is not distinctive in granulometry and sediments type. The large section of the estuary can account for this a lack of differentiation (slow tidal current despite the mid-bay arrow). Sands and Shelly fragments fronts are mixed with the mud, in less abundance than in the Châteaulin River. The facies of the shore strikes are the same as usual (angular fragments at the foot of low head cliffs). Furthermore, like the Châteaulin river branch, the banks are bordered by small active cliffs portion, with related head elements, and Devonian schists debris; according to sedimentology indices, this estuary bears witness to quite strong marine dynamics influences, at least in its shores, almost at the high sea levels – especially in its lowest part. Like others branches, also this one bears estuarine arrows (bars) (GUILCHER *et al.*, 1957; GUILCHER, 1973; ANDRADE, 1981).

Camfrou

The Camfrou River also known as river of Hôpital-Camfrou is another Aulne estuarine branch 4 km long, and 430 m large at its confluence. The port of L'Hôpital-Camfrou was an active fishing port in the past, now active especially for touristic purposes. The village is 6 m above sea level and is in the background of Ria (Ria is a local word for small rivers and estuaries). According to GUILCHER *et al.* (1982), the river cuts a Middle Devonian friable schist, with a muddy sedimentation. Between the hamlets of Rosmorduc and Kerascoet, the estuary is affected by a strangulation with stiffening of the banks, because of veins of Kersantite in the shale. This results in an acceleration of the tidal current and the increase of the granulometry. There is also an increase in the gravel fraction, and in the mineral/shell fragments ratio.

GUILCHER *et al.* (1982) affirm that the maerl formations are absent from the whole Aulne estuary (meander of Landévennec included); in the Rivière du Faou, it is found only at the entrance, front of Lanvoy and Prioldy, in small quantities. In the Hôpital estuary northern branch, the maerl is very abundant: from the mouth to Hanvec, then it becomes scarce, and disappears completely. During field prospections we found maerl beds relatively developed in the “Le Pal” bar surroundings, at Landevennec. We considered the maerl as part of slikke and Schorre (Shore) communities, during our zonation study.

The main settlements of this estuarine complex system are: Hôpital-Camfrout, Le Faou, Landévennec and Châteaulin towns. The Estuarine portion is reduced at 18 km between Châteaulin and Rosnoën because of the “Barrages de Gully Glas” dam that regulates the water flow. Aulne estuary flows into the bay of Brest with some others rivers like Elorn and Penfeld.

Elorn

The Elorn is an estuary that derives from a river with the same name, flowing into Brest harbor - in the Atlantic Ocean. It is 14 km long, with an estuarine mouth of 1 km large, over 700 m after the Pont de l'Iroise. The estuarine portion stops at Landerneau, where the Rohan inhabited bridge, prevents navigation and regulates the flow of water upstream. It is one of the last French rivers where Atlantic salmon fishing is still possible, despite the recurring pollution of which it is the object. This estuary is very open on its mouth to the sea and is subjected to very marked sea currents, in fact dominating pebbly or rocky outcrops, which inner land let place for gravels then sandy sediment and mud. The estuarine bed is at least for three quarters of its course excavated in the rock or in the surrounding ground.

Blavet-Scorff double estuary

The Blavet-Scorff estuary flow into the Atlantic Ocean after the meeting of Blavet and Scorff rivers at Lorient City in the same estuary. Up, from Lorient to Inzinzac-Lochrist, there is the Blavet estuarine branch, stopped by a dam barrage. From Lorient up the Pont Scorff, there is the Scorff estuarine branch. In the lower estuary, the Ter small river flows into the estuary in the left side; while in the right side the “Anse de Gâvres flow in it, supplied by some torrents and rivulets. This estuary is sandy and muddy to the mouth and excavated in cliffs for its middle part. The upper part is from fluvial bed type geomorphology.

Within the estuaries with a prevalently sandy sedimentation, we can cite:

Abers estuaries

The Abers estuaries are rias (Torrent) type estuaries that cut the coast, and for that reason similar in some ways to fiords. They show a remarkable tides effect. At high tide levels the water came quickly very upstream, while at low tide, the Abers remains almost dry, discovering quickly its bottom.

The name “Aber” comes from the Breton, designates a confluence, but also the estuary mouth to the sea. This word appears also in compositions as it is for the city of Quimper (ken + aber = Kember, Kemper) and of other localities like Quimperlé (Kemperle)

The Aber-Benoît and the Aber-Wrac'h, are separated by the Sainte-Marguerite peninsula. The Aber-Wrac'h is 32 km long estuary. The Aber Benoît is 8 km long. The Aber-Ildut is 2 km (GUILCHER *et al.*, 1961; ANDRADE, 1981) long. They are relatively small and deep-water waterbodies. Aber-Wrac'h is the largest of the three Abers of the north Finistère coast, while the Aber-Ildut is the smaller one. Aber-Ildut is the smaller of the Aber triplet; it is denominated

in Breton, Abéric (Aberig) meaning “little aber”. On it, the port of Portsall (Ploudalmézeau municipality) is established.

According to GUILCHER *et al.* (1982), the Aber Benoît comprises two different geomorphologic parts: downstream and upstream of the Tréglonou bridge, which corresponds approximately to three-quarters and one-quarter respectively. Very recent artificial dredging modified consistently the downstream part. Sands with limestone exists all across the width of the estuary. With some rocky outcropping and pelitic presence patches. On the other hand, on the right bank the limestone content could be zero, with also an absence of the pelitic fraction. This could be explained by the head cliffs supply, and leaching process.

In the upstream quarter, and in the pockets like that of Locmajan, the contrast is evident: sliques and Schorres are more pelitic, and the limestone content decrease. For GUILCHER & BERTHOIS, 1957; GUILCHER, 1967 these sediments come mainly from the pelitic particles from the head cliffs of the estuary. Here again, sedimentology is therefore very indicative of the geomorphologic processes, showing the most inner influence supply about sediments.

Aber Ildut bed is excavated in the pink porphyry granite rock. The bed of this stream contains a series of rocks alterations. In the currently maritime part, there are two estrangulations (narrow passages), one just at the sea entrance, and the other across the Lanildut Church, with a basin between them, where the sedimentation process is consequently different.

Until the Second World War, the downstream part of the marine basin was rich in sand, and discovered at low tide. This sand was dumped just after the war by specialized boats for the reconstruction of the city of Brest, so it became an artificial body of water several meters deep. The original natural situation was therefore similar to the actual downstream parts of the Goayen and the Laïta, but on a much shorter length, and with a more rapid passage to a pelitic mud upstream. In any case, this sand is to be considered a sea water supply, very rich in limestone, and for that appreciated in construction (GUILCHER *et al.*, 1982). Perhaps it had come from upstream, where a Pleistocene and superabundant tertiary source existed in a much larger basin in the marshes of Saint-Renan (GUILCHER & KING, 1961; CHAURIS & PLUSQUELLEC, 1980), in this case it could be considered as an estuary with sandy embankment of inverse origin as the usual.

Laïta

The Laïta river, or river of Quimperlé is a 16 km long estuary between Finistère and Morbihan departments of Brittany. It represents the estuary of two main rivers (Isole and Élle) both taking part in the Laïta estuary only for their lower portion, corresponding to the confluence at Quimperlé city. The city has indeed been subjected to recurring exceptional flooding. This problem was amplified as a result of the forest logging and the rarefaction of groves and bocages due to agricultural development policies, to the point of reaching decisions to safeguard and reintegrate these formations by new programs and policies targeted by local communities trying to countereact this problem (i.e.: Stratégie bocagère du Pays de Quimperlé. Programme Breizh Bocage 2015-2020).

Along the estuary, numerous other minor affluent are homogeneously distributed to its marine mouth, but sometimes subjected to barrages. For the sedimentology and morphology of this estuary the thesis of BERTHOUS (1964) and OLIVIERO (1978) were taken as reference. The Laïta is one of the sandiest type from the study area together the Étrel estuary. The main channel is sandy all along (medians: 180 to 900 μm); the deadest water parts (slowest water flux) like bays and lateral branches are muddy. Moving up a sandy cobble deposits are

dominating at level of the rocky outcrops of the D224 bridge. Up, sandy sediments dominate, till to muddiest deposits to Quimperlé. Slikke and Schorre consequently are generally sandy, with gravel or muds mixed portions following water fluxes, then muddiest. The calcium carbonate content is zero in the upstream two-thirds; downstream, it increases along the vast banks sediments typical of this estuary (reaching 5 to 25% approximately), with a mixture of mud; sand and pebbles. The deposition of marine sediments in the estuary is remarkable in size deposits (pebbles) and in the inner position of the deposits carried by the sea flux.

Étel

Étel estuary is a small bay containing some islets, whose mouth is located at the level of the Étel and Plouhinec municipalities (LE LAN, 2014). In total, the Étel River is average 35 km long. Its estuary covers 22 km² and it is 15 km long. From the origin to the sea, the river widens at Nostang municipality and the influence of the tide begins to be clear. Shortly after joining the Landévant river and the Ster channel in Istrec at Locoal, the aber of the river begins to be very large and the Étel estuary widens strongly. The estuary then crosses Belz municipalty. North of the village of Étel, the estuary is joined by the Sac'h River, a small tributary.

Due to the large volumes of water that are displaced by the tides, the estuary is the seat of violent currents. Its mouth is characterized a moving position sandbar “bar of Étel”, a famous underwater sandbank formed by the crossing of currents. This bar makes navigation very difficult, and for that reason, a semaphore was built in 1960, on the Plouhinec side, in order to safely guide the sailors towards the entrance to the estuary.

Vilaine

The Vilaine estuary_area of its watershed is around 11000 km² with an estuarine flow (Arzal) of 80 m³/s. Throw into the Mor Braz, between the Billiers village on the right bank (north side), facing the lighthouse of Penlan and the Pénestin village at a place called Le Halguen, on the left bank (south side).

The estuary is now closed by the dam of Arzal built in 1970s, in order to channel the regular floods of the Vilaine River, caused by rising tidal waters that severely restricted the flow of river water. It gave place to the port of Arzal on the right bank, and those of Camoël and Férel on the left bank (MENOZZI & RAPILLARD, 2011). This dam has created a freshwater zone upstream of it, where Vannes, La Baule and Saint-Nazaire conurbations capture actually an important part of their drinking water. The dam has two different main objectives according to the season. In summer low-water period, the dam maintains a sufficient level of water, ensuring drinking water supply. The locks opening is limited in number and is done avoiding the entry of salty water, even if a siphoning of the lock is operated to evacuate the salt water brought by a North-South lift). Navigation is therefore very limited. In winter floods, the dam evacuates the maximum amount of river water at low tide. The locks are closed and opened at special times, to prevent the tides rise. Navigation on the water level and in the mouth then becomes dangerous and prohibited during the extended opening of the locks. The Vilaine estuary upstream of the Arzal dam has manifested remarkable ecological changes and consequences as also the downstream.

In 1982, a massive mortality of fish in the Vilaine Bay triggered a study by Ifremer (MERCERON, 1985) that calls into question the presence of the dam. Anoxia of the bottom waters due to the slowing of tidal waters by the dam was identified as the main cause. The virtual disappearance of the muddy plug swing has greatly aggravated the pollution of the Vilaine Bay

by nitrates and organic matter. The Arzal dam has strongly modified the aquatic flow and the tides do not go up again until Redon (LEFEUVRE & LE DÉMÉZET, 1984; LE RHUN & PRIOUL, 1983). The estuary is confronted with a strong problem of siltation, affecting the environment and the economic activities of the municipalities bordering the estuary located between Damgan, Billiers and Pénestin.

The stream eases and at low tides, only a very thin stream of water between two mud flanks cannot replace the high tide river levels. Estuarine fish species have been replaced with river species following the environmental changes induced by man (MERCERON, 1985). The marshes along the estuary continue to provide hay to farmers, but in dry years, the harvest is lower than in the past (RENARD, 1977). The establishment of intensive forage crops such as maize, which was a secondary objective of the dam was unsuccessful (MERCERON, 1985).

Rance

The Rance estuary is more than 20 km long and its Schorre are carved into bays, small river ports, and some peninsulas popular between hikers and fishermen.

The catchment basin of the Rance is 380 km². The average flow is 2.57 m³/s. The Rance estuary surface is of 6356 hectares, which is classified natural protected site on 3127 hectares, since May 1995. The hydroelectric dam of la Rance, builded in the 70s modified the tidal regime and affected the vegetation zonation in the upper part of the estuary (GÉHU & BIORET, 1992).

The majority of the Rance estuary is covered by natural protected areas, including several natural areas of ecological interest:

- Bras de Châteauneuf (298 hectares);
- Île Notre-Dame (4 hectares);
- Anse de la Richardais (83 hectares);
- Anse de Gareau and La Ville-ès-Nonais (90 hectares);
- Anse de Pleudihen (223 hectares).

Following LANGOUET & SOUILLET (1974), TANGUY (1999), CHAIGNEAU-NORMAND (2002), historically this estuary was home to many human activity and manufactures, like shipbuilding companies, many of which have disappeared.

3.2.2.2 Other estuaries

3.2.2.2.1 The Hâvres of Cotentin (Lower Normandy)

These estuaries belongs to the so-called “Côte des hâvres”, consisting in 8 harbor type estuaries.

Vanlée

This hâvre is located southwest of the department of Manche, between Agon-Coutainville and Granville. It serves as an estuary at Vanlée. It has the peculiarity of a huge large sand tongue (bar) facing north and so-called "le bout du monde". This hâvre consists on salt meadows occupied by flocks of sheep during low tides. During high tides, the water covers large surfaces and even the “submersible” road.

Regnéville

This h vre is situated in Regn ville-sur-Mer. It consist in the Siena estuary flowing into the France-English Channel, and its estuary covers nearly 900 hectares between the Spiers of Agon and Montmartin-sur-Mer.

Blainville

This h vre is located at the height of Blainville-sur-Mer, behind a berm of coastal dunes, this estuary bed is very sandy. The bay was largely converted for agricultural, oyster and tourist activities.

Geffosses

The Geffosses h vre estuary is a nature reserve covering 185 hectares spread over the municipalities of Geffosses and Anneville-sur-Mer. It is a waterfowl site for migratory stopover, overwintering or during the breeding season.

Surville

This h vre is developed within a large dunes system, which extend deep inside the country. It has been relatively well spared by urbanization and agriculture. The site is characterized by a dense network of watering ponds, very important amphibians.

H vre de Saint-Germain-Sur-Ay

Also known as Ay, it is a sandy estuary composed of dunes and salt meadows. It is the largest estuary between the H vres, sited on the west coast of Cotentin (600 ha). It is delimited to the north and west by the Pointe du Banc in Saint Germain sur Ay, and south by the dunes of Cr ances.

Port Bail H vre

This harbor estuary is located in the village of Portbail on the mouth of the Olonde river. The sand tongue is formed by the dunes of Sainte-Marie and the south dunes of Lindbergh.

Carteret

This harbor estuary develops between the Cape Carteret, on which a lighthouse was built in 1837. The port of Carteret was built there.

3.2.2.2.2 Estuaries from Picardie and Nord-Pas-de-Calais

They are sandy bay type estuaries between dunes and marshy areas; the river supply consists from small rivers. The seven main estuaries are:

Authie

The mouth of this estuary form a vast bay, between Fort-Mahon-Plage and Berck, as it is typical of Picardy estuaries, it homes a rich fauna and flora that attract many visitors.

Canche

This estuary is typical bay type for Picardy, with its pulley and its head in a protected area, harboring a variety of flora and fauna.

Liane

It flows into the France-English Channel at Boulogne-sur-Mer. It is channeled artificialized and equipped with a lock.

Wimereux

It flows into the France-English Channel. It is artificialized, urbanized and canalized. Uppermost sediments came from marly-argillaceous cliff. Wimereux has significant seasonal flow fluctuations; high water occurs in late autumn and winter.

Slack

It flows into the France-English Channel, its average inter-annual flow, is 0.6 m³/s.

Calais

It is formed by the “Canal des Pierrettes”, “Canal de Calais à Saint-Omer” and other various drainage streams, all completely canalized.

Aa

flows into the North Sea, almost all is channeled and it flows through the villages of Saint-Omer (Pas-de-Calais) and Gravelines. It is almost artificialized, as well as the previous and as it happens in the complex that forms the Dunkerque Port estuary.

3.2.2.2.3. Other estuaries of Aquitaine

These estuaries are characterized by distinctive waters and sediments from Pyrenees mountains.

Courant de Mimizan

Is the biggest of the Courant estuaries, it consists in very small and short sandy estuaries from torrents and rivulets (often channeled) within the large sandy dunes front of Aquitaine.

Adour

Is the largest estuary of the Aquitaine basin in southwestern France; and it is a medium estuary at the Atlantic French scale. After crossing the city of Bayonne it flows into the Atlantic Ocean. The mountain river type flowing in the estuary has a pluvio-nival regime, with a remarkable flow variation, ranging from a maximum of 2 000 m³/s to a minimum of 30 m³/s.

Nivelle

The geographical situation of the basin makes its climate mild (average temperature 14 °C) under the influence of humid air masses blowing from the sea. The clash between these air currents and the Pyrenean region spurs sudden influence the average annual rainfall on the watershed (2 000 mm). On May, 2007, like in 1983, the banks go through dire consequences on account of floods (i.e.: 170 mm pour down in 24 hours at Saint-Pée-sur-Nivelle). The whole basin was subject to extensive flood and damages and the Lurberria dam was built in 2008 in order to contain swollen waters. The upper estuarine portion take place in the lowest Dorréa-Ascain inhabited zone. Always according to the average river flow rate is 5 m³/s measured at

Saint-Pée-sur-Nivelle. The estuarine banks are almost channeled and urbanized with meadows and pastures.

Bidasoa

It is running between Spain (right orographic side) and France (left orographic side) considered as natural frontier between them, within the Basque Country (MONTERO *et al*, 2006). The estuary is called Bidasoa-Txingudi combining the name of the river Bidasoa, with the bay of Txingudi (BRAY, 2004). The estuary mouth is a bay-type (Figuier-Hondarribiko bay) and the dynamic type portion is at the Biriadou zone; with some estuarine bays (the biggest is Txingudi bay), and estuarine islands (Chingoudy island, Santiagoaurra islands, Iru Kanale island, “Isla de los Faisanes” island). The banks are almost artificialized, urbanized and channeled; also secondary meadows and crops take place (especially in the upper portion). Some salty marshes and primary meadows still exist (especially in the middle portion and lesser in the lowest portion).

4. METHODOLOGY

4.1. Main bioclimate, biogeography and abiotic aspects

Given the numerous estuaries in France, some of them were selected as a result of sampling based on geographic, geomorphologic and ecological criteria. A preliminary work was carried out, analyzing the available bibliography; thematic maps related to vegetation, habitats soil uses and protected areas: in order to collect and synthesize all the estuaries available data concerning abiotic and biotic factors. Additional data have consequently been collected by fieldwork, further bibliographical analysis, phytosociological, cartographic and synphytosociological elaboration, and photo-interpretation: in order to refine the ecological characterization and models of estuarine systems (bioclimatology, geomorphology, ecology and phytogeography), to create a first basis on typology, plant landscape units and cartography knowledge; and to provide elements of reflection on bio-assessment, outlooks and policies in a territory management perspective.

Following these steps, the preliminary data were used to define the most important estuarine ecological factors, the directions of the related gradients: to state main hypothesis and to propose a first prototype to be used as basic track. The further research was also used to look at whether these drivers and gradients sound sufficient and realistic, and if the first model proposed is valid, improvable or rejectable.

Special consideration was given to the estuarine vegetation characterization and mapping activities and the role of ecological gradients has been take into account trying to understand the response of vegetation to constraints such as stress and ecological disturbances. The elaboration of the methodology therefore had to take into account not only these preponderating factors, but also the human influence, sometimes making it difficult to interpret the dynamics and consequently the separation of the different categories of series.

Geosynrelevés have been carried out in order to identify the different geoseries and geopermaseries, to describe their arrangement on the territory and to highlight possible synendemisms (syntipicity); and in other hand the similarities (invariant elements) between estuaries. The cartographic exploitation of the data provided a general model of spatial representation of the studies series and their organization following ecological gradients.

In France, five major types of climate are distinguished¹⁰:

- Oceanic; oceanic - more or less altered; mountain; Mediterranean; and continental.

Several bioclimatic studies concerning the French coastline had been conducted (GÉHU *et al.*, 1984; GÉHU 2007a; DEMARTINI, 2016). We compared this data with the WorldClim data set (HIJMANS *et al.*, 2005) to characterize bioclimate of each vegetation series and geoseries. Climatic data were taken from a raster of 30 arc-seconds, corresponding to a spatial resolution of ~1 km. Bioclimatic variables (derived from the monthly temperature and rainfall values¹¹) for synphytosociological relevés were obtained through the overlay of the plot coordinates with the QGIS software. Bioclimatic belts are defined by different bioclimatic indices I_t , I_c , and I_o (RIVAS-MARTÍNEZ, 1987, 2007; RIVAS-MARTÍNEZ *et al.*, 2011) from the temperature and rainfall data. I_t , I_c , and I_o indices are in fact related to thermotypes, ombrotypes and continentality.

Météo-France: http://pluiesextremes.meteo.fr/aper_r2.html, consulted the 26.09.2018.

¹¹ <http://www.worldclim.org/bioclim>

Bioclimatic variables (derived from the monthly temperature and rainfall values¹²) for synphytosociological relevés were obtained through the overlay of the plot coordinates with the QGIS software. Bioclimatic belts are defined by different bioclimatic indices It, Ic, and Io (RIVAS-MARTÍNEZ, 1987, 2007; RIVAS-MARTÍNEZ *et al.*, 2011) from the temperature and rainfall data. It, Ic, and Io indices are in fact related to thermotypes, ombrotypes and continentality.

On the map of bioclimatic belts (GÉHU *et al.*, 1984) the Manche-Atlantic coastline is divided into two bioclimatic zones: the northern planitial zone, relayed southwards by the Collinean zone to the Pyrénées-Atlantiques département. This division is based on the thermoclimatic limits defined by Rivas-Martínez (previously cited) and adapted by GÉHU *et al.* (1984) to the French context:

- mountain belt < 10 °C;
- collinean (or hilly) belt < 12°C;
- planitial belt > 12°C.

To qualify the atlanticity and hyperatlanticity differences, GÉHU *et al.*, (1984) based on minimum temperature values ratio for the three coldest months of the year, because the hyperoceanic climate is “mild”: with less thermic amplitude (yearly and daily); basically it is rainier, with a higher air humidity, and windy (GÉHU *et al.*, 1984; DEMARTINI, 2016).

The climatic and bioclimatic divisions and classification followed in this work derived from CHOISNEL & PAYEN (1988), RIVAS-MARTÍNEZ (2004), GÉHU *et al.* (1984) and DEMARTINI, 2016. The hyperatlantic zone is located in the north of Brittany (with the exception of Ille-et-Vilaine) and at the top of Finistère, with an exclave in the north of Cotentin (Fig. 14).



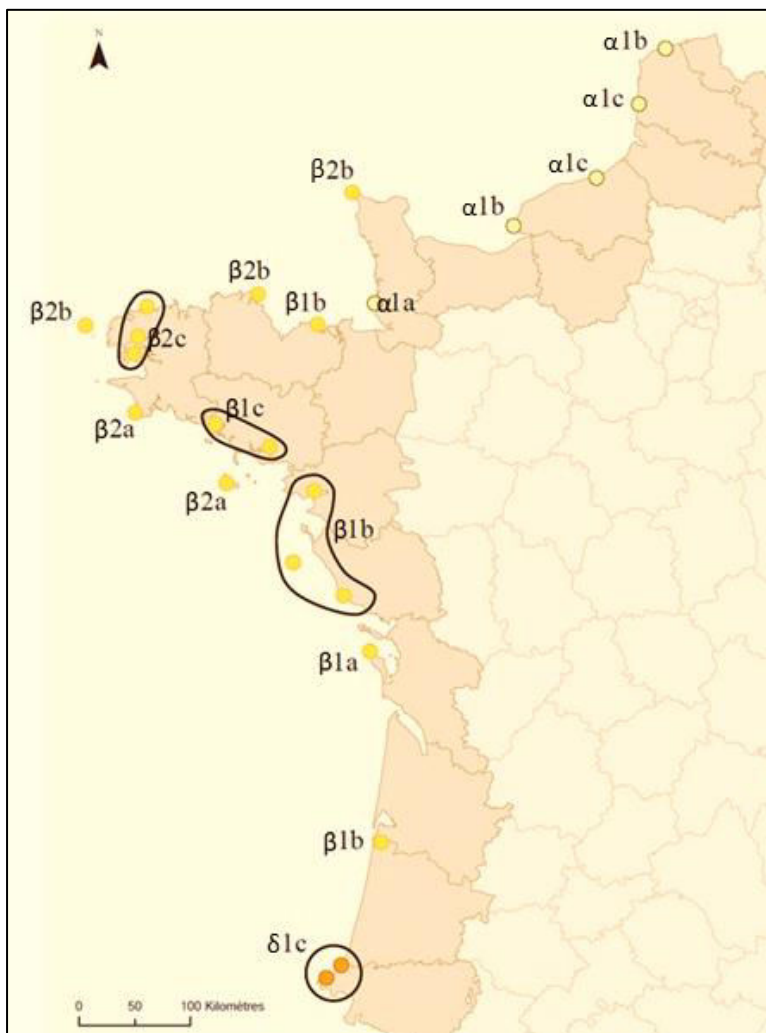
Figure 14 - Ombrothermic “Rivas-Martínez” horizons (Io) - Demartini (2016 - adapted).

To the south, the climate tends to be thermoatlantic, with shades more resembling to the Mediterranean climate notes. The local climatic variations depend from certain factors such as latitude, altitude, distance to the sea or distance to the mountain massifs (LEBOURGEOIS, 2010). DEMARTINI (2016) produced a complete study using numerous bioclimatic indexes, defining more accurately the bioclimates and climatic types of the French Atlantic coast, updating the

old researches from bibliography with new climatic data for the next 30 years (till 2100), when available (Fig.14).

According to GÉHU (2007a) bioclimatic factors must be studied at the scale of the general climate and at the scale of the stational or microclimatic patches. For that, considering geographically estuaries as coastal environment (see part 2), we used DEMARTINI (2016) as a basic reference to investigate possible differences in estuaries: from the mouth to their inner portions, looking for any remarkable climate influence in vegetation expression due to possible climatic variations, or to any continental bioclimatic influence. DEMARTINI (2016) demonstrates that in general, a latitudinal temperature gradient (mean annual temperatures increase) is observed from north to the south. On the coast, periods of drought are rare and not very pronounced. Finally, it must be emphasized that the variations of the altitude on the Atlantic coast are too weak to play a significant role. The stations with a greater continentality rate are spread out at various points along the coast; in contrast, the strongly oceanic character expresses at the most extremity of Brittany (Fig. 15).

Dry period tendencies concern only seven stations out of 23, there are observed during the summer (June to August) and no more longer than one month per year. In other hand, other seven stations are never subjected to drought periods, even during the warmest months.



Upper collinean belt (α)

1: Semihyperoceanic

a: Lower subhumid

b: Upper subhumid

c: Lower moisture

Eucollinean belt (β)

1: Semihyperoceanic

a: Lower subhumid

b: Upper subhumid

c: Lower moisture

2: Low hyperoceanic

a: Lower subhumid

b: Upper subhumid

c: Lower moisture

Upper thermocollinean belt

(δ)

1: Semihyperoceanic

c: Lower moisture

Figure 15 Bioclimatic Typology of Atlantic French coast DEMARTINI (2016 - adapted) by the combination of the three Rivas-Martinez indices (It, Ic, Io).

To study the main environmental characteristics, we firstly analyzed the bioclimatology and climatologic available data making. We used the WorldClim data set (HIJMANS *et al.*, 2005) to characterize bioclimate of each vegetation series and geoseries. Climatic data were taken from a raster of 30 arc-seconds, corresponding to a spatial resolution of ~1 km. We refer on annual precipitation data, mean annual temperature, solar radiation, evaporation, wind. We analyzed mean annual temperature and precipitation, to elaborate a bioclimatical classification of the study area following RIVAS-MARTÍNEZ *et al.* (2011) and using Ic (Tab. 1), It (Tab. 2), and Io (Tab. 4) indices.

Type	Sub-Type	Level	IC Values
Hyperoceanic		Lower	0-2
	Ultrahyperoceanic	Upper	2-4
		Lower	4-6
	Euhyperoceanic	Upper	6-8
		Lower	8-10
	Subhyperoceanic	Upper	10-11
Oceanic		Lower	11-12
	Semihyperoceanic	Upper	12-14
		Lower	14-15
	Euoceanic	Upper	15-17
		Lower	17-19
	Semicontinental	Upper	19-21
Continental		Lower	21-24
	Subcontinental	Upper	24-28
		Lower	28-37
	Eucontinental	Upper	37-46
		Lower	46-56
	Hypercontinental	Upper	56-66

Tab. 1. The "Ic" Bioclimatic table and values

Thermic horizon	level	type	It value	Tp: Ic ≥ 21, Itc < 120
Infratempered	Lower	Infracollinean	> 410	> 2351
	Upper	Thermocollinean lower	350-410	2176-2350
Thermotempered	Lower	Thermocollinean upper	290-350	2000-2175
	Upper	Eucollinean	240-290	1700-2000
Mesotempered	Lower	Submountain (upper collinean)	190-240	1400-1700
	Upper	Mesomountain	(120)-190	1100-1400
Supratempered	Lower	Altimountain	-	800-1100
	Upper	Subalpin lower	-	590-800
Orotempered	Lower	Subalpin upper	-	380-590
	Upper	Alpin	-	100-240-380
Cryotempered	Lower	Infracollinean	-	1-50-100

Tab. 2. The "It" Bioclimatic table and values

Ombrotype	Level	Io Values
	Lower	0-0.1
Ultrahyperarid	Upper	0.1-0.2
	Lower	0.2-0.3
Hyperarid	Upper	0.3-0.4
	Lower	0.4-0.7
Arid	Upper	0.7-1
	Lower	1-1.5
Semiarid	Upper	1.5-2
	Lower	2-2.8
Dry	Upper	2.8-3.6
	Lower	3.6-4.8
Subhumid	Upper	4.8-6
	Lower	6-9
Humid	Upper	9-12
	Lower	12-18
Hyperhumid	Upper	18-24
Ultrahyperhumid		>24,0

Tab. 3. The "Io" Bioclimatic table and values

4.1.1. Worldclim

In his bioclimatic study on the French Atlantic coast, GÉHU (2007a) emphasizes the interest of studying the climate at the local scale (microclimate). Since most coastal plant communities are dependent on stationary microclimatic conditions, their study can provide a lot of information. However, microclimatology requires taking account for a number of ecological variables (ventilation, solar radiation, air humidity, slope, soil...) that require specific equipment and protocol. Being geographically the estuaries, a coastal environment (see part 2), we used DEMARTINI (2016) as basic reference to investigate the French Atlantic Bioclimate. DEMARTINI (2016) produced a complete and complex study using numerous bioclimatic indexes, defining more accurately the bioclimates and climatic types of the French Atlantic coast - updating the old researches from bibliography with new climatic data analyzing 30 year range till 2010.

To meet our goal, we selected climate data available from existing French national net "Meteofrance" using them on the available indices, looking for possible differences in estuaries from the mouth to their inner portions about any remarkable climate influence in estuarine vegetation expression; any possible climatic variations; or to any continental bioclimatic influence from the mouth to the inner land estuaries, because bioclimatic factors that must be studied at the scale of the general climate and at the scale of the stational or microclimatic patches following the GÉHU (2007a). We compared this data with the WorldClim data set (HIJMANS *et al.*, 2005) to characterize bioclimate of each alliance. We used "WorldClim, version 2" that has an average monthly climate data for minimum, mean, and maximum temperature and for precipitation for 1970-2000 years' time range, as follows:

Variable	10 min	5 min	2.5 min	30 sec
Min. temp. (°C)	tmin 10m	tmin 5m	tmin 2.5m	tmin 30s
Max. temp. (°C)	tmax 10m	tmax 5m	tmax 2.5m	tmax 30s
Average temp. (°C)	tavg 10m	tavg 5m	tavg 2.5m	tavg 30s
Precipitation (mm)	prec 10m	prec 5m	prec 2.5m	prec 30s
Solar radiation (kJ m-2 day-1)	srad 10m	srad 5m	srad 2.5m	srad 30s
Wind speed (m s-1)	wind 10m	wind 5m	wind 2.5m	wind 30s
Water vapor pressure (kPa)	vapr 10m	vapr 5m	vapr 2.5m	vapr 30s

Climatic data were taken from a raster of 30 arc-seconds, corresponding to a spatial resolution of ~1 km. Bioclimatic variables (derived from the monthly temperature and rainfall values¹³) for phytosociological relevés were obtained through the overlay of the plot coordinates with the QGIS software.

¹³ <http://www.worldclim.org/bioclim>

4.1.2. Ombrothermic diagrams

The ombrothermic diagrams represents the monthly mean precipitation (P in mm) and temperature (T in °C) to give a relative expression of the duration and intensity of the summer drought (GAUSSEN, 1948, 1956, 1971; GAUSSEN & BAGNOULS, 1952; BAGNOULS & GAUSSEN, 1957). A given month is considered dry when $P < 2T$ (i.e.: when the water decrease supposedly caused by a too high temperature) are greater than the inputs (precipitation). Conversely, when $P > 2T$, the month is considered wet. This diagram type superimposes the two temperature and precipitation curves for the 12 months of the year; highlighting the drought period. Larger is the superposition area, and longer the season is dry (value of the integral). WALTER (1954) proposes to add the period of tendency to drought (subdrought) within ombrothermic diagrams. The representation of the latter is done by the curve $P < 3T$. In addition to this diagram, GAUSSEN & BAGNOULS (1952) also defined a xerothermic index but it was elaborated looking for the Mediterranean region, that takes into account the number of biologically dry days through the consecutive dry months. We do not test this hypothesis because in Atlantic Oceanic climate the drought is not so influent like in Mediterranean climate. In any case we decided to actually test only the features applicable in Atlantic Oceanic conditions.

4.2. Plant landscape methodology

4.2.1 Methodological approach to define vegetation series and vegetation series complexes

To define vegetation series and vegetation series complexes we used the basic approaches of Geosynphytosociology. It constitutes the third level (higher) of landscape analysis, focuses on the analysis of catenal and geographical phenomena of relations between plant groups or between plant series within phytotopographic units of the landscape (geoseries or geosigmata) (GÉHU, 1986). If not specified, the pedology issues of this study follow the World Reference Base for Soil Resources (WRB) – of the International Union of Soil Sciences (IUSS), 2015 version¹⁴.

The vegetation series concept was proposed by RIVAS-MARTÍNEZ (1982a, b) and considered as being the basic unit of synphytosociology; to classify systems of higher units in this down-up sense: sigmassociation, sigmalliance, sigmaordo, sigmaclass (GÉHU and RIVAS-MARTÍNEZ, 1981). Each series has proper typical features and is characterized by a certain repeatability and by a certain ecological and geographical homogeneity (alias: Tessella or Sigmata). In one hand there are several vegetation series which are represented by different associations of heads, in different Tessella. In other hand there are also particular case of various types of series that express on apparently homogeneous surfaces but under posed by recurrent natural disturbances that cut off the series in certain level, not allowing to overstep it permanently: volcanic eruptions, avalanches, landslides, actives scree, eroded/sedimented banks, extreme climatic events, salt intrusions...

Following this and depending on their topographic position and the importance of water supplies, the series can be divided into several types according to RIVAS-MARTÍNEZ (1996, 2005b); PINTO-GOMES and LAZARE (2002); LAZARE (2009, 2014); LOIDI *et al.*, (2011):

- climatophilic series, which develop on mature soils under rain water;

¹⁴ <http://www.fao.org/3/i3794en/i3794en.pdf>

- edaphoxerophilic series, which occur on xeric soils (sandy-soils, leptosol, gypsisol, serpentine soils ...), in biotopes such as dunes, steep slopes, scree, ridges and cliffs;
- edaphohygrophilous series, which are found on soils rich in water (histo-soils, fluvial-soils, halo-soils ...) in alluvial valleys, marshes, peat bogs, salty mud and others aquatic environments. In addition to rainfall, there is a strong influence of ground waters (i.e.: phreatic supply, flooding, slopes runoff...);
- temporhygrophilous series, which develop on very wet soils or water saturated not at all the year round; while during the dry season, they could be even very well drained and aerated (RIVAS-MARTÍNEZ, 2005b, 2007; RIVAS-MARTÍNEZ *et al.*, 2011; LOIDI *et al.*, 2011). The temporhygrophilous series, first placed within the climatophilous series (RIVAS-MARTÍNEZ, 2005a,b, 2007), were subsequently proposed into a fourth category by Rivas-Martínez *et al.* (2011), specifies that the term can be used in some cases for climatophilous series and in other cases for edaphohygrophilous series: when the soil has high humidity rates and the lack of aeration duration is determinant (RIVAS-MARTÍNEZ, 2005b, 2007). According to the general model of toposequence crest - slope - piedmont - valley (RIVAS-MARTÍNEZ, 2005b, LAZARE, 2009), the temporhygrophilous series can thus be intercalated between the climatophilous series and the edaphohygrophilous series.

In our work we will focus mainly in edaphohygrophilous and temporhygrophilous series types; in fact, for their abiotic characteristics, both could be considered as azonal vegetation, while the zonal vegetation is found between the contact vegetation to the estuarine ecosystems. Following WALTER (1976), WALTER & BOX (1976), RUTHERFORD *et al.* (2006), and PEDROTTI (2013) in biogeography we can distinguish two types of vegetation:

zonal vegetation occupies zonal (macro)habitats that are primarily under control of macroclimate (also controlling formation of zonal soil patterns) over long time scales; large-scale, natural disturbance factors such as heavy animal grazing and recurrent fire also contribute as important drivers of the zonal vegetation physiognomy (defined by typical combination of plant functional types), typical of particular (zono)biome;

azonal vegetation consist in plant communities and their complexes occurring across several zonal (macro) habitats (such as latitudinal zones or altitudinal belts) that are primarily shaped by soil (substrate) and hydrological extreme conditions (including flooding, high salinity, high heavy-metal content, extremely low nutrient-status of soils) rather than by macroclimate.

Following HILL *et al.* (2002) we can state that also the human pressure (disturbance) tends to transform the vegetation from zonal to azonal types through the phenomena of ruderalization and banalization within the regression process (PEDROTTI, 2013). More rarely, in exceptional cases these processes can also take place under natural conditions (PEDROTTI, 2013) and in aquatic systems like estuaries it could be an important clue of the natural dynamics; often it is indication of human impact (DAUVIN & RUELLET, 2009; ELLIOTT *et al.*, 2007; ELLIOTT & QUINTINO, 2007; DUCROTOY, 2018).

Thanks to the development of synphytosociology new concepts were proposed, bringing complements concerning the environments subjected to strong ecological constraints, like littorals, polar regions, deserts, steppes, mountain tops, screes, peat bogs, marshes, springs, rocky outcrops, ponds... The very constraining ecological conditions characterizing these environments (salt intrusion, spray, wind, desiccation, low water reserves, substrate ...) preventing or inducing a stop in the dynamics of vegetation. Depending on the importance of ecological constraints, three categories of series develop on these particular Tessella: permaseries, curtaseries and minoriseries (LAZARE, 2014). First defined by RIVAS-MARTÍNEZ

(1996, 2004) as "microsigmeta" or "vegetation micro-series", permaserie represents a stable perennial plant community that occupy small surfaces (one microtessella or a microtessellar complex), localized in particular places such the polar regions, high mountain ridges, coastal areas, mobile dunes, cliffs, coastal reefs beaten by the sea waves...

The mature stable stage (even corresponding to the climax), corresponds to a perennial vascular community, generally less stratified and without further successional stages. With the exception of ephemeral annual species and plant communities that can establish themselves temporarily in open or degraded areas, only perennial plants in the mature community can thrive and reorganize the same permanent plant community (RIVAS-MARTÍNEZ, 2005b). This plant community is therefore at the same time a pioneer stage and a stage of maturity (LAZARE, 2009). These special types of series identification were highlighted by LAZARE and LANNIEL (2003), LAZARE (2009a, 2014) under the name of "mesoserie" and defined from the example of the euskaro-cantabrian thicket (*Rubus ulmifolii-Tametum communis* subass. *salicetosum atrocineriae*). then proposed to change the term of "mesoserie" with "curtaserie" or "truncated series" to avoid any confusion with others geobotany concept. In any case, special series type correspond to a shorter dynamic series, blocked by climatic adversities (i.e.: sea winds laden with sea spray), which may include the three stages of meadow, moor and thicket.

Curtaserie concerns intermediate cases, where the vegetations are subjected to less extreme ecological constraints, allowing the appearance of a more successional stages (i.e.: chamaephytes or even shrubs but that could never be able to reach the stage of forest). By analogy with the concept of permatessella, the spatial expression of a curtaserie is named curtatessella. On the shoreline, curtatessels on which are developed curtaserie are frequent and intercalated most of the time, within other serial types along the gradient of ecological constraints. For RIVAS-MARTÍNEZ (2011), curtaserie and minoriserie are synonyms. But LAZARE (2014) distinguished between these two concepts:

- minoriserie is linked to permanent ecological constraints, while
- curtaserie is linked to periodic and strong ecological constraints (especially in the case of hydraulic disturbances).

The geoserie is the basic unit of geosynphytosociology and theoretically ranks in a system of higher ranks as follow: geosigmalliance, geosigmorder and geosigmaclasse. Vegetation geoserie is a larger geomorphological unit corresponding to a quantified spatial expression of all the plant associations (and groupings) sets in contact (GÉHU & RIVAS-MARTÍNEZ, 1981). For that, they correspond to a set of similar series (Sigmeta, or Tessellas) array. In this work we used the geopermaseries as Tessellas array type because they consist in a permaserie set (in contact between them) with a very close determinism, and with very similar geographical and ecological features (according to: RIVAS-MARTÍNEZ, 1982a, 2005b; BIONDI *et al.*, 2002). Even the surfaces dimension, distribution and patchiness are similar and closer (GÉHU, 1986, 1991a; RIVAS-MARTÍNEZ, 2005b, 2007; BIONDI *et al.*, 2002). We called these geopermaseries in order to the most common association. When small series develops within larger series after small ecological variations, we decided to treat them within the larger ones, as linked series and specifying how they are linked. All this, in order to simplify the models functioning and according the generalization concept of plant mapping (PEDROTTI, 2013).

According to LAZARE (2009a, b) and RIVAS-MARTÍNEZ (2011), in our case, the permageoserie consist in a topographic permaserie chain (or geomorphologic series cline) which expresses the general permageoserial model from a lowest to a highest topographic level of its expression potential: regrouping similar contiguous series according to an altitudinal gradient (toposequence). If it is complete, the geoserie should include all the

edaphohygrophilic series, which correspond to a topographic catena (series chain) located in the same geomorphological, biogeographical and ecological area. Finally, it represents the landscape synthesis of the zonation phenomenon. GÉHU (2006b) proposed that the catena designates not only a vegetation toposequence, but also the spatial framework of this topographic gradient.

4.2.2. Potentiality, phytodynamics and vegetation tendencies analysis

When the head series were lacking, in order to analyze the vegetation potential, we based on ecological continuity (i.e.: same soil type, topographic level range, exposition...) and as possible, also on indicator species; as previously described between the general concepts, definitions and principles.

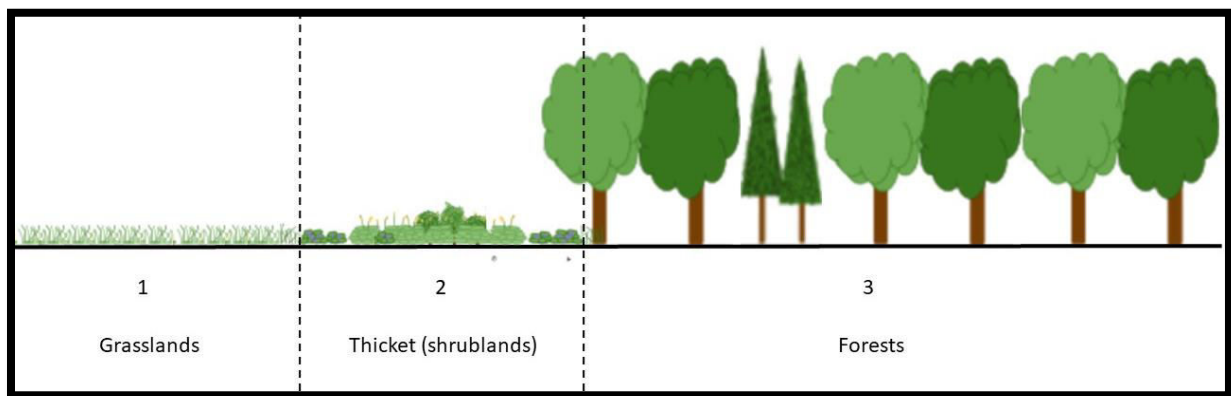


Figure 16. - Theoretical spatialization in a series, following the secondary succession in a Tessella (1 to 3). From communities in substitution (secondary associations) going to the primary community (potential vegetation, or head series association).

In Fig. 16 as example, (1) stage could be composed by several secondary meadows, according to land uses (i.e.: ruderal, pastures, mowed...); (2) stage is the related successional shrub-land under some possible associations, following the land uses history. All them are association in substitution to the head series (5), till to the pre-forest stage comprised. All the associations in the figure express in the same Tessella (area with homogeneous geographical and ecological characteristics according to RIVAS-MARTÍNEZ, (1985). The vegetation potential of this theoretic Tessella is the forest (5) association. About phytodynamics and vegetation tendencies observations we started from the actual vegetation to the expected potential vegetation, looking for signs of the actual vegetation and soil uses in order to understand whether the trajectories are actually moving away (-) or approaching (+) the potential vegetation.

4.2.3. Field relevés

Fieldwork was organized after the preliminary work. We explored the estuary area following a complex transect. The complex transect consist in a longitudinal transect (down to up, along the estuary bed) and in each kilometer intertwined by a perpendicular transect, from the small to the major estuary bed. We make phytosociological, plant dynamic, synphytosociological and environment observation. We placed the vegetation limit on aerial photos and topographic maps, making a raw map and tables field version.

We repeated this complex transect for each estuary side, in the main channel and in the lateral channels, comprised in the estuary.

The synphytosociological surfaces were recalculated per larger surfaces using the partial field surveys and by QGIS elaboration, to obtain more homogeneous surfaces. Only when too large or too small surface were present we had smaller or bigger surface cover values. The phytosociological relevés date of tables corresponds to the same places and dates of the synphytosociological relevés table.

About phytosociological survey, species cover is quantified by numeric coefficients (values). They could be in numeric way, percentages or in classes. In our work, the field relevés were prospected and then ordered in tables, according to the classic Braun-Blanquet approach (BRAUN-BLANQUET, 1921, 1928, 1964; BRAUN-BLANQUET & PAVILLARD, 1922). The typical phytosociological method is according to the classic Braun-Blanquet abundance-dominance scale, where value classes are from + to 5 (BRAUN-BLANQUET & PAVILLARD, 1922, BRAUN-BLANQUET, 1928; BRAUN-BLANQUET *et al.*, 1932). We refined the lowest values (+) through (+, r, i) as used by Pignatti and Géhu (BOULLET, 1999). The scale here used represent this values:

- 5 (species that have a cover percentage is almost 75%);
- 4 (species that have a cover percentage between 50 and 75%);
- 3 (species that have a cover percentage between 25 and 50%);
- 2 (species that have a cover percentage between 5 and 25%);
- 1 (species that have a cover percentage between 1 and 5%);
- + (species that have a cover percentage lower than 1%);
- r (as very rare species, with a very low cover and negligible abundance) ;
- i (as species represented by a unique very small sample, like a seedling or not well developed sapling).

Following the phytoassociation physiognomy, based on its structure, and height, we distinguished some vegetation levels (herbaceous, shrubby and arboreal). In case of woody associations (more complex also in height and in layers), we proceeded to distinguish the three level of plant cover occurrence per vegetation layer (Arboreal or Tree, Shrubby, Herbaceous). Cryptogamae (ferns and ground mosses, algae, lichens, bryophytes...) are considered within the herbaceous vegetation. Epiphytic vegetation was considered according the vegetation layer of occurrence. Plant cover for each level (BARDAT, 1993) was noted basing on typical, occasional, accessory, transgressive... plant species. The minimum survey (relevés) area is the minimal surface or volume representing the minimal portion of the territory where the studied unit can be identified and where it can express the most of its characteristics. For example, a forest association will have necessarily a larger minimal surface than a grassland association, following the minimal surface needs of its related characteristic species to join a full (mature) sample (species) development.

From a phytodynamic (PEDROTTI *et al.*, 1996) point of view (Phytodynamic is the study of the different aspects of the plants populations and community's dynamics), the use of "progressive" and "regressive" adjectives, is applied to the type of the vegetation (conenoses, groups, series, associations...) process observed, indicating the direction and the distance to the potential equilibrium status with the soil and the local climate conditions (GÉHU, 2006b). In large sense, we can define this as the distance from the theoretical head series vegetation or to the attempted climax in some way. *Vice-versa*, "regressive" is used when the observed vegetation moves away from the most mature vegetation stage (GÉHU, 2006b). Regressive phenomena could be of natural or anthropogenic origins, or even from mixed factors. About synphytosociological relevés, we follow the principles of the inductive approach proposed by GÉHU and RIVAS-MARTÍNEZ (1981) to typify vegetation series and geoseries, through the analysis of concrete cases, this work is a contribution to specify some elements for the factual investigation of the vegetal landscape by the realization of plant community complexes relevés. Following the shared review within CarHAB project (CHOISNET *et al.*, 2018), three main approach types can be identified for the description of community complexes and the realization of (geo)sigmarelevés:

- deductive mapping approach: with the generalized development of Geographic Information Systems (GIS), this approach consists in crossing the maps of the ecological parameters with the maps of the syntaxons, in order to reveal the envelopes of the Tessellas and their associated potential vegetations. The maps of the vegetation series established by BLASI (2010), BIONDI *et al.* (2009) and PINTO-GOMES and PAIVA FERREIRA (2005) are based on this principle. In the same way, the geoserial analysis can be deduced from the vegetation series maps.
- deductive-inductive mapping approach: the (geo)sigmarelevés are carried out under GIS according to the previous deductive approach, using ecological mapping layers and syntaxon maps (BIONDI *et al.*, 2011). The relative frequency of plant associations within Tessellas and catenas is established by GIS request and transposed into abundance-dominance code. The second step (inductive) consists in a classical sigmataxonomic analysis of the (geo)sigmarelevés to define the (geo)sigmassociations.
- inductive approach: the methodological basis are the vegetation relevés. Their analysis constitutes the founding stage on which the characterization of the typological units is based. In the bibliography, it lacks concrete elements to support this step, which is always confronted with the problems of scale and homogeneity: "it is the art of the synphytosociologist, like the phytosociologist, to know how to work on the timeliest and appropriate scale of homogeneity for the problems to be solved" (GÉHU, 1977).

As for phytosociology, the synphytosociological methodology includes two steps (BÉGUIN *et al.*, 1979; GÉHU & RIVAS-MARTÍNEZ, 1981):

- an analytical phase (realization of sigmarelevés);
- a synthetic phase (elaboration and ordination of tables).

In the analytical phase, the sigmarelevé (or synrelevé) is realized within a Tessella (GÉHU & RIVAS-MARTÍNEZ, 1981; GÉHU, 1986). This consists of establishing the list of existing plant groups (syntaxons), accompanied by ecological and landscape factors and related coefficient. The symbolism for coding the shape of the individuals within the relevés was proposed by GÉHU (1974), from TÜXEN (1973); BÉGUIN *et al.* (1979) and GÉHU & RIVAS-MARTÍNEZ (1981) proposed to complete this coding by adding other signs. Taking into account our necessities and the works already carried out within the CarHAB network (CHALUMEAU and BIRET, 2013; DELBOSC, 2015; DEMARTINI, 2016; ROUX, 2017; and CHOISNET *et al.*, 2018),

in this work we used the following categories and symbols:

- O = large spatial surface
- o = small spatial surface
- / = linear presence
- ... = scattered mosaic patchiness
- . = punctual presence
- , = small linear (o long punctual) communities, very narrow, short and very localized.
- O = broad fringe, a spatial-linear form (larger than the linear one but lesser wide than the spatial one),
- o = small fringe (smaller and shorter)
- /.. = linear discontinuous or linear mosaic patchiness

The same way as for species in a phytosociological survey, the groups are quantified according to the classic abundance-dominance scale of the Braun-Blanquet school as already mentioned in the phytosociology scale of values.

Some information concerning the local conditions, in ecological and physiognomic ways must be reported between the synrelevés factors (like: mesological, anthropozoogenic, contact groupings, general topographic situation, block diagram, structural physiognomic aspects...) following BÉGUIN *et al.* (1979). To characterize a new unit, it is preferable to perform the relevés on a surface that includes the maximum number of substitution steps within the series (GÉHU 1991a); the minimum area will depend on the characteristics of the studied series, following the logic of phytosociology methodology.

4.2.4. Transect pointing and spatialisation

After the previous analysis, we decided to establish the fieldwork, making a double transect for both the shores (estuary right and left sides): from the lowest to the highest limit. In each kilometer a crossed transect from the minor to the major estuarine bed was carried out till the most floodable areas, in order to analyze more as possible, the vegetation distribution (spatialization and organization) and variations along geographic and related ecological gradients, under the possible different soil uses and environmental constraints. Along transects, we carried out as necessary phytosociological and synphytosociological relevés together with vegetation series limits, phytodynamic, ecological, geographical and environmental observations, as useful to our study goals.

Additional relevés and longer transects were carried out occasionally, to test the vegetation limits and estuarine associations if compared with non-estuarine surroundings – in order to not overstep the estuary system during our field work and to observe the vegetation contacts.

4.3. Cartography, generalization, modeling and extrapolation

4.3.1. Time and surface scale

According to the previous paragraphs, the elaboration a geobotanical mapping focused on plant series, integrated in time and surface, requires a preliminary reflection about time scale

and a surface scale of reference. The CarHAB research project reference scale is 1: 25 000. In order to better adapt to estuaries representation of vegetation distribution following the dynamico-catenal phytosociology (Landscape Phytosociology) approaches, we decided to use test also largest scales (i.e.: 1:10 000, 1:5 000, 1:2 000 and 1:1 000) (see point 2.2.1). This provides more detailed resolution plant map restitution; that could be adapted to the CarHAB standard scale to join the French national plant mapping goal and to underline more complex estuarine portion in geomorphology or in vegetation.

Time scale is necessary to fix the potential vegetation model representation reference, to be applied in order to establish the expected series potential vegetation and the related succession head series as reference. More the time scale is shorter in time, and more easily the potential vegetation became closer to the actual vegetation. The time scale can be adjusted following the goals of the survey and the filed evidences, on the average life of the dominant(s) species of the plant association (or plant community) consisting in the series head (if present) or on the expected potential vegetation (if series head is lacking).

We decided in this study to consider an average time scale of 100 years for some reasons. The first reason is according to the average life time (biological cycle) of the most developed (in biomass volumes) head series and related potential vegetation corresponding to the dominant forests species (*Salix* sp. pl., and *Fraxinus excelsior*). This time scale allows us to maintain within the CarHAB expectations. The third reason is that this time scale it is considerably adequate to represent azonal and very dynamic vegetation. In fact, the azonal vegetation (even the forests) if compared to drier zonal vegetation is composed by species that generally grows faster, with a shorter average life. In addition, following the natural burial tendencies and the deposition/erosion dynamics that are very common and sometimes very accentuated in these places, all this makes these habitats very variable. Concerning these habitats more the time table is longer and more difficult is to aspect a reliable potential vegetation prevision – because more difficult is to forecast the changes in a naturally stressed area, and permanently unstable system where changes could happen easily and quickly (BOUSQUET, 1970; ELLIOTT *et al.*, 2007; ELLIOTT & QUINTINO, 2007; DAUVIN & RUELLET, 2009).

4.3.2 The scale problem and resolution factor

The scale factor decision is a crucial choice to obtain a good resolution factor and to optimize field work according to the expected mapping quality.

During the first plant mapping restitution we tried different solutions using different scale levels and different geopermaseries cutting to decide the better cartographic restitution.

The scale restitution depends on the complexity in the organization of vegetation and its representation type, and by the area surface of the mapped site.

An appropriate scale can represent the area with a size large enough to identify all the objects mapped, and to allow a good view of the ensemble. Due to the surface disparity of the estuarine sites to be represented, this condition has forced to use a variable different restitution scale choice case dependent.

We decided to follow more as possible the salty marshes geopermaseries cutting from DEMARTINI (2016) considering the geomorphological range from slikke to very high Schorre - adapted for estuaries.

This was possible working on PC digital interface by GIS programs, working on largest scale (from 1:1000 even to 1:100); in this way it is possible to have from largest to smaller scales restitution of vegetation map by zoom-out and zoom-in estuaries or their portions of interest. This makes us possible to let the possibility to adapt scales from the CarHAB standard to smaller or larger scales according to our study needs and to any possible further application: making zoom out or zoom on special portion of particular complexity or interest zone.

The designed scale range for the CarHAB program also for the coastal environments is 1: 25000, with the possibility of zooming to 1: 10000, requiring a greater resolution and fineness of mapping. To better represent plant mapping graphical restitution, we chose the average scale of 1: 4000 to delineate the field entities. It makes it possible to correctly distinguish the nuances of the plant landscape, being enough precise in relation to the fixed survey objectives. These contours are then refined during the digitization phase, which is performed between 1: 1000 even to 1:50 following the complexity of sites. This allows a good appreciation of the different landscape units, but does not underline details that are irrelevant from one point of plant mapping, according to the generalization principles in thematic cartography (PEDROTTI, 2013).

The area of the smallest cartographic unit by the CarHAB program was set at 0.5 ha. Because of the smallest surfaces, high patchiness of the studied vegetation and the finer scale proposed for the littoral-estuarine restitution, we chose to reduce this minimal area to 0.1 ha, to avoid losing some information. This choice was resulted useful in coastline plant mapping experience (DEMARTINI, 2016).

4.3.3. Sampling: choice of test points, relevés, synrelevés/géosynrelevés, and transects

To delimit the watershed, we used the estuarine related IGN (French National Geographic Institute) basic topographic maps 1: 25000. While the estuarine limits were established also making reference to the bibliographic data and databases from local rivers/estuaries authorities. In order to establish fieldworks (transects and relevés points), once the estuarine watershed was identified with the related average limits from the estuarine mouth (lower limit - to the sea) to the dynamic tide limit (upper limit - to the river), we started to make a first analysis of aerial photos to identify the most complex vegetation areas, and the most natural or the most anthropic places (secondary meadows, crop field, urbanized areas...).

4.3.4. Mapping series and geoseries according to the dynamico-catenal approach

Since the late 1970s, the development of landscape phytosociology concepts has been accompanied by the production of vegetation series and geoseries maps in several European countries:

- France - (GÉHU, 1979b; BIRET & BOULLET 2014, DELBOSC, 2015);
- Spain - (LÓPEZ PACHECO & PUENTE GARCÍA, 1987; RIVAS-MARTÍNEZ, 1987a, 2007; LOIDI & BÁSCONES, 2006; PERALTA DE ANDRÉS, 2010; LOIDI *et al.*, 2011; RIVAS-MARTÍNEZ, 2011, DÍAS- GONZÁLEZ, 2014; PERALTA DE ANDRÉS *et al.*, 2015);

- Italy – (CATORCI *et al.*, 1996; PEDROTTI, 1998, 1999, 2000, 2004, 2013; BIONDI *et al.*, 2002, 2004, 2011; BLASI *et al.* 2005; STANISCI *et al.* 2005, GIANGUZZI & LA MANTIA, 2008; BACHETTA *et al.*, 2009; BLASI, 2010; FACIONI, 2012);
- Portugal – (PINTO-GOMES *et al.*, 2003; CAPELO, 2004; PINTO-GOMES & PAIVA-FERREIRA, 2005; CAPELO *et al.*, 2007);
- Switzerland – (THEURILLAT, 1992a,b; BÉGUIN, 2009).

We analyzed all these plant map experience, and in addition we analyzed also the European multinational cooperation for the Europe plant map, coordinated by Udo Bohn (BOHN *et al.*, 2000a,b, 2003).

We used these examples to understand the main lines and principles, trying to make a first methodological shared basis that lead us to the definition of ecological envelopes and to structuring plant landscape maps.

Four schools of plant landscape analysis and mapping have been described since the beginning of the synphytosociology (following: SCHWABE, 1989; THEURILLAT, 1992a; CHALUMEAU & BIRET, 2013; DEMARTINI, 2016).

These schools have been classified from the country of origin, although there is always been a strong influence of authors from other countries in each country. In addition, the authors in general follow the directions taken by the different schools but they do not necessarily belong to the country from which the school was individualized:

- Swiss school: generally it uses a method that is both deductive and inductive and is followed by BÉGUIN & HEGG (1975), ZOLLER *et al.* (1978), BÉGUIN & THEURILLAT (1982);

- Franco-Iberian school: generally it uses an inductive approach based on the Tessella, that is to say an ecologically homogeneous area carrying the same natural potential vegetation, leading to the development of a sigmasyntaxinomic system; this Franco-Iberian school is that of RIVAS-MARTÍNEZ (1976), GÉHU (1977), TÜXEN (1973, 1978, 1979);

- German school: generally it is based on an inductive method, without necessarily using sigmasyntaxonomy; this approach, consisting of identifying homogeneous geomorphological units that may include different potential natural vegetations. It was developed mainly by Pignatti and Asmus (THEURILLAT, 1992a), and SCHWABE (1989).

- Italian school: initially based on methods from German and Franco-Iberian schools (CHALUMEAU & BIRET, 2013); the Italian teams then developed their own methodology, based on an inductive and deductive approach (BLASI *et al.*, 2000, 2004, 2005; BIONDI *et al.*, 2002, 2004, 2011; PEDROTTI, 2004, 2013; BLASI, 2010).

The different plant mapping approaches used by these four schools are better detailed in the synthesis report of CHALUMEAU & BIRET (2013). We have chosen to focus on the mapping methodology proposed by the Italian school, because it presents the advantage of using both types of approach (inductive and deductive at the same time), combining a maximum of ecological data (synfloristics, geology, climatology...), following a fine phytosociological and dynamico-catenal approach that helps to characterize and treat homogeneous tessellary envelopes (DEMARTINI, 2016).

4.3.5. Semiotics: the choice of colors in plant mapping

Semiotic studies concern the analysis and design of meaning-making, sign process (semiosis) and meaningful communication. Semiotics includes the study of signs and symbols,

their use, interpretation and related processes, indication, designation, likeness... (ECO, 1976; DEELY, 2006; EMMECHE & KULL, 2011).

GAUSSEN (1936, 1938a,b, 1942, 1954, 1956, 1961) proposed a color code in order to represent different type of vegetation in plant mapping. This code was subsequently retaken by Ozenda and his team (OZENDA, 1982, 1994; OZENDA & LUCAS, 1987) during some important plant map works, that follows a more physiognomic approach (PEDROTTI, 2013). The general idea was to use a color code to describe the different vegetation types (environmental conditions, and ecological characteristics); in case of vegetation series, the color corresponds to the ecological conditions (or series or plant associations) determining the most mature stage (head series).

Among the literature and plant mapping works already mentioned, we can underline two major types of map legend organization observed. The structure can be developed according to an altitudinal gradient corresponding to the vegetation stages (BACCHETTA *et al.*, 2009; BLASI, 2010; LOIDI *et al.*, 2011) or according to the series types (climatophilic, edaphoxerophilic, edaphohygrophilic...) (PINTO-GOMES *et al.*, 2003; PERALTA DE ANDRÉS, 2010; GONZÁLEZ DE PAZ, 2012).

Other elements sometimes are taken into account, such as series categories (series, geoseries, permaseries, geopermaseries); bioclimate...

For example, the legend of the plant map of Italy (BLASI, 2010) is organized from:

level 1. Bioclimatic regions;

level 2. Vegetation levels;

level 3. Geographical Sectors;

level 4. Type of series (from climatophilic to edaphoxerophilic).

The riparian units are integrated into "riparian and freshwater hygrophilic geosigma" and ranked according to the related altitudinal gradient. Coastal units are grouped into "halophilic geosigma".

The map of Navarra (PERALTA DE ANDRÉS, 2010) follows the second structuration (type of series). Its legend is declined in this way:

level 1. Type of series (climatophilic and edaphohygrophilic);

level 2. Vegetation levels.

The co-authors and collaborators of the Italian plant mapping edited by BLASI (2010) used a legend organization based on serial plant mapping on coastal area, and organized on general principles that we have adapted to our geoserial map, according to DEMARTINI (2016).

4.3.6. Map restitution and the geographic information system

In order to understand how vegetation series are representable and modeled, and after a first bibliographic review, we decided to use as organization sample CAPELO *et al.* (2007), BACCHETTA *et al.* (2009), BLASI (2010), LOIDI *et al.* (2011), DÍAZ-GONZÁLEZ (2014), and PEDROTTI (2017). The synrelevés were treated in a geographic information system (GIS). Spatial analysis of littoral series and geoseries requires their integration into a geographic information system (GIS). This tool, which has become essential for the production of modern thematic maps, is essential to meet the following objectives (LACROIX *et al.*, 2005): to improve knowledge of plant groups, associations, series and geoseries; identify and locate heritage issues

for plant associations, series and geoseries; and provide long-term monitoring of vegetation groups, series and geoseries. GIS is a PC program consisting in a set of computer tools designed to describe and analyze elements, events and phenomena inherent to the Earth's surface; in our case vegetation distribution and mapping. Creating an integrate vegetation serial model within the plant landscape models. The GIS technology integrates in a single environment the most common operations related to the use of databases (queries, statistical analysis...) with the geographic analysis allowed by numerical cartography, both raster and vector. The GIS allows to analyze a geographical entity both for its complete geometric (and symbolic) nature and for its total informative content. This is made possible by the integration of two previously separate systems: computerized drawing systems (CAD-Computer Aided Design) and relational databases (DBMS-Data Base Management System). The GIS implementation is done through the territorial information systems. The GIS software has the functions and tools necessary to collect, analyze, and display geographical information; and its fundamental elements are: tools for the input and management of geographical elements; a relational database; tools that support queries, analyzes and visualizations; graphical user interface (GUI) to allow easy access.

The GIS software used in this work is QGIS ver. 2.18.24 'Las Palmas'. The projection system used is the projected coordinate system "RGF93_Lambert-93".

Depending on the spatial nature of the entities identified in the fieldworks, the GIS offers several representation possibilities: polypoints (point data), polylines (linear data), or polygons (surface data). Although some serial entities are structured in a linear way (for example, geopermaseries), it seemed preferable to store all the areal objects and their corresponding information in a single layer of polygons. This choice has the advantage of not multiplying the layers, and storing the information in only one point. Within a series polygon, the GIS must store a certain amount of information related to its general environmental data. This information is contained in the attribute table related to the polygon layer (serial, plant-association, geoserial layer...); they fall into four categories, each with several fields (i.e.: the polygon information as ifs for ID, coordinates, surface...); the administrative information (region, department, municipality); the environmental information (bioclimate, geology, geomorphology, altitude, exposition, salinity range, soil use, phytodynamic processes...); the information specific to the synrelevés (ID code, Legit, date of observation, type of (geo)sigma, name of (geo)sigma, characteristic syntax, contact vegetation, salinity...). The data tables include information related to (geo)synphytosociological records. They could be also stored as database management software. This makes it possible to relate the polygons with the information provided by the field relevés and polygons. The (syn)phytosociological data could then be valorized by the creation of distribution maps of the vegetation underlining some environmental aspects in the database. Geographic reference, as images and vectorial type (PEDROTTI, 2013) are essential for the interpretation of plant landscapes (DELBOSC, 2015). They serve as input tool on one hand, and as a base of environmental thematic mapping, allowing a good superposition of layers of themes, objects and related issues. Most of the cartography references used in this work come from the French National Geographic Institute (IGN) as is the case for: orthophotographs (BD ORTHO) are the most important reference for mapping series and geoseries. They serve as a topographic base and as support for the delimitation of serial entities both in the fieldworks and on the GIS digitization. The spatial resolution of our used orthophotographs is 0.5m. The years of acquisition could differ by department and ranges following the current availability (in general they are from 2009 to 2012). For the same purposes, between others ortho-images data, there are further useful sets as a reference background (GEOFLA, SCAN 25...) these references are useful also as descriptors of the

elements of the territory (road network, hydrographic network, tides, floodings, buildings, urbanized areas...). RGE ALTI according to IGN product descriptions is a large-scale geographical reference to describe the French relief (shape and altitudes of the ground surfaces). Litto3D is a land-sea altimetry database of metric resolution. It provides a 3D representation of the shape of the soil on French coasts. On land, it concerns the coastal strip up to an altitude +10 m and at least 2 km inland. On the sea, it has a right of way up to the continuous bathymetric curve of depth 10 m and at most up to 6 miles from the coast. The superposition of these layers to other ecological information allowed us to specify certain limits and to clear the Tessellar envelopes on which the synrelevés must be made. These repositories can be used upstream, during pre-cuts, or to adjust the limits during the scanning phase.

5. DATA ANALYSIS AND RESULTS

5.1. Theoretical Ecological compartments scheme of an estuary

We analyzed literature in order to elaborate a first theoretical generic model of estuarine system functioning and plant distribution. To this purpose we followed the hydrodynamic and the geomorphology description and classification of estuaries (see part 2.3 and 3) and the river hydro-morphology and geomorphology description and classification (BILLI, 1992; CALOW & PETTS, 1992; BRINSON, 1993; GURNELL & PETTS, 1995; CARLING *et al.*, 1996; THORNE *et al.*, 1997; HERITAGE *et al.*, 2001; ROBERT, 2003; CHURCH, 2006; GIBLING, 2006; CHARLTON, 2007; ARNAUD-FASSETTA & LAGANIER, 2009; EINSELE G., 2012; MIAL, 2013; KNIGHTON, 2014) as follows.

Usually, the estuarine minor riverbed is without terrestrial vegetation, especially in the lowest topographic portions, because of strong currents or frequent environmental changes (i.e.: salty and non-salty, dry and aquatic...). Going up to the slikke, Schorre, until the banks (in large sense) we observe terrestrial (amphibian) vegetation subjected to the recurrent high water flows. Upper, the vegetation is always more and more exposed out of waters but flooded following the tidal dynamics and river flooding's phenomena (seasonal flood and even occasional extreme events). Following the previously cited literature and that from paragraph 2 and 3, from river mouth to the freshwater portion, in the minor riverbed we can observe a variable vegetation cover and zonation; from salt algal coverage to aquatic water plants (pleustophytes, amphibian...) and fresh water algal cover. The slikke corresponds to the part of the mudflat covered at each tide. It is mostly composed of soft smooth mud. The lowest slikke level is also generally without terrestrial vegetation, while the upper slikke could have the first levels of terrestrial (amphibian) vegetation especially consisting in *Spartina*, *Salicornia* (large sense) and *Suaeda* species. The slikke houses a huge amount of bacteria that allow it to play an essential role in the processes of self-purification and recycling of necromass. It also shelters a varied fauna of bivalve mollusks, gastropoda, crabs, and fishes. Slikke is frequented by wading birds; but also by many terrestrial or marine animals.

The Schorre also known as the Breton word "Palud", is the upper part of the mudflat, flooded during the high tides. The Schorre is characterized by a halophilic vegetation (DEMARTINI, 2016). The lowest Schorre is covered with each tide, except during the dead

waters. The lowest Schorre is colonized by plants, such as *Suaeda maritima*, *Tripolium pannonicum*...

The middle Schorre presents a more developed vegetation, reaching even a chamaephytic structure due to *Atriplex portulacoides*. The upper Schorre is characterized by *Limonium* species *Artemisia maritima* and tall grass like *Bolboschoenus maritimus*, *Schoenoplectus tabernaemontani* and *Scirpus triqueter*. Up to this point, the *Salicornia* species and *Sarcocornia perennis* (glasswort in large sense) became rarer.

The very high Schorre is characterized by a very dominant cover of *Bolboschoenus maritimus* in wettest point or by a dominant cover of *Elymus athericus* and a remarkable presence of *Beta vulgaris* subsp *maritima* or *Atriplex prostrata*; and large reed beds (*Phragmites australis*). From this point we could also start to observe the first ligneous vegetation (*Ulex europaeus*, *Prunus spinosa*, *P. x fruticans*, *Tamarix* sp.pl., *Rubus* sp.pl., *Atriplex halimus*, and even *Salix* sp.pl., *Fraxinus excelsior*, *F. angustifolia*, and *Quercus robur*).

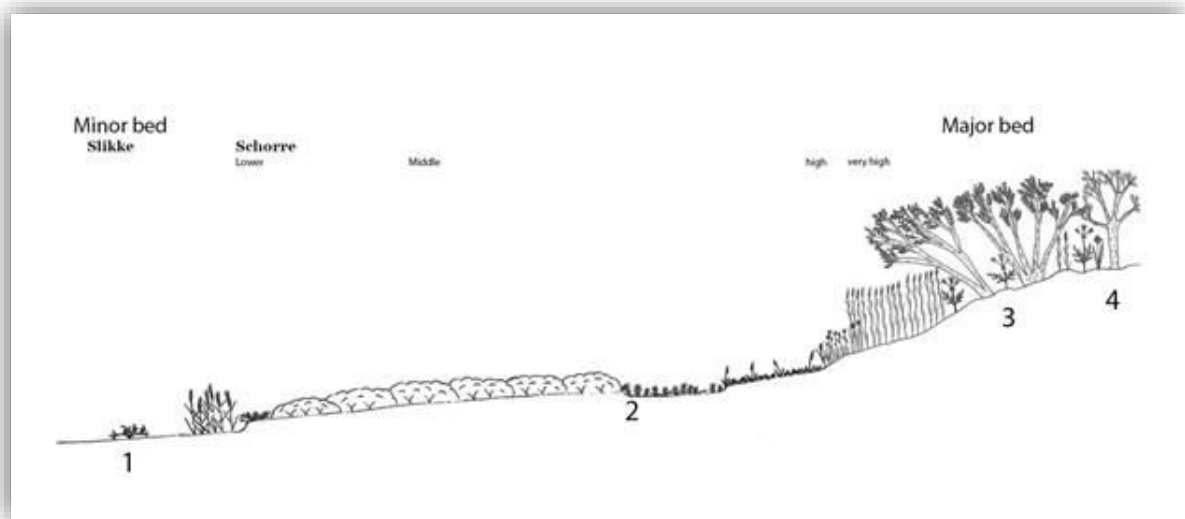


Figure 17. - Plant ideal zonation in transversal direction in salty sector ecosystem.

Right now, we analyzed the plant zonation in longitudinal and transversal direction in salty ecosystem (Fig. 17). In fresh water (RAUNKIAER, 1934; ELLENBERG & MUELLER-DOMBOIS, 1965/66; SHARP and KEDDY, 1986; PUHAKKA *et al.*, 1992; PEDROTTI & GAFTA, 1996, 2003; JAROLÍMEK *et al.*, 1999; LOIDI *et al.*, 2011; LIENDO *et al.*, 2013; BIURRUN *et al.*, 2014, 2016; NONES & VARRANI, 2016; SCHMIDT-MUMM & JANAUER, 2016; SENDER *et al.*, 2014, 2017) in rivers, lakes and marshes as example; and in brackish aquatic systems (CARUS *et al.*, 2017) generally the vegetation zonation is also differentiable in various altitudinal levels from the center to the banks (Shore), following this scheme: submerged hydrophytes; floating hydrophytes; helophytes; hemicriophytes; wet meadows; wet forests; and mesic forests (Fig. 18).

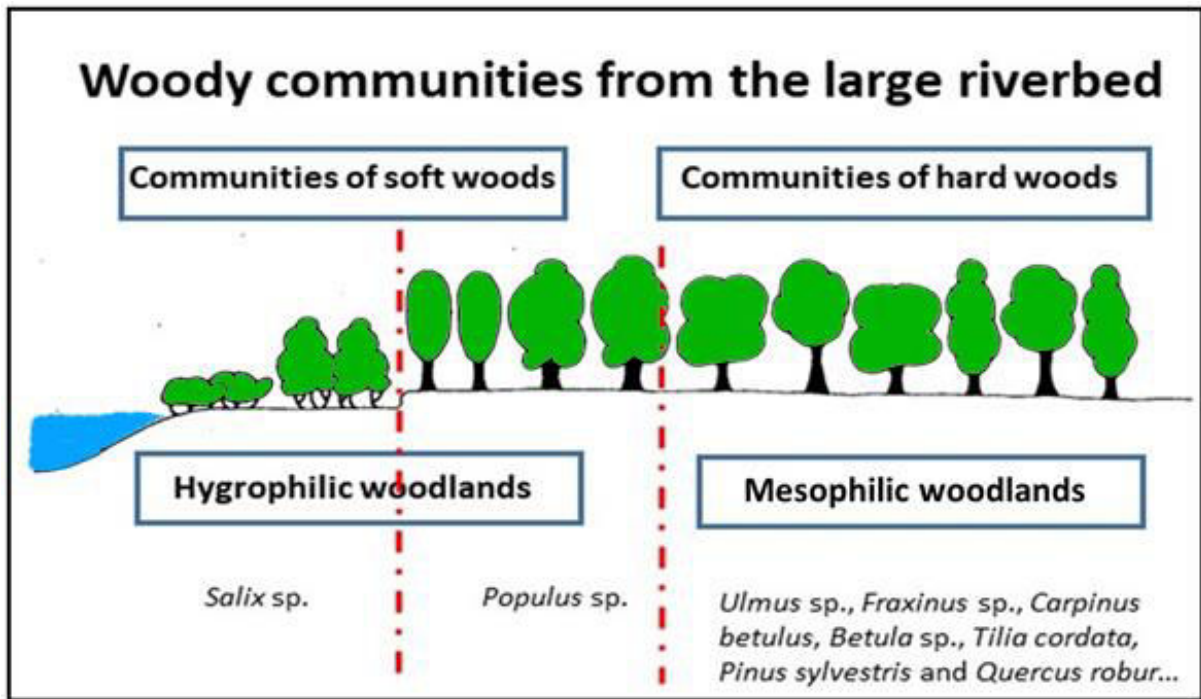


Figure 18. - General major riverbed forest type transversal gradient. From hygrophilic woodlands (soft wood community) dominated by Willows and Poplar species (*Salix* and *Populus* sp. pl.), to mesophilic woodlands (hardwood community); dominated by several genera of trees. The hardwood community distinguish to the softwood by the presence of hard wood species, like Elms (*Ulmus* species) and Pedunculate oak (*Quercus robur*).

Geomorphological forms previously analyzed can contribute to the manifesting floristic and vegetation features that will be analyzed case by case in this study.

Following the different levels of floods from minor to major riverbed we can observe an increasing in community biomass (volume). Following various authors remarks about plant community type per topographic level nomenclature: Diels, *in*: DE WILDEMAN (1910), RAUNKIAER (1934), ELLENBERG & MUELLER-DOMBOIS (1965/66), LEBRUN (1966), PEDROTTI & GAFTA (1996), PEDROTTI, (2004a); GÉHU (2006); the aquatic vegetation has a cline from lowest to highest topographic levels (Fig. 18 and 19).

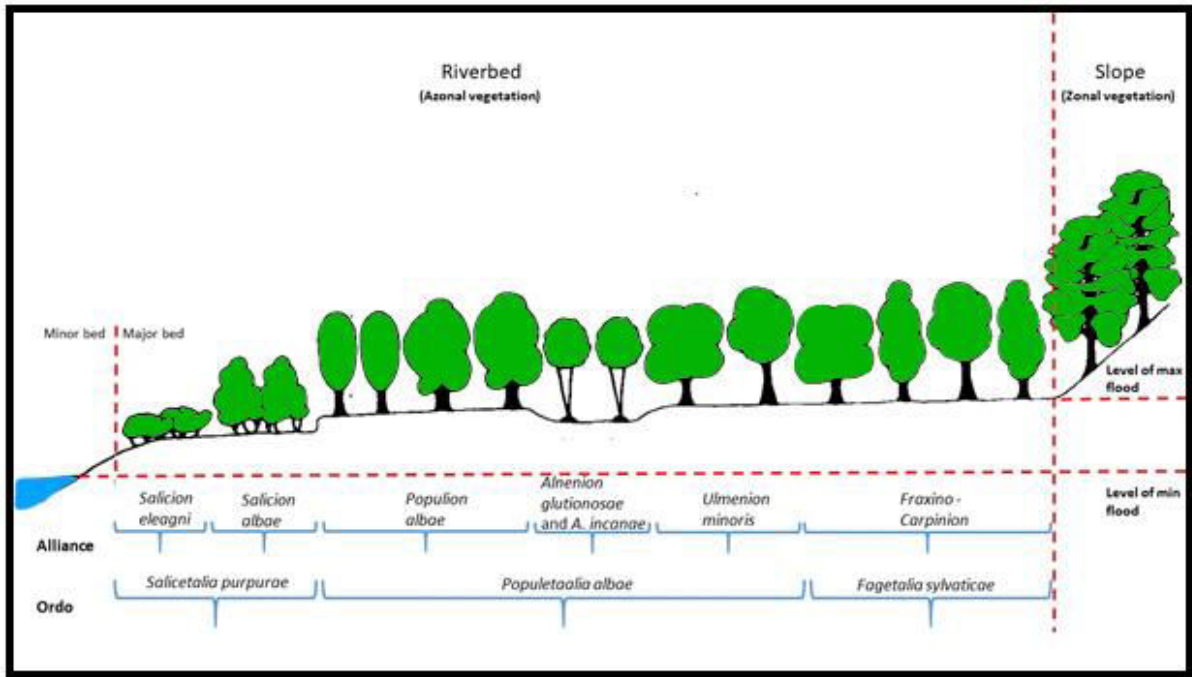


Figure 19 - An ideal complete vegetation sequence from the minor riverbed to the slope (out of the estuary) for European ecosystems.

At lowest levels we can find hydrophytes, consisting in the most aquatic plant type community; to the highest levels where we have mesophytes, consisting in plant that tolerate occasional or seasonal flooding (especially in the coldest season) and even dry conditions during driest season peaks (Fig. 19 and 20).

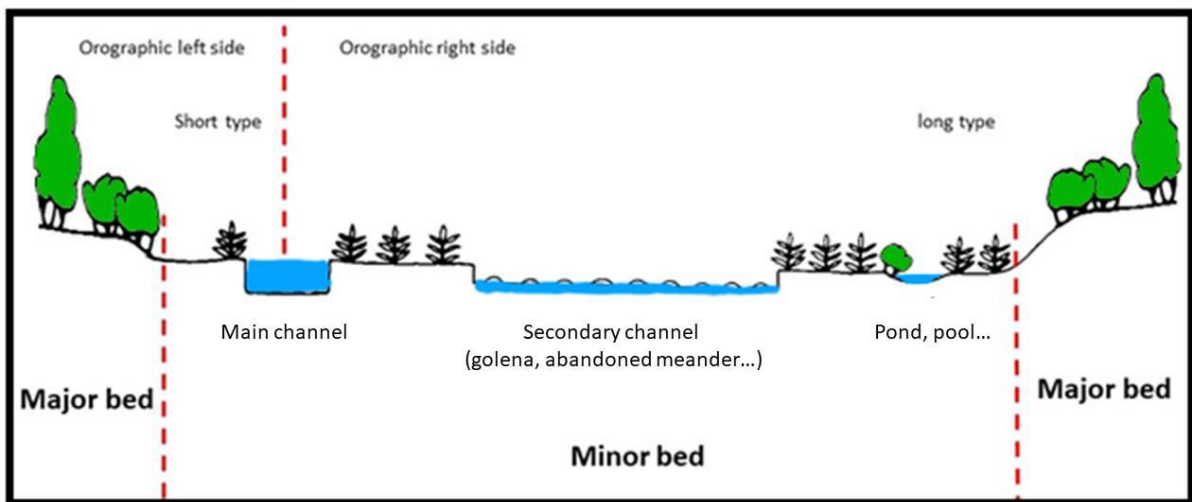


Figure 20 - An example of vegetation zonation with geomorphologic exceptions (i.e.: secondary channel, ponds, pool and estuarybed islands...).

Hydatophytia, are submerged formation and they are subdivided in: thalassium (sea formations), limnium (lentic formations), potanium (lotic formations).

Hydrophytes could be of three types of submersion habitus: totally submerged; partially submerged (rooting type with emerged or floating leaves or flowers).

Hygrophytes could be subdivided in hydrophytes, helophytes (rooted in the marshy ground) and pleustophytes (completely floating non rooted in the ground). They could have a different level of amphibious behavior (in lowest part most aquatic tolerating water retreats, to more terrestrial plants tolerating flooding. These plant levels correspond to the slikke and Schorre levels described in salty vegetation (including the halodrymium).

Upper we have the therodrymium level, corresponding to the large leaves dominated forests, with an upper portion (mesic) and a lower portion (hygrophilic).

Between hygrophytes level we can find some communities like: hygropoium (i.e.: grasslands, meadows and pastures), hygrophorbium (i.e.: alkaline bog and fens), megaphorboium (herbaceous formations domined by very large leaves or very large size herbaceous species) and roselières (graminoids dominated formations like reed bed, *Carex*, *Scirpus*...) (Fig. 21).

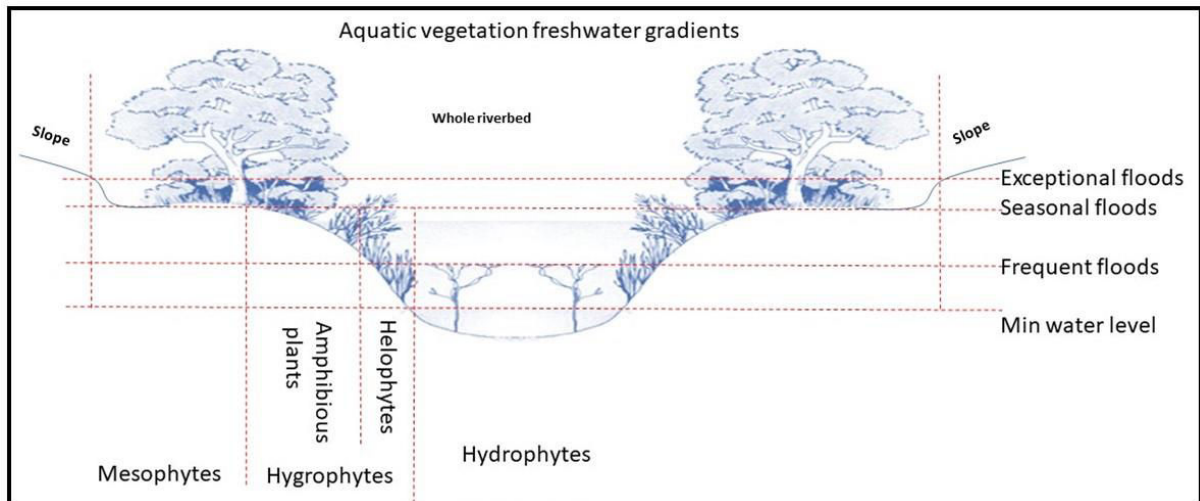


Figure 21. - Vegetation zonation in the entire estuarine riverbed, related to water levels of floods

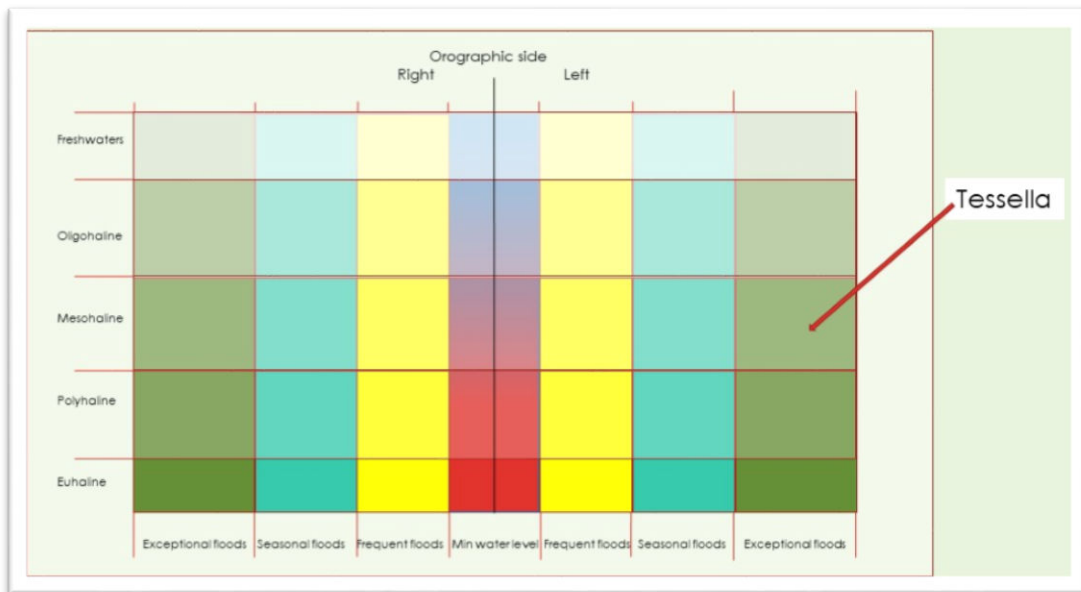


Figure 22 - Theoretical square grid system of the expected ecological compartments distribution of estuaries, obtained crossing floods and salt levels.



Figure 23 - Exemples of intensity and frequency of floods in Loire estuary. From frequent (right) to exceptional (left) flood levels.

These communities could be also found in secondary succession in mesophytes level or as primary in exceptional geomorphologic cases (depressions, springs...).

The following vegetation scheme (Fig. 24) was produced analyzing all these bibliographical data, observations and features: making a first hypothesis of plant distributions, series, sigmeta and catenas, useful to refine the fieldwork organization and to elaborate a first hypothesis to be refuted and refined by our study.

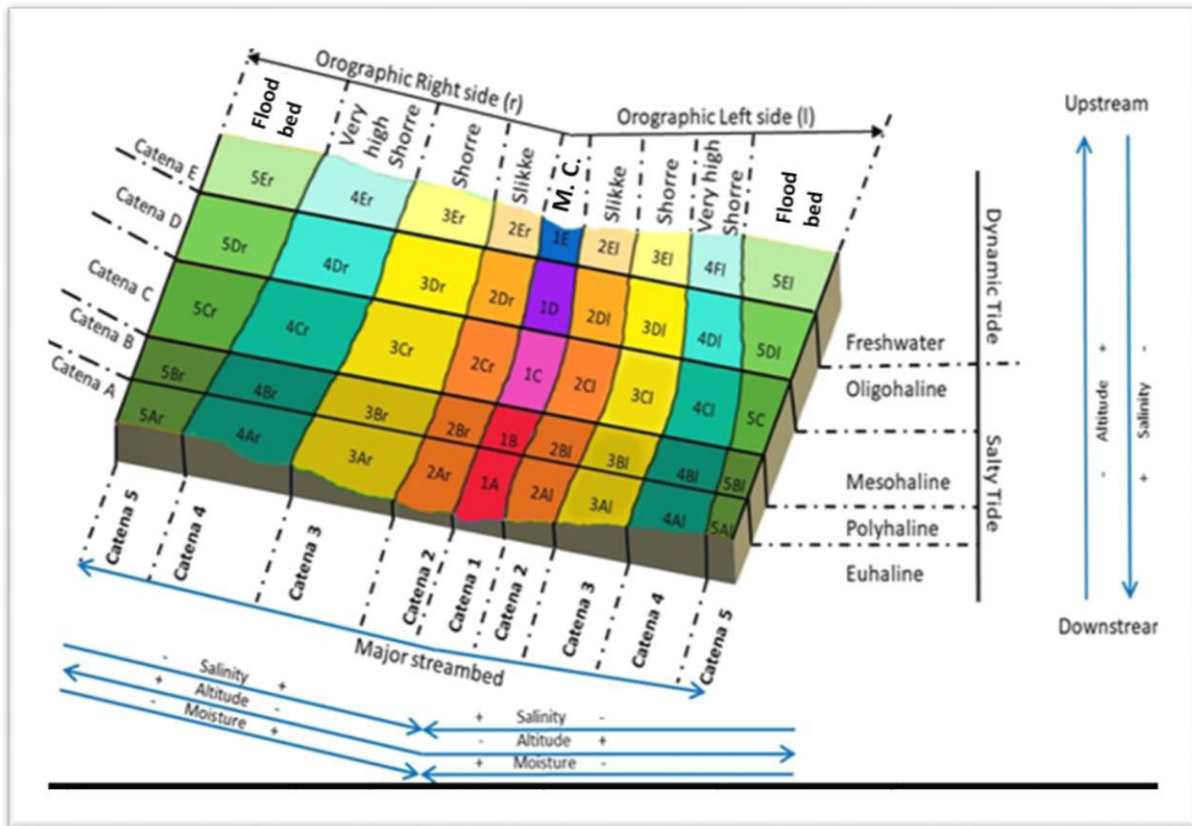


Figure 24 - Theoretical generic scheme of awaited ecological compartments of estuaries contextualized by main ecological factors (blue arrows) gradients and per geo-hydro-morphology sectors. From the main channel (M. C.) in the middle, to the flood bed.

According to the precedent paragraphs considering estuarine geomorphology (paragraph and the synphytosociology issues (paragraph 2.3 and 3) we can see in picture how any patch is an awaited Tessella; and the catenas consist in longitudinal and transversal catenas.

Transversal catenas are delimitate by grouping the same capital letter per each orographic side (i.e.: in the right side, the catena A is composed by all the right “A” Tessellas in this way - 5Ar, 4Ar, 3Ar, 2Ar and 1A). Longitudinal catenas are delimited by grouping the same numbers per each orographic side (i.e.: in the right side, the catena 5 is composed by all the right “5” Tessellas in this way – 5Ar, 5Br, 5Cr, 5Dr and 5Er).

The lowest Tessellas (above sea level, per salty compartment) corresponds to the minor riverbed (the minor streambed or smaller riverbed); these Tessellas belongs halfway to right side (right bank) catena and half to the left side (left bank) catena. More precisely these Tessellas are separable in two sides (right and left according to the orographic bank side). The division

between left and right side in this case is due from the deepest point of the minor riverbed (minor streambed).

The upper Tessella (above sea level per salty compartment) correspond to the terrace, to the point where only the exceptional flooding could occur rarely during extreme events (the highest flooding points).

5.2. Bioclimate mapping

5.2.1. Bioclimatic map of Atlantic phytoregion

The Atlantic phytoregion corresponds is characterized by an Oceanic climate type, with some nuances and gradients, as showed by the following elaborations.

We defined all the climate and bioclimate elaborations within the Atlantic region, following the biogeographical boundaries source from “European environments agency – Europa, EU 2016” (<https://www.eea.europa.eu/fr>).

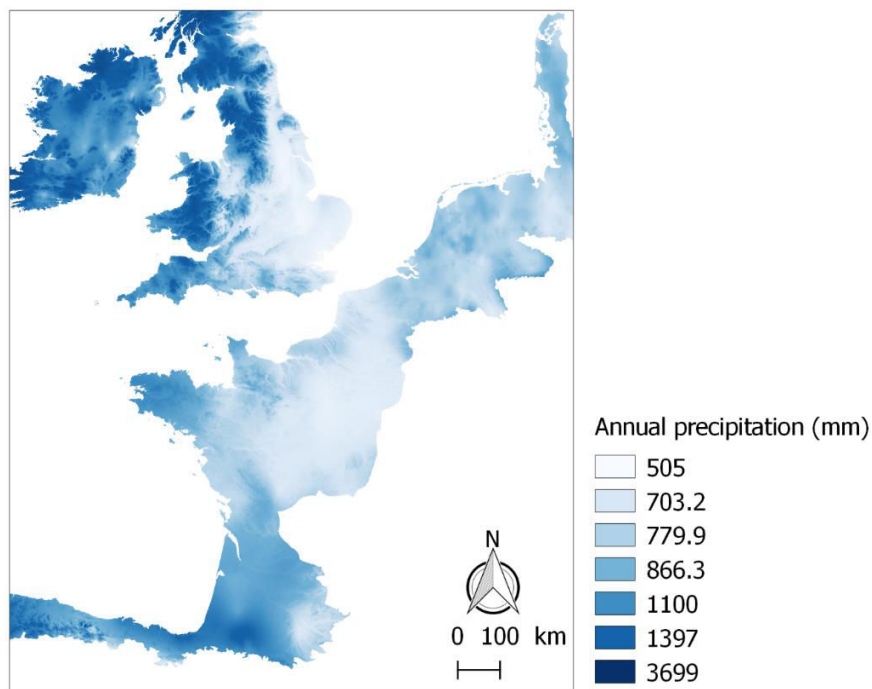


Figure 25 - The precipitation spatialization in the Atlantic bioclimatic region

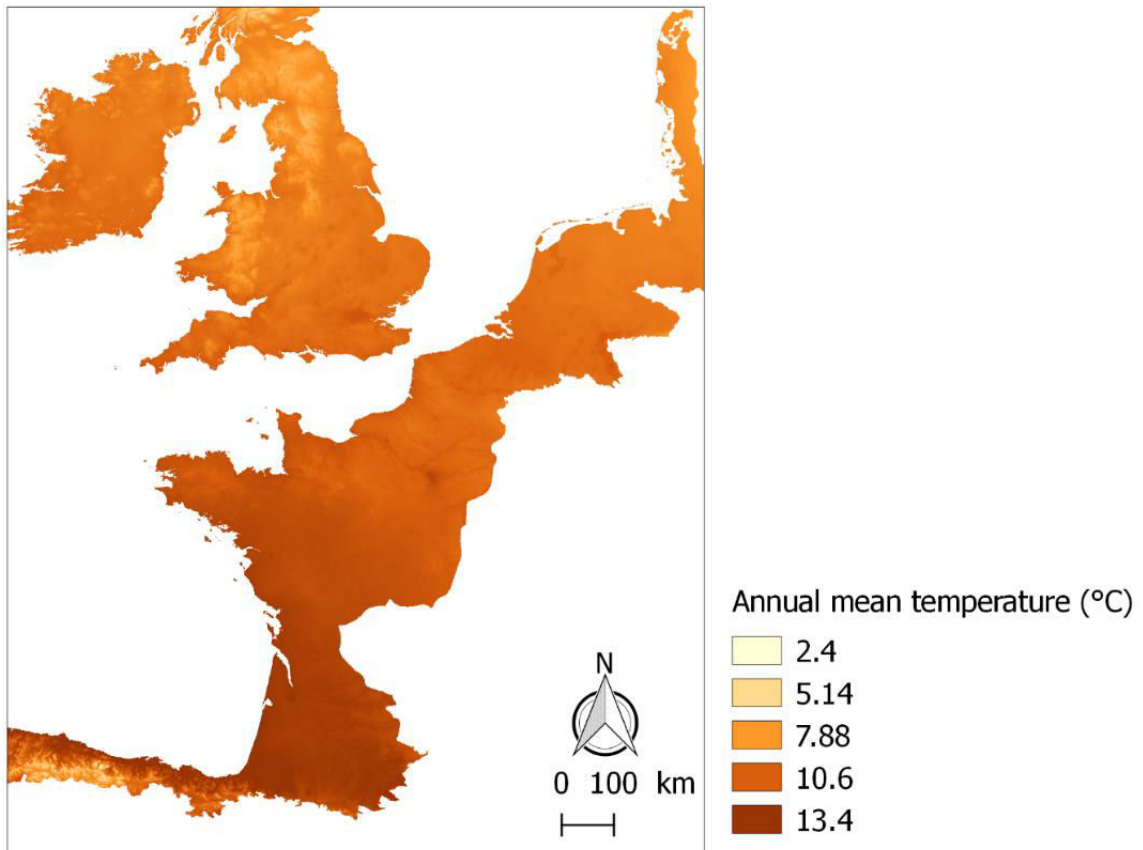


Figure 26 - The mean annual temperature spatialization in the Atlantic bioclimatic region

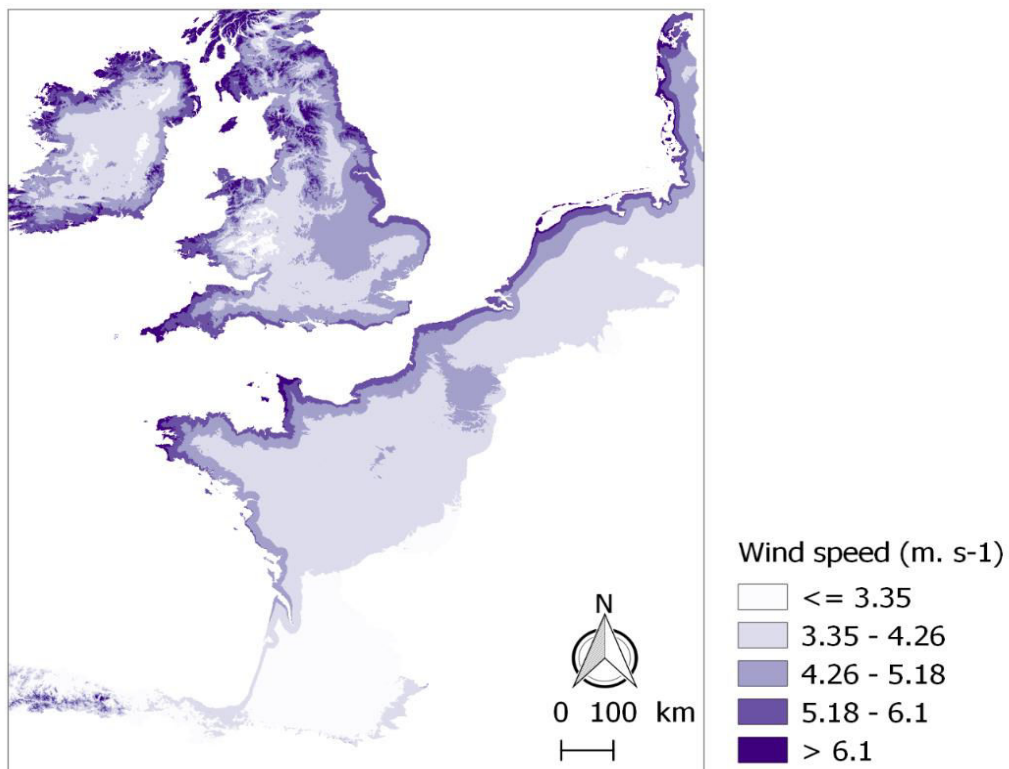


Figure 27 - The wind speed values spatialization in the Atlantic bioclimatic region

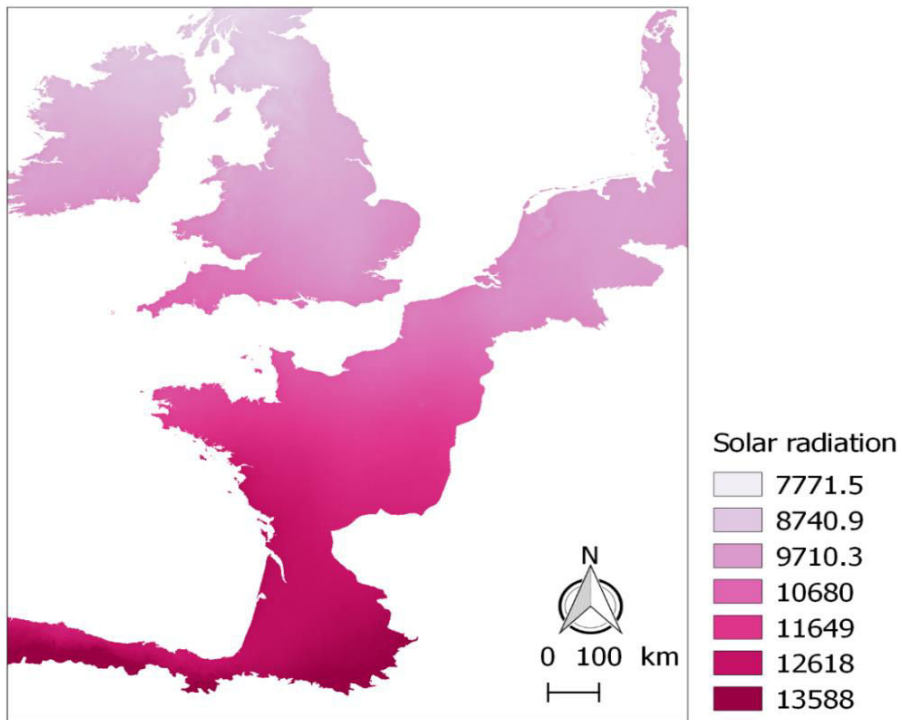


Figure 28 - The solar radiation spatialization in the Atlantic bioclimatic region

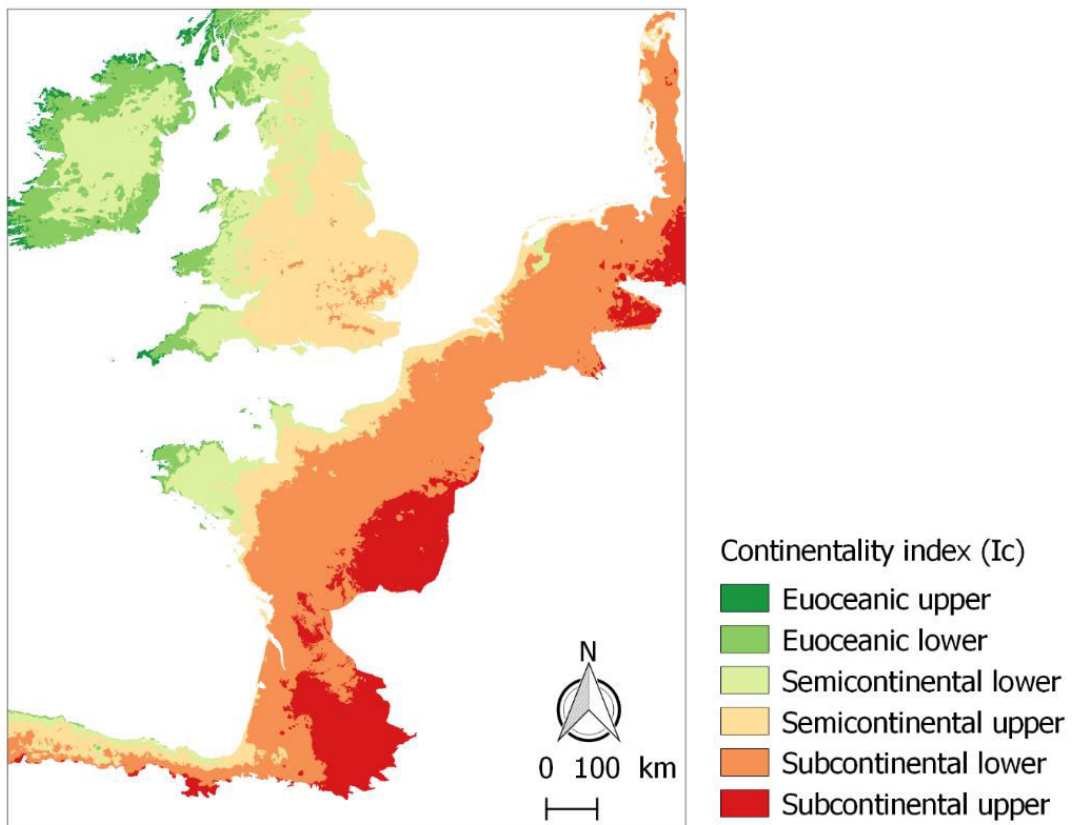


Figure 29 - The Ic index spatialization in the Atlantic bioclimatic region

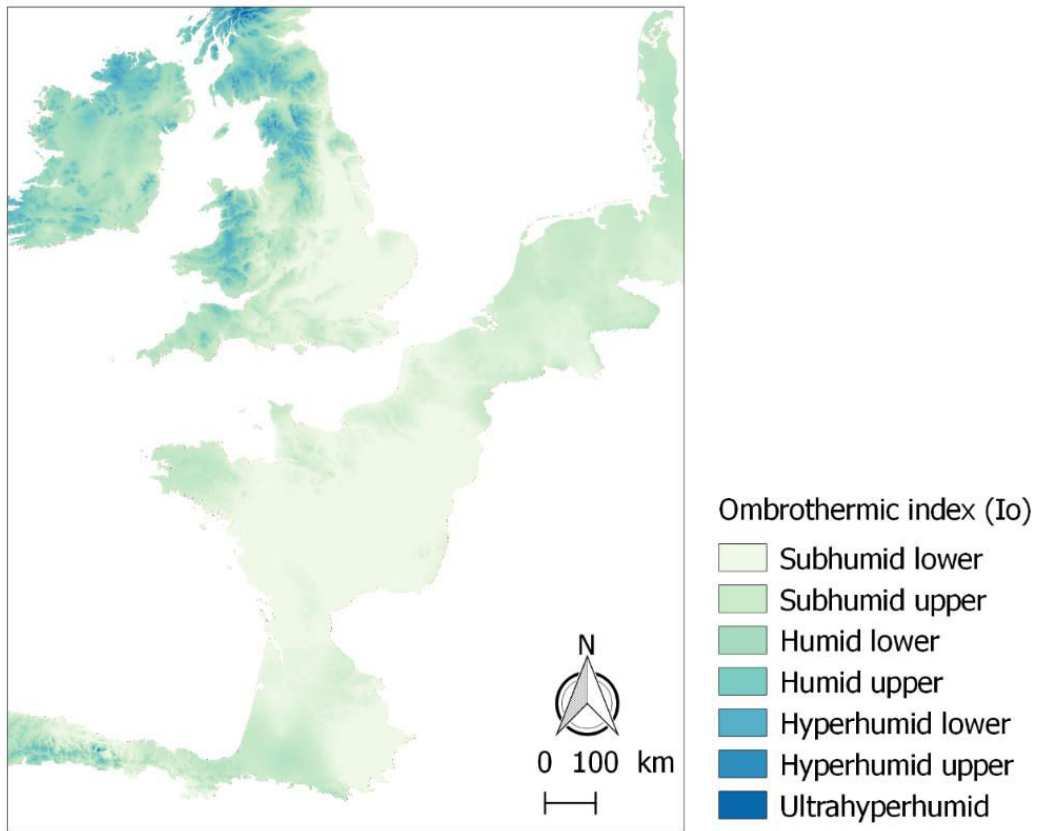


Figure 30 - The Io index spatialization in the Atlantic bioclimatic region

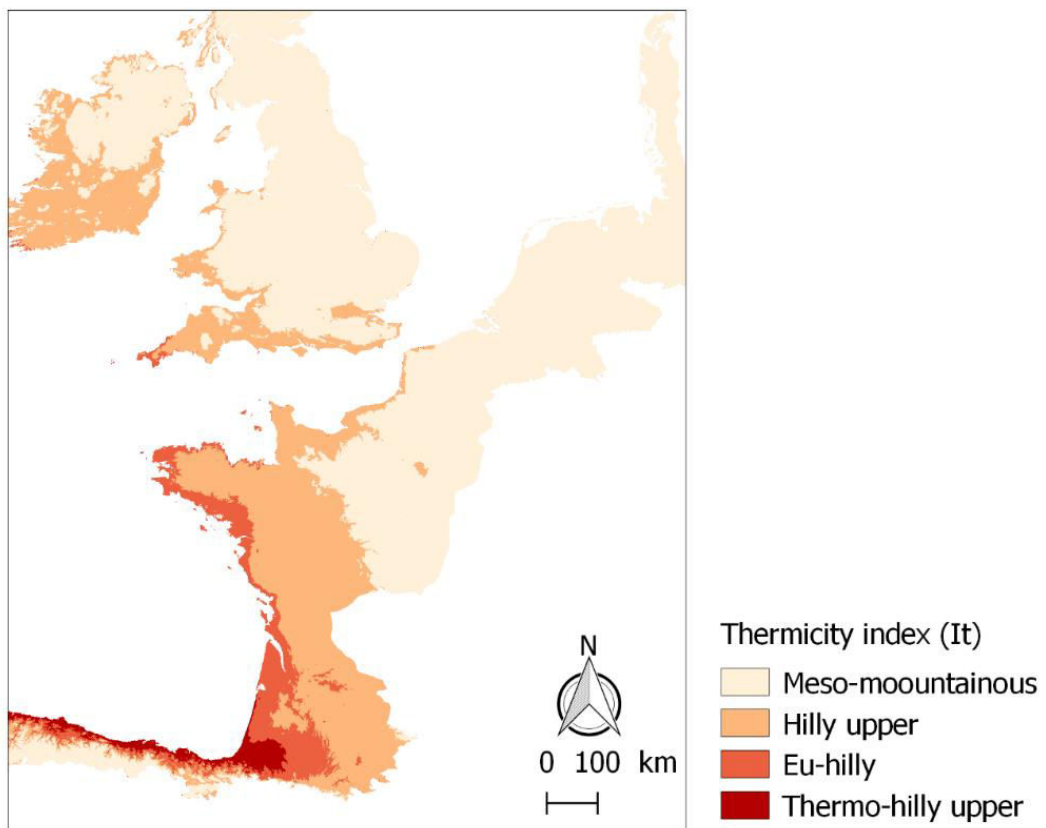


Figure 31 - The It index spatialization in the Atlantic bioclimatic region

These general bioclimatic and climatic elaborations figures, within the Atlantic oceanic climate zone let us to propose some selected estuaries to be primarily studied and taken as a model for fieldworks. We choose from north to the south cline: Elorn, Aulne, Laïta, Blavet-Scorff, Étel, Vilaine, Loire and Charente. In the following tables we analyzed climatic data to obtain the ombrogram for the available climatic station along the estuaries in longitudinal down-up direction. We choice this sector for deeper and fieldwork studies, according to the same biogeographic sector due to association and species distribution According to the coastal vegetation chorology (DEMARTINI, 2016). In according, at the estuarine level we can add as example that our sector of study could be defined as the zone of *Angelica heterocarpa*, a species endemic for Western France estuaries (CIANFAGLIONE & BIRET, 2018); while the northern portion is typical represented by *Angelica archangelica* subsp. *litoralis* in the same ecosystems (REDURON, 2007). Another example of remarkable floristic chorology difference is that the western Atlantic coastal sector is differentiable by a stronger presence of *Salix atrocinerea*; while the north sector (especially east to the Manche) by a stronger presence of *Salix cinerea* (DUVIGNEAUD, 1947; VAN DER MAAREL & WESTHOFF, 1964; PETIT-BERGHEM, 1996; DE FOUCAULT, 1984; VAN DER MAAREL *et al.*, 1985; ALLIENDE & HARPER, 1989; SMITH, 2006; SMITH & KIMPTON 2008; CATTEAU *et al.*, 2010; DEMARTINI, 2016; PERRIN *et al.*, 2018). In addition, this sector is homogeneous in its geography exposition, and represents a climatic cline from hyper-Atlantic to Thermo-Atlantic. This sector was also considered as thanks to the presence of large and small estuaries and human impact degree.

5.2.2. Bioclimatic characterization of selected estuaries

After the climatic and bioclimatic elaborations, we saw that evaporation and radiation are uniform in the area not determining any difference between the selected estuaries.

The wind analysis showed how between the selected estuaries, the ones from the Brest roadstead (Elorn and Aulne) are the most wind exposed; while the southern are the less exposed.

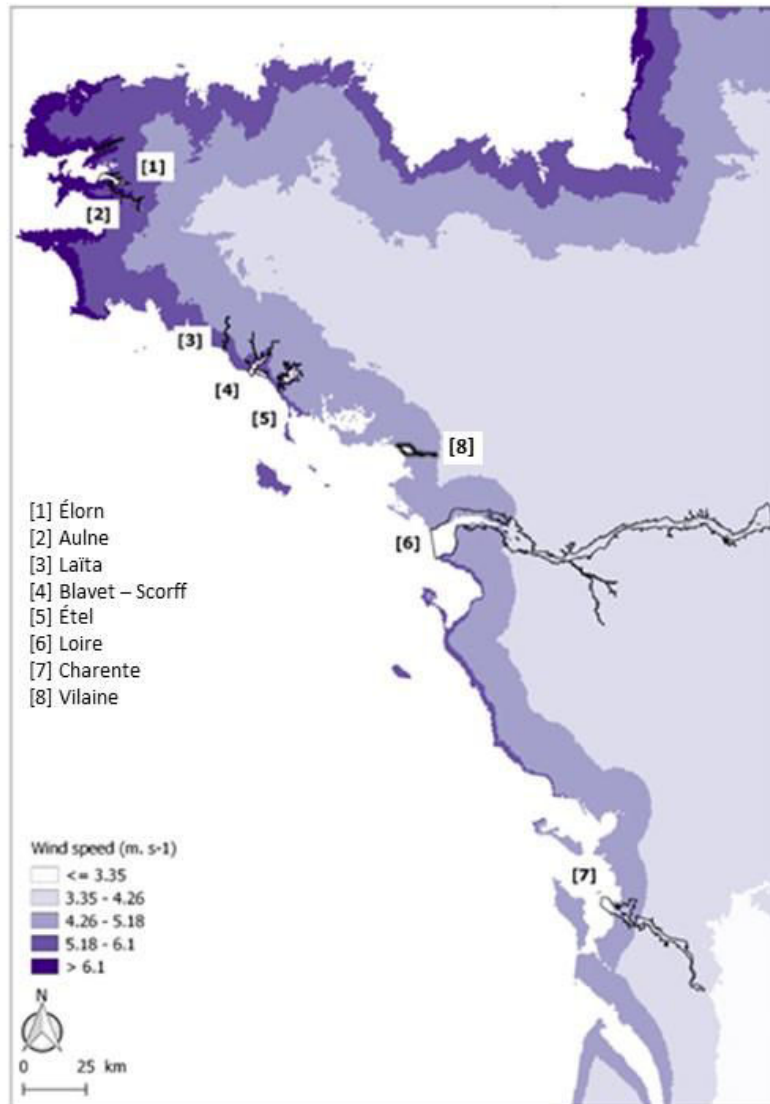


Figure 32. - The wind speed for studied estuaries

In any case, all the estuarine mouths are more exposed to wind intensity (Fig. 32) and related salt sprays carried out. This justifies the vegetation exception in the large estuarine riverbed and in contact vegetation (slope); favouring the development of *Salix atrocinerea* forest as head series, even in mesic conditions. In most sheltered conditions, the *Fraxinus excelsior* forests could develop as alluvial or in slope.

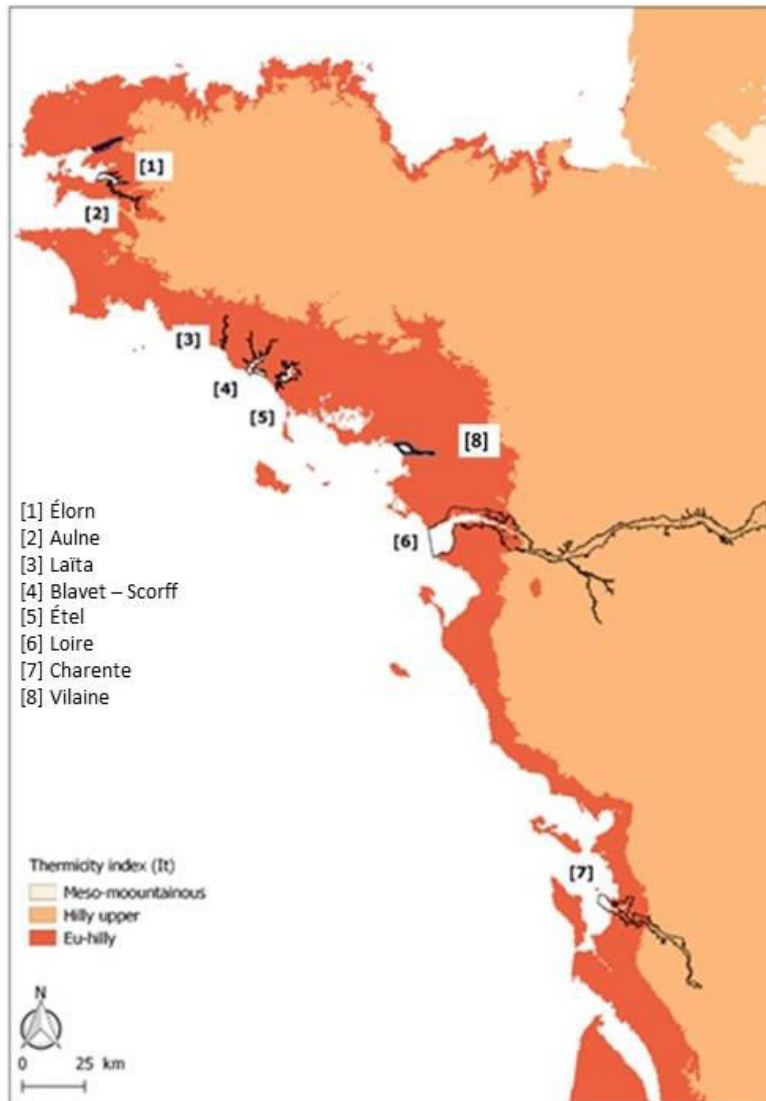


Figure 33. - The It index for studied estuaries

The analysis of the temperatures (by the IT index) show how the most coastal portion of estuaries is hotter (Fig. 33). In any case it shows how small estuaries can be distinguished to biggest ones because the smaller fall completely in the most coastal zone, while the biggest ones develops more in much inner conditions.

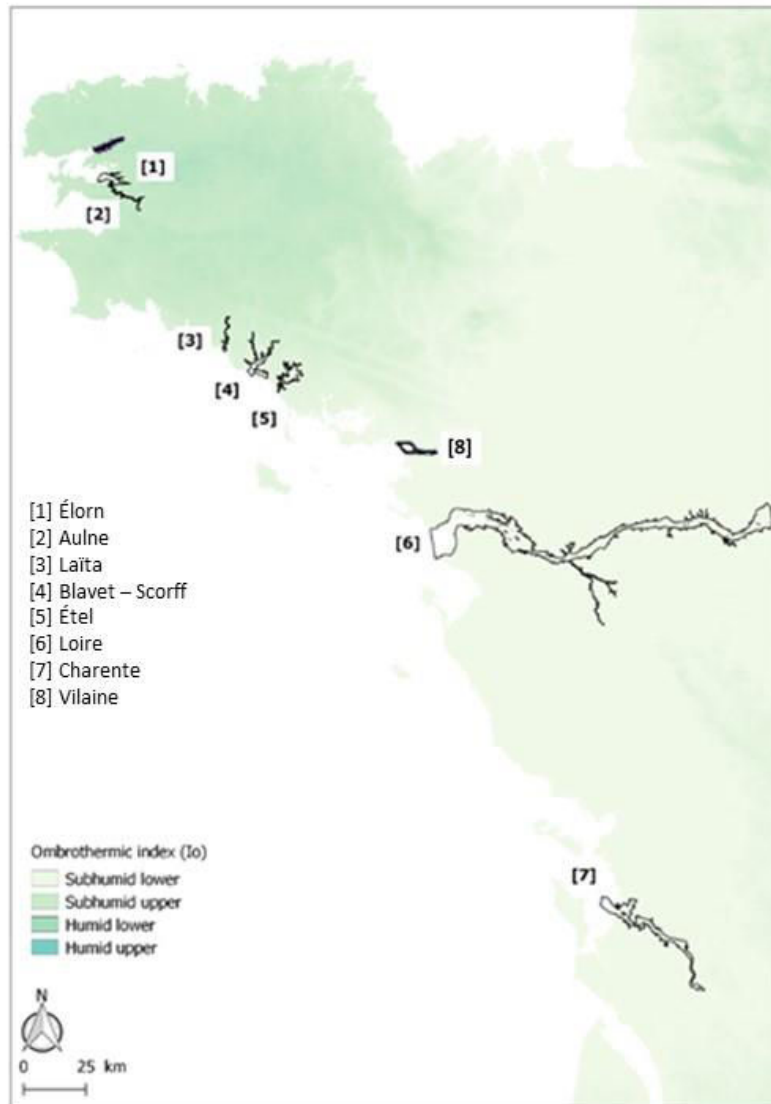


Figure 34. - The Io index for studied estuaries

The ombrothermic analysis (Fig. 34) shows how there is any remarkable difference between more coastal and innermost estuarine portions. However, it is possible to distinguish the northern (Breton) estuaries to the southern ones.

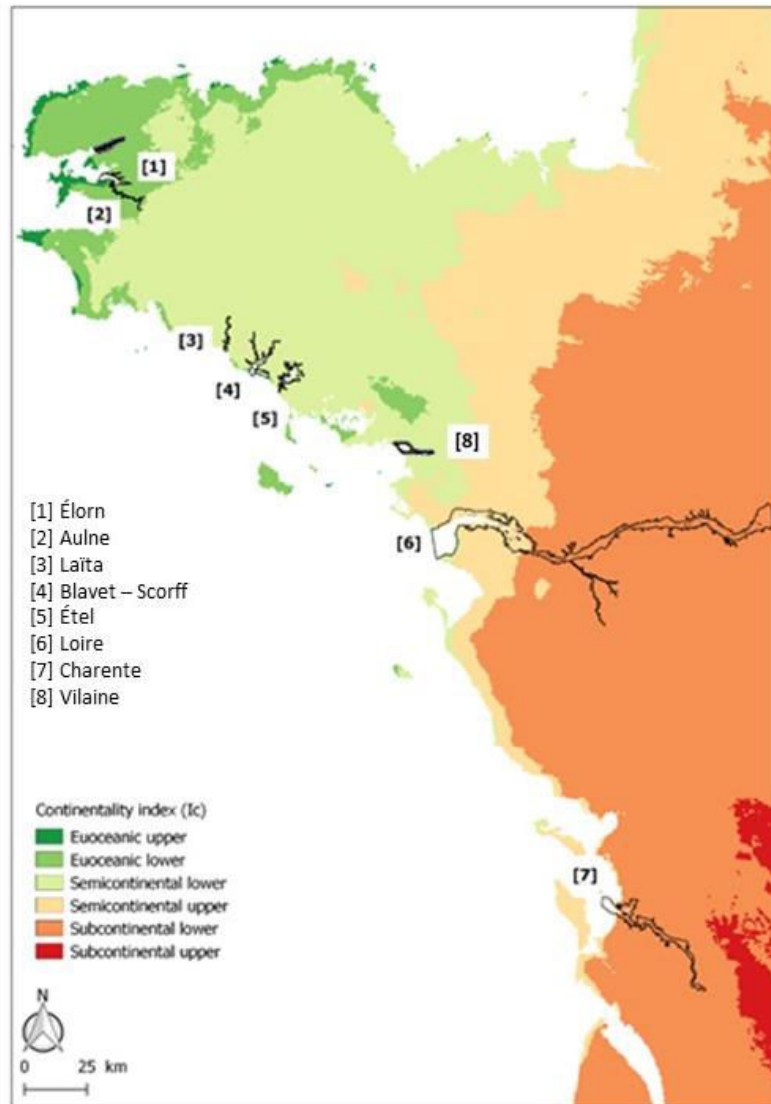


Figure 35. The Ic index for studied estuaries

The analysis of the continentality degree (by the IC index) shows how the coastalmost portion of estuaries are more oceanic and the inner sectors have a more continental influence (Fig. 35). In other hand, this analysis shows a huge gradient between the northern to the southern estuaries, from euoeceanic to subcontinental. This could explain the lesser representation of *Salix alba* and *S. fragilis* in northern estuaries; and the strongest presence of *S. atrocinerea* tendencies approaching to the estuarine coastal sectors.

5.2.3. Ombrothermic diagrams of estuaries

Ombrothermic diagrams were elaborated to characterize the drought periods of a given station (GAUSSEN & BAGNOULS, 1952; GAUSSEN, 1956; BAGNOULS & GAUSSEN, 1957) and to test micro variation and microclimate of estuaries.

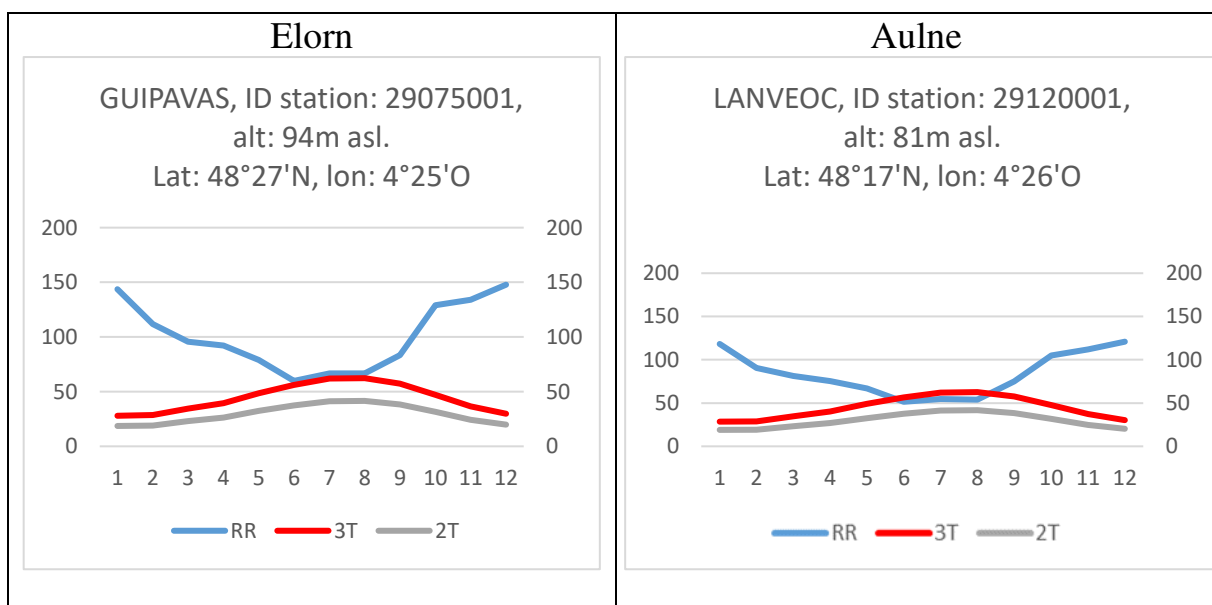
The diagram superimposes the curves of temperatures (2T and 3T) and precipitation for the 12 months of the year, defining an ombrothermic (precipitation and temperature) area: the area of the overlap between the T and P curves express the importance (subsistence, intensity and duration) of the drought period.

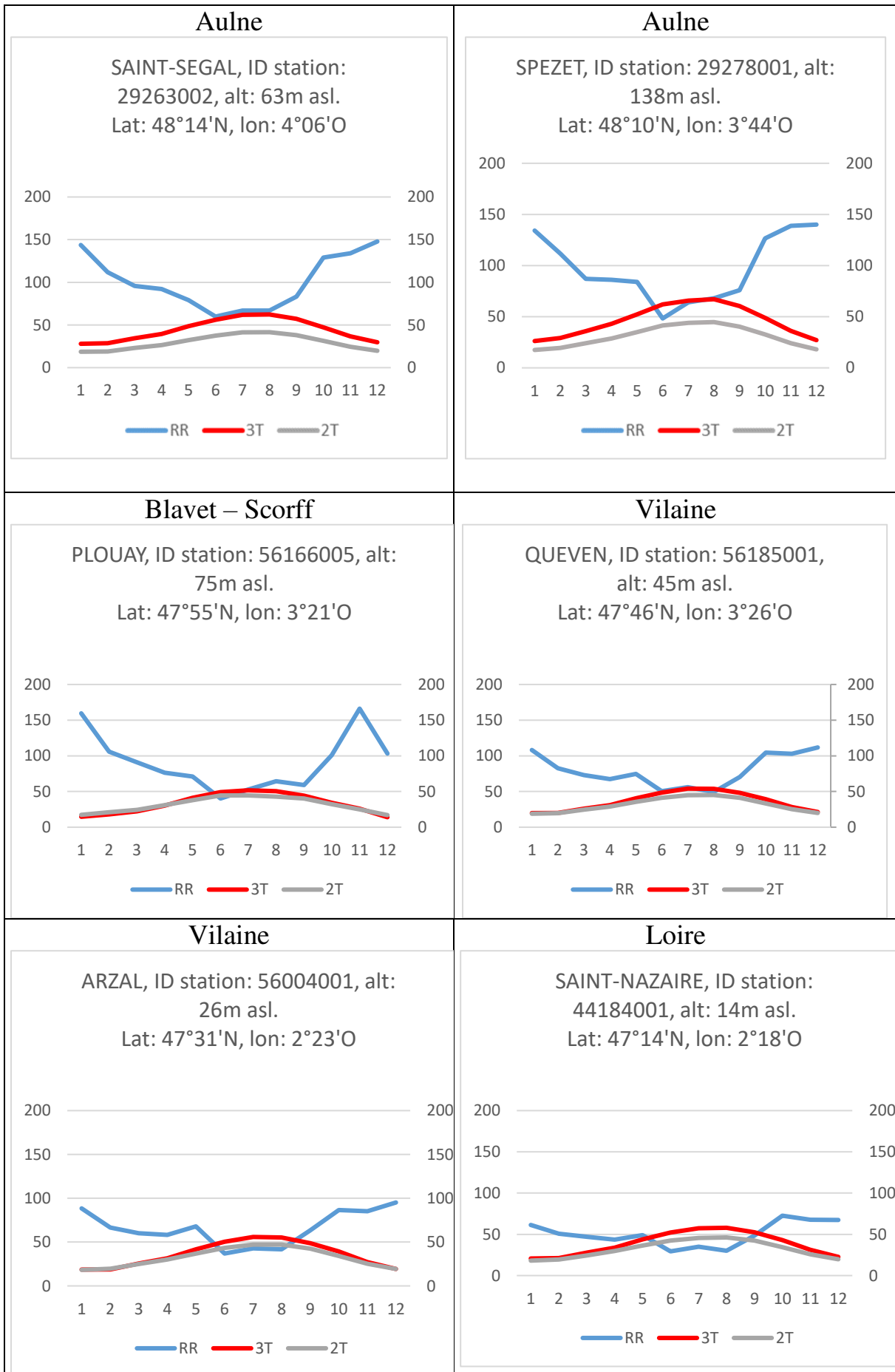
The results of this climate data after the ombrothermic elaboration are in accordance with those obtained by bioclimatic indices and the characterization previously described, and make it easy to distinguish the stations marked by a certain degree of summer aridity. In the previous bioclimatic elaboration, some coastal portion data are lacking, showing white (blank) surfaces on estuaries (see estuary 7, Charente) because no related data appear in the database.

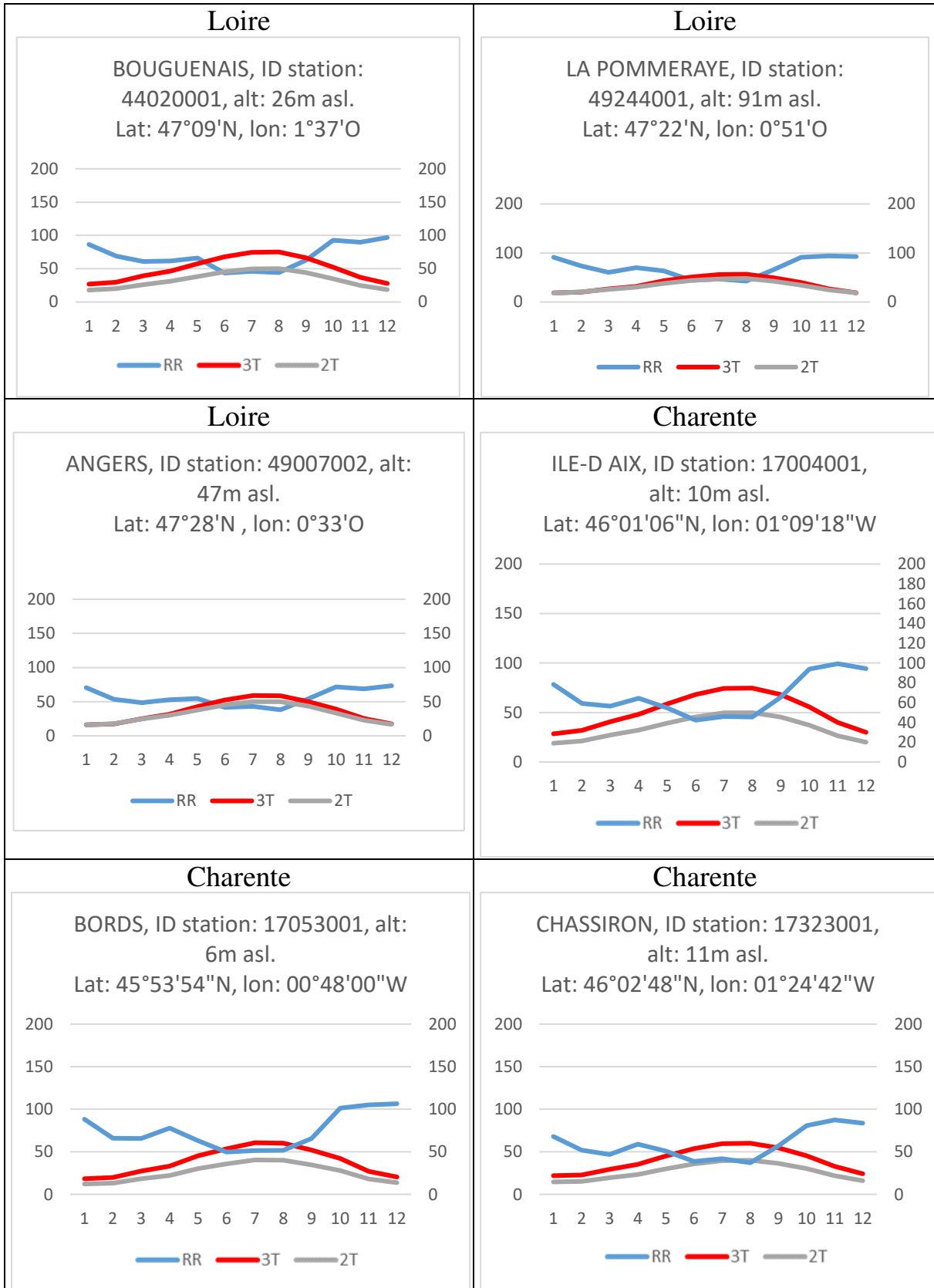
The climatic micro-variation analysis by ombrothermic diagrams we underlined also the littoral effect, meaning the bioclimatic difference occurring between the littoral and the inland. Generally, in littoral surfaces the climate is more sunny, tempered, less rainy, generally hotter and dryer.

Our analysis confirm this difference in our study area, but highlighting the littoral effect on the largest estuaries because their longer characteristics, distinguishing estuaries in two groups: largest and smaller.

Some littoral stations are (almost) never affected by a period of drought but the most coastal portion of the Loire estuary appears more Mediterranean, and justifies the local exception within the *Fraxinus* forest belt replaced and penetrated by *Pinus pinaster* forests and the enrichment of *Salix* forests on *Populus alba* and *P. nigra* all along the estuarine stream: more then in Charente – according to the local bioclimatic and micoclimate issues. Going to the south, the climate corresponds to a thermoatlantic type, showing a more Mediterranean climate tendency. This justify the increasing presence of more thermophilic species (i.e. *Thypha domingensis*, *Silybum marianum*...).







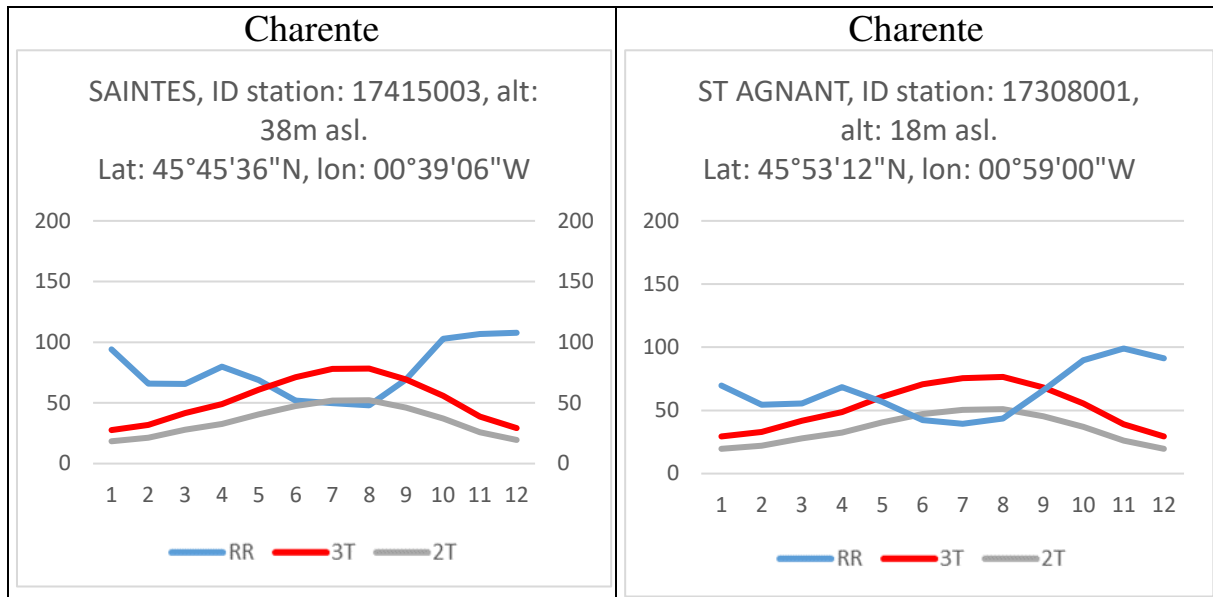


Figure 36. - Ombrothermic diagrams: RR is for annual mean precipitation, 2T and 3T are for two and three times the mean annual temperature

Ombrothermic diagrams (Fig. 36) are listed from the north-to south cline and from the longitudinal up-down direction per estuary. Results confirm the previous climatic and bioclimatic tendencies for the study area. Between these diagrams we can see how the coastal Loire portion makes a small climatic exception that could easily explain the exception from where pines (*Pinus pinaster*, *Quercus ilex* and *Rhamnus alaternus*) are developing on sands instead *Fraxinus* forest or *Salix atrocinerea* forests. Even if in our lower level of study, a mix of these species is possible. In any case, *Pinus pinaster* and *Quercus ilex* forests are more characteristic and spread, from the Garonne to the south on sandy soils; where the climate is thermoatlantic. South Bassin d’Arcachon, *Quercus ilex* is replaced by *Q. suber*.

5.3. Phytosociology

5.3.1. Table of associations, and plant groupments

About plant species authorities, (unless otherwise indicated) nomenclature and taxonomy we make reference to “The plant list” database (<http://www.theplantlist.org/>). We identified 131 plant associations, 60 alliances, 43 ordos and 28 classes, presented in the following syntaxonomic system. The syntaxa are listed according to the criteria adopted in others phytosociological works (OBERDORFER, 1992; MUCINA *et al.*, 1993). The vegetation classes are presented according to their complexity; from the most pioneer vegetation to the most complex vegetation (forests) and forest linked vegetation (as it is for clearings):

- 1 - Vegetation of aquatic environments (fresh water) and terrestrial (listed in the following order: aquatic vegetation, marshy vegetation, prairial (meadows and pastures) vegetation, grasses, and synanthropic vegetation);
- 2 - Salty vegetation (aquatic and terrestrial environments) in this order: aquatic vegetation, marshy vegetation, and terrestrial vegetation;
- 3 - Arbustive and forests vegetation;
- 4 - Vegetation of clearings (forest clearings).

1) Vegetation of aquatic environments

LEMNETEA MINORIS R. Tüxen *ex* O. de Bolòs & Masclans 1955

Lemnetalia minoris R. Tüxen *ex* O. de Bolòs & Masclans 1955

Lemnion minoris R. Tüxen *ex* O. de Bolòs & Masclans 1955

Lemnetum minoris Soó 1927

Lemneto minoris-Spirodeletum polyrrhizae (Kelhofer 1915) W. Koch 1954
em. Th. Müller & Görs 1960

Lemno minoris - Azolletum filiculoidis Br.-Bl. *in* Br.-Bl., Roussine & Nègre 1952

Hydrocharitetalia Rübel *ex* Klika *in* Klika & Hadač 1944

Hydrocharition morsus-ranae Rübel *ex* Klika *in* Klika & Hadač 1944

Ceratophyllenion demersi Felzines 2012

Ceratophylletum demersi Corillion 1957

POTAMETEA PECTINATI Klika *in* Klika & Novák 1941

Potametalia pectinati W. Koch 1926

Nymphaeion albae Oberdorfer 1957

Nymphaeo albae - Nupharetum luteae Nowiński 1927

Potamion pectinati (W. Koch 1926) Libbert 1931

Potametum natantis Hild 1959

Potametum crispum von Soó 1927

Elodeetum canadensis Nedelcu 1967

Myriophylletum verticillati Gaudet *ex* Šumberová *in* Chytrý 2011

Ranunculion aquatilis Passarge 1964

Zannichellietum obtusifoliae Brullo & Spampinato 1990

- PHRAGMITI AUSTRALIS-MAGNOCARICETEA ELATAE** Klika in Klika & Novák 1941
- Magnocaricetalia elatae* Pignatti 1953
- Magnocaricion elatae* W. Koch 1926
- Cypero longi-Caricetum otrubae* R. Tüxen. in R. Tüxen. & Oberdorfer 1958
- Carici pseudocyperi – Rumicion hydrolapathi* Passarge 1964
- Caricetum ripario – acutiformis* Kobendza 1930
- Galio palustris – Caricetum ripariae* Bal.-Tul., Mucina, Ellmauer & Walln. in Grabherr & Mucina 1993
- Caricetum acutiformis* Egger 1933
- Phragmitetalia australis** W. Koch 1926 p.p.
- Phragmition communis* W. Koch 1926
- Scirpetum lacustris* (Allorge 1922) Chouard 1924
- Phragmitetum communis* Savič 1926
- Glycerietum aquaticae* Nowiński 1930
- Sparganietum erecti* Roll 1938
- Typhetum angustifoliae* Allorge ex Pignatti 1953
- Typhetum latifoliae* (Soó 1927) Nowiński 1930
- Typho domingensis-Phragmitetum maximi* Costa, Boira, Peris & Stübing 1986 corr. Rivas-Martínez, Fernández González, Loidi, Lousã & Penas 2002
- Phalaridion arundinaceae** Kopecký 1961
- Iridetum pseudacori* Egger ex Brzeg & Wojterska 2001 (Brzeg & Ratyńska, 1991)
- Rorippo sylvestris – Phalaridetum arundinaceae* Kopecký (1960) 1961
- Eleocharido palustris – Sagittarion sagittifoliae** Passarge 1964
- Eleocharidetum palustris* Ubrizsy 1948
- Butometum umbellati* Konczak ex Philippi 1973
- Bolboschoenetalia Maritimi** Hejný in Holub, Hejný, Moravec & Neuhäusl 1967
- Scirpion maritimi** Dahl & Hadač
- Cochleario aestuariae – Scirpetum maritimi* Bioret, J.-M. Géhu & Magnanon 1995
- Scirpetum maritimi* Langendonck 1932
- Astero tripolii – Phragmitetum communis* Jeschke ex Krisch 1974
- Schoenoplectetum tabernaemontani* Soó (1927) 1947
- Apio nodiflori – Eleocharidetum amphibiae* J.-M. Géhu & Géhu-Franck 1972
- Scirpetum triquetri* Zonneveld 1955 corr. et em. J.-M. Géhu & Biondi 1988
- GLYCERIO-NASTURTIETEA OFFICINALIS** (Zohary 1974) J.-M. Géhu & J. Géhu 1987
- Nasturtio-Glycerietalia** Pignatti 1953
- Nasturtion officinalis* J.-M. Géhu & J. Géhu 1987
- Helosciadetum nodiflori* Br.-Bl. 1952
- MOLINIO-ARRHENATHERETEA** R. Tüxen 1937
- Arrhenatheretalia elatioris** R. Tüxen 1931
- Arrhenatherion elatioris* W. Koch 1926
- Rumici obtusifolii-Arrhenatherenion elatioris* de Foucault 1989

- Heracleo sphondylii* – *Brometum mollis* de Foucault 1989
- Molinietalia caeruleae*** W. Koch 1926
- Calthion palustris* R. Tüxen 1937 em. Balátová-Tulácková 1978
- Lysimachio vulgaris* – *Filipenduletum ulmariae* Balátová-Tulácková 1978
- Plantaginietalia majoris*** R. Tüxen ex von Rochow 1951
- Lolio perennis-Plantaginion majoris*** Sissingh 1969
- Lolio perennis* – *Plantaginetum majoris* Sissingh 1961
- Lolio perennis* – *Plantaginetum coronopi* (Kühnholtz-Lordat 1928) Sissingh 1969
- Potentillo-Polygonetalia*** R. Tüxen 1947
- Potentillion anserinae*** R. Tüxen 1947
- Dactylido glomeratae* – *Festucetum arundinaceae* R. Tüxen ex Lohmeyer 1953
- AGROSTIETEA STOLONIFERAE** Oberdorfer 1983
- Deschampsietalia cespitosae*** Horvatić 1958
- Carici vulpinae-Eleocharitenalia palustris*** Julve ex de Foucault, Catteau & Julve in de Foucault & Catteau 2012
- Oenanthion fistulosae*** de Foucault 2008
- Eleocharido palustris* – *Oenantheum fistulosae* de Foucault (1984) 2008
- Ranunculo ophioglossifolii* – *Oenanthion fistulosae*** de Foucault in de Foucault & Catteau 2012
- Ranunculo ophioglossifolii* – *Oenantheum fistulosae* de Foucault 2008
- Junco gerardi* – *Oenantheum fistulosae* de Foucault 2012
- Potentillo anserinae* – *Polygonetalia avicularis*** R. Tüxen 1947
- Bromion racemosi*** R. Tüxen in R. Tüxen & Preising ex de Foucault 2008
- Oenanthe peucedanifoliae* – *Brometum racemosi* de Foucault 1981
- Senecioni aquatici* – *Oenantheum mediae* Bournérias & J.-M. Géhu in Bournérias, Provost, Maucorps, Dorigny, Tombal, Lecointe, Wattez, Delpech, J.-M Géhu & Solau 1978
- Hordeo secalini* – *Lolietum perennis* (Allorge 1922) de Foucault in J.M. Royer, Felzines, Misset & Thévenin 2006
- Alopecurion pratensis*** Passarge 1964
- Alopecuretum pratensis* Eggler 1933
- Alopecurion utriculati*** Zeidler 1954
- Trifolio maritimi* – *Oenantheum silaifoliae* (Dupont 1954) de Foucault 2008
- Mentho longifoliae* – *Juncion inflexi*** Th. Müller & Gôrs ex de Foucault 2008
- Pulicario dysentericae* – *Juncetum inflexi* de Foucault in J.M. Royer, Felzines, Misset & Thévenin 2006
- Mentho longifoliae* – *Juncetum inflexi* Lohmeyer ex Oberdorfer 1957
- Loto pedunculati-Cardaminenalia pratensis*** Julve ex de Foucault, Catteau & Julve in de Foucault & Catteau 2012
- Ranunculo repentis* – *Cynosurion cristati*** Passarge 1969
- Alopecuro pratensis* – *Cynosuretum cristati* Passarge 1969
- Cirsio palustris* – *Juncetum effusi* Gallandat 1982
- Junco acutiflori* – *Cynosuretum cristati* Sougnez 1957
- Lolio perennis* – *Potentilletum anserinae* Oberdorfer 1957
- Plantagini majoris* – *Trifolietum resupinati* de Foucault 2008

- BIDENTETEA TRIPARTITAE** R. Tüxen, Lohmeyer & Preising in R. Tüxen 1950
Bidentetalia tripartitae Br.-Bl. & R. Tüxen 1943 ex Klika in Klika & Hadáč 1944 em. Felzines & Loiseau 2005
Bidention tripartitae Nordhagen 1940 em. R. Tüxen in Poli & J. Tüxen 1960
Persicario hydropiperis - *Bidentetum tripartitae* (W. Koch 1926) Sissingh in Westhoff, van Dijk, Passchier & Sissingh 1946
Bidentetum tripartiti W. Koch 1926 em. Libbert 1932
Rumici maritimi-*Ranunculetum scelerati* Oberdorfer 1957
- JUNCETEA BUFONII** de Foucault 1988
Nanocyperetalia flavescens Klika 1935
Radiolion linoidis Pietsch 1971
Centunculenion minimi (Rivas Goday 1964) Pietsch 1973
Ranunculo sardo – *Myosuretum minimi* Diémont, G. Sissingh & V. Westh. ex Oesau 1973
- AGROPYRETEA PUNGENTIS** J.-M. Géhu 1968
Agropyretalia pungentis J.-M. Géhu 1968
Agropyron pungentis J.-M. Géhu 1968
Agropyro pungentis-*Inuletum crithmoidis* J.-M. Géhu 1979
Atriplici hastatae-*Agropyretum repentis* J.-M. Géhu 1976
Atriplici prostratae-*Elymetum atherici* Beeftink & Westhoff 1962 corr. J.-M. Géhu & Wattez 2007
Beto maritimae-*Elymetum atherici* J.-M. Géhu 1976 corr. J.-M. Géhu 2006
Agropyretalia intermedio-repentis Oberdorfer, Th. Müller & Görs in Th. Müller & Görs 1969
Convolvulo arvensis-*Agropyron repentis* Görs 1966
Convolvulo arvensis – *Elytrigietum repentis* Feldföldy (1942) 1943
- FILIPENDULO ULMARIAE-CONVOLVULETEA SEPIUM** J.-M. Géhu & Géhu-Franck 1987
Convolvuletalia sepium R. Tüxen ex Mucina in Mucina, Grabherr & Ellmauer 1993
Convolvulion sepium R. Tüxen ex Oberdorfer 1949
Epilobio hirsuti-*Convolvuletum sepium* Hilbig, Heinrich & Niemann 1972
Urtico dioicae - *Convolvuletum sepium* Görs & Th. Müller 1969
Phalaridetum arundinaceae Libbert 1931
Calystegio sepium-*Althaeion officinalis* de Foucault 2011
Calystegio sepium-*Angelicetum heterocarpae* J.-M. Géhu & Géhu-Franck 1987
Cochleario aestuariae - *Oenanthetum crocatae* Bioret, Géhu & Magnanon 1995
Loto pedunculati - *Filipenduletalia ulmariae* Passarge (1975) 1978
Thalictro flavi - *Filipendulion ulmariae* de Foucault in J.M. Royer, Felzines, Misset & Thévenin 2006
Valeriano officinalis - *Filipenduletum ulmariae* Sissingh ex Westhoff 1949
Filipendulo ulmariae - *Chaerophyllion hirsuti* de Foucault 2011

Epilobio hirsuti-Filipenduletum ulmariae Sougnez 1957 *nom. inv.* Ellmauer & Mucina 1993

STELLARIETEA MEDIAE (Br.-Bl. 1931) R. Tüxen, Lohmeyer & Preising *ex von Rochow* 1951

Chenopodietalia muralis (Br.-Bl. 1936) O. de Bolòs 1962 *em.* Rivas-Martinez 1978

Chenopodion muralis (Br.-Bl. *in* Br.-Bl., Gajewski, Wraber & Walas 1936) *em.* O. de Bolòs 1962

Portulaco oleraceae - Amaranthetum deflexi Bioret, Lahondere & Botineau 1993

Geranio - Cardaminetalia hirsutae Brullo *in* Brullo & Marcenò 1989

Smyrnion olusatri Rivas Goday 1964

Galio aparines - Smyrniotum olusatri (Izco & J.-M. Géhu 1978) Bioret, Lahondère & Botineau 1993

GALIO APARINES-URTICETEA DIOICAE Passarge 1967 *ex* Kopecký 1969

Galio aparines-Alliarietalia petiolatae Oberdorfer *ex* Görs & Th. Müller 1969

Aegopodion podagrariae R. Tüxen 1967 *nom. cons. propos.*

Anthriscetum sylvestris Hadac 1978

Sambucetum ebuli Felföldy 1942

Calystegio sepium - Aristolochietum clematitidis de Foucault & Frileux 1983

Geo urbani-Alliarion petiolatae Lohmeyer & Oberdorfer *ex* Görs & Th. Müller 1969

Torilidetum japonicae Lohmeyer *in* Oberdorfer, Görs, Korneck, Lohmeyer, Müller, Philippi & Seibert 1967 *ex* Görs & Th. Müller 1969

SISYMBRIETEA OFFICINALIS Korneck 1974

Sisymbrietalia officinalis J. Tüxen *ex* Görs 1966

Bromo - Hordeion murini Hejný 1978

Sisymbrio officinalis - Hordeetum murini Br.-Bl. 1967

Hordeetum murini Allorge 1922

POLYGONO ARENASTRI-POËTEA ANNUAE Rivas-Martínez 1975 *corr.* Rivas-Martínez, Báscones, Díaz, Fernández González & Loidi 1991

Polygono arenastri-Poëtalía annuae R. Tüxen *in* J.-M. Géhu, Richard & R. Tüxen 1972 *corr.* Rivas-Martínez, Báscones, Díaz, Fernández González & Loidi 1991

Saginion procumbentis R. Tüxen & Ohba *in* J.-M. Géhu, Richard & R. Tüxen 1972

Poo annuae - Plantaginetum coronopi (Le Neveu 1978) de Foucault 2008

ARTEMISIETEA VULGARIS Lohmeyer, Preising & R. Tüxen *ex* Von Rochow 1951

Carthametalia lanati Brullo *in* Brullo & Marcenò 1985

Silybo mariani-Urticion piluliferae Sissingh *ex* Br.-Bl. & O. de Bolòs 1958

Silybo mariani-Urticetum piluliferae Br.-Bl. *in* Br.-Bl., Gajewski, Wraber & Walas 1936

Arctio lappae-Artemisietalia vulgaris Dengler 2002

Arction lappae R. Tüxen 1937

Arctienion lappae Rivas Martínez, Báscones, Díaz, Fernández González & Loidi 1991

Heracleo sphondylii - Rumicetum obtusifolii de Foucault in Royer, Felzines, Misset & Thévenin 2006

Arctio lappae - Artemisietum vulgaris Oberdorfer, Görs, Korneck, Lohmeyer, Th. Müller, Philippi & Seibert ex Seybold & Th. Müller 1972

Dauco carotae-Melilotion Görs ex Rostański & Gutte 1971

Melilotetum albo - officinalis Sissingh 1950

2) Salty vegetation

RUPPIETEA MARITIMAE J. Tüxen 1960

Ruppietalia maritimae J. Tüxen 1960

Ruppion maritimae Br.-Bl. ex Westhoff 1943 *nom. ined.*

Ruppietum maritimae (Warm. 1904) Hocquette 1927

Ranunculetum baudotii Hocquette 1927

ZOSTERETEA MARINAE Pignatti 1954

Zosteretalia marinae Béguinot ex Pignatti 1954

Zosterion marinae Christiansen 1934

Zosteretum noltii Harmsen 1936

ASTERETEA TRIPOLII Westoff & Beeftink in Beeftink 1962

Glauco maritimae-Puccinellietalia maritimae Westoff & Beeftink in Beeftink 1962

Puccinellion maritimae Christiansen 1927 *nom. corr.* in Bardat, Bioret, Botineau, Boulet, Delpech, J.-M. Géhu, Haury, Lacoste, Rameau, Royer, Roux & Touffet 2004

Puccinellienion maritimae J.-M. Géhu in J.-M. Géhu & Géhu-Franck 1984

Puccinellietum maritimae Christiansen 1927

Triglochino maritimi-Limonietum humilis Annezo, Bioret & J.-M. Géhu 1992

Armerion maritimae Br.-Bl. & Leeuwen 1936

Festucetum littoralis Corillion 1953 *corr.* J.-M. Géhu 1976

Juncetum gerardii Warming 1906

Limonietum lychnidifolio - dodartii J.-M. Géhu & Géhu-Franck 1975

Cochleario anglicae - Plantaginetum maritimae J.-M. Géhu 1976

Plantagini maritimae - Limonietum vulgaris Westhoff & Segal 1961

Glauco maritimae-Juncion maritimi J.-M. Géhu & Géhu-Franck 1984 *ex* J.-M. Géhu in Bardat, Bioret, Botineau, Boulet, Delpech, J.-M. Géhu, Haury, Lacoste, Rameau, Royer, Roux & Touffet 2004

Junco maritimi-Caricetum extensae (Corillion 1953) J.-M. Géhu 1976

Astero tripolii-Agrostietum stoloniferae J.-M. Géhu 2006

Oenantho lachenalii-Juncetum maritimi R. Tüxen 1937

CAKILETEA MARITIMAE R. Tüxen & Preising *ex* Br.-Bl. & R. Tüxen 1952

- Cakiletales integrifoliae* R. Tüxen ex Oberdorfer 1950 *corr.* Rivas-Martínez, Costa & Loidi 1992
Atriplicion littoralis Nordhagen 1940
Beto maritimae-Atriplicetum prostratae J.-M. Géhu ex J.-M. Géhu 1984
corr. et nom. invers. J.-M. Géhu 2009
Beto maritimae-Raphanetum landrae Bioret 2008
- SAGINETEA MARITIMAE** Westhoff, Leeuwen & Adriani 1962
Saginetalia maritimae Westhoff, Leeuwen & Adriani 1962
Saginion maritimae Westhoff, Leeuwen & Adriani 1962
Parapholiso strigosae-Hordeetum marini J.-M. Géhu & de Foucault 1977
- SALICORNIETEA FRUTICOSAE** Br.-Bl. & R. Tüxen ex A. de Bolòs & O. de Bolòs in A. de Bolòs 1950
Salicornietalia fruticosae Br.-Bl. 1933
Halimionion portulacoidis J.-M. Géhu 1976
Puccinellio maritimae-Salicornietum perennis (Arènes 1933) J.-M. Géhu 1976
Bostrychio scorpioidis-Halimionetum portulacoidis (Corillion 1953) R. Tüxen 1963
Agropyro pungentis – Suaedetum verae J.-M. Géhu 1976
- SPARTINETEA GLABRAE** R. Tüxen in Beeftink 1962
Spartinetalia glabrae Conard 1935
Spartinion anglica J.-M. Géhu in Bardat, Bioret, Botineau, Boulet, Delpech, J.-M. Géhu, Haury, Lacoste, Rameau, Royer, Roux & Touffet 2004
Spartinetum maritimae Corillion 1953 *corr.* J.-M. Géhu & Géhu-Franck 1984
Spartinetum anglica Corillion 1953 *corr.* J.-M. Géhu 1984
Spartinetum alterniflorae Corillion 1953
- THERO-SUAEDETEA SPLENDENTIS** Rivas-Martínez 1972 *em.* Rivas-Martínez, Fernández González & Loidi 1998
Thero-Salicornietalia dolichostachyae R. Tüxen ex Boulet & J.-M. Géhu in Bardat, Bioret, Botineau, Boulet, Delpech, J.-M. Géhu, Haury, Lacoste, Rameau, Royer, Roux & Touffet 2004
Salicornion dolichostachyo – fragilis J.-M. Géhu & Rivas-Martínez ex J.-M. Géhu in Bardat, Bioret, Botineau, Boulet, Delpech, J.-M. Géhu, Haury, Lacoste, Rameau, Royer, Roux & Touffet 2004
Salicornietum dolichostachyae J.-M. Géhu & Géhu-Franck 1982
Salicornietum fragilis J.-M. Géhu & Géhu-Franck 1982
Astero tripolii-Suaedetum maritimae J.-M. Géhu & Géhu-Franck (1982) 1984
Salicornietum obscurae J.-M. Géhu & Géhu-Franck 1982
Salicornion europaeo-ramosissimae J.-M. Géhu & Géhu-Franck ex Rivas-Martínez 1990
Puccinellio - maritimae-Salicornietum ramosissimae J.-M. Géhu 1979

Spergulario mediae – *Salicornietum brachystachyae* J.-M. Géhu 1974 *corr.*
J.-M. Géhu 1992

3) Arbustive and forests vegetation

RHAMNO CATHARTICAE-PRUNETEA SPINOSAE Rivas Goday & Borja *ex* R. Tüxen
1962

Pyro spinosae-Rubetalia ulmifolii Biondi, Blasi & Casavecchia *in* Biondi, Allegrezza,
Casavecchia, Galdenzi, Gasparri, Pesaresi, Vagge & Blasi 2014

Lonicerion perichlymeni J.-M. Géhu, de Foucault & Delelis 1983

Ulici europaei-Prunetum spinosae J.-M. Géhu & Delelis 1972

Prunetalia spinosae R. Tüxen 1952

Pruno spinosae - Rubion ulmifolii O. de Bolòs 1954

Irido foetidissimae - Prunetum spinosae J.-M. Géhu 2007

Rubio peregrinae - Prunetum spinosae J.-M. Géhu 2007

Rubio peregrinae - Ligustretum vulgare J.-M. Géhu 2007

Hedero helioides - Atriplicetum halimi J.-M. Géhu 2007

Hedero helioides - Rhamnetum alaterni J.-M. Géhu 2007

SALICETEA PURPUREAE Moor 1958

Salicetalia albae Th. Müller & Görs 1958 *nom. inval.*

Salicion albae Soó 1930

Salicetum albae Issler 1926

Salicetum fragilis Passarge 1957

Salicetalia purpureae Moor 1958

Salicion triandrae Th. Müller & Görs 1958

Salicetum triandro-viminalis R. Tüxen (1931) 1951

Salicetum purpureae Wendelberger-Zelinka 1952

Group of *Salix x rubens* community

NERIO OLEANDRI - TAMARICETEA AFRICANAE Br.-Bl. & O. de Bolòs 1958

Tamaricetalia africanae Br.-Bl. & O. de Bolòs 1958

Tamaricion africanae Br.-Bl. & O. de Bolòs 1958

Solano dulcamarae - Tamaricetum gallicae de Foucault 2008

QUERCO ROBORIS-FAGETEA SYLVATICAE Br.-Bl. & Vlieger *in* Vlieger 1937

Populetalia albae Br.-Bl. *ex* Tchou 1948

Alno glutinosae-Ulmenalia minoris Rameau 1981

Alnion incanae Pawłowski *in* Pawłowski, Sokołowski & Wallisch 1928

Alnenion glutinoso-incanae Oberdorfer 1953

Filipendulo ulmariae - Alnetum glutinosae (Lemée 1937) Rameau 1994

Carici remotae - Fraxinetum excelsioris W. Koch *ex* Faber 1936

Groupments of marshy *Salix atrocinerea* forest

Ulmenion minoris Oberdorfer 1953

Ulmo minori - Fraxinetum angustifoliae (Breton 1956) Rameau & Schmitt 1980

Fagetalia sylvaticae Pawłowski in Pawłowski, Sokolowski & Wallisch 1928

Carpino betuli-Fagenalia sylvaticae Rameau ex J.M. Royer, Felzines, Misset & Thévenin 2006

Dryopterido affinis-Fraxinion excelsioris (Vanden Berghen 1969) Bœuf, Bardat, Gauberville, Lalanne,

Renaux, Royer, Thébaud, Timbal & Seytre in Bœuf 2010

Dryopterido affinis - Fraxinetum excelsioris (Bardat 1993) Bardat, Bœuf, Gauberville, Lalanne, Renaux, Royer, Thébaud, Timbal & Seytre in Bœuf 2010

Aro neglecti-Fraxinetum excelsioris J.-M. Géhu & J. Géhu 1988

Aro neglecti-Ulmetum minoris J.-M. Géhu & J. Géhu 1985

Groupments of mesic *Salix atrocinerea* forest

5) Vegetation of clearings (forest clearings)

MELAMPYRO PRATENSIS-HOLCETEA MOLLIS Passarge 1994

Melampyro pratensis-Holcetalia mollis Passarge 1979

Holco mollis - Pteridion aquilini Passarge (1994) 2002

Holco mollis-Pteridietum aquilini Passarge 1994

5.3.2. Description of plant associations

Following the previous syntaxonomic system table, we started the estuarine communities' elaboration, from our fieldwork findings.

The pleustophitic communities belongs from the *Lemnion minoris* alliance with the following associations: *Lemno minoris - Azolletum filiculoidis*; *Lemnetum minoris* and *Lemneto minoris-Spirodeletum polyrhizae*. These plant associations belongs to the pleuston (the floating sails) from the meso-eutrophic to hypertrophic waters; mainly of freshwater type but occasionally remarkable also in salty and brackish sectors (in sub-salty conditions, as occasional presence, or as seasonal community, according to the water and salt fronts). Pleuston are the organisms that live in the thin surface layer existing at the air-water interface of a body of water habitat (LISS and SLINN, 1983). In our case it represents vegetation of macroscopic dimensions that lives floating in the water, submerged or floating at the water or immediately above or below. They are characterized by the presence of the *Lemna* species s.l. and often also *Azolla* species, others floating ferns and liverworts (MAIORCA *et al.*, 2007; CIANFAGLIONE, 2011). It is an aquatic freely floating, annual herbaceous community of calm waters. This vegetation is dominated by small pleustophytes; it could be very dense, with a uniform appearance. The floristic aspect and the species diversity is generally from pauci- to mono-specific (MARCENÒ and RAIMONDO, 1977; PEDROTTI, 2004a). They could survive on waters sometimes slightly brackish and often polluted (BRULLO *et al.*, 1994; BIONDI *et al.*, 2009; LASTRUCCI *et al.*, 2012). They are point or spatial communities within lentic aquatic systems,

often in superposition or between others aquatic vegetation. This community was found in every ecological compartment, but especially in freshwaters accessions on all the studied estuaries.

About the hydrophytes communities we can distinguish from fresh waters the: *Ceratophylletum demersi*, *Elodeetum canadensis*, *Myriophylletum verticillati*, *Potametum crispum*, *Potametum natantis* associations. They are mono or pauci-specific communities belonging to the rooted submerged or emergent floating vegetation from the meso-eutrophic to hypertrophic freshwaters. These communities could have a variable morphology depending on the degree of the habitat shading and the sediment type on the bottom; they occur in flowing waters, ponds, oxbows, channels and flooded sand pits; and they could adapt to anthropogenic eutrophication (DEN HARTOG and SEGAL, 1964; PASSARGE, 1995). These associations are typically common across the lowland and they were only found in freshwater portion estuaries.

We can distinguish between them the *Elodeetum Canadensis*, formed by *Elodea canadensis*, an alien species from north America (ŠUMBEROVÁ, 2011a).

Nymphaeo albae - Nupharetum luteae is an association dominated by *Nuphar lutea*, which usually has large leaves floating on the water surface. In flowing or deeper waters, it produces also submerged leaves. It occurs in mesotrophic to eutrophic water of oxbows, pools, channels and lentic sections of streams. Most often it is found at water depths of 50–150 cm, tolerating strong fluctuations of the water level (ŠUMBEROVÁ, 2011b). It was found only at oligohaline and freshwater sections of the big river estuaries as is for Loire and Charente.

From brackish to salty sectors with freshwaters influence or accession, we can find: *Ranunculetum baudotii*, *Zannichellietum obtusifoliae* and *Ruppium maritima*.

Ranunculetum baudotii is an association dominated by *Batrachium baudotii*, an aquatic submerged macrophyte with floating leaves and flowers. It occurs in eutrophic water bodies, often with a high salt concentration (especially in summer), in sunny (and could be dry-out) spots in summer.

Zannichellietum obtusifoliae is a pioneer association developing in shallow to flooding (exondable) environments. In the actual state of knowledge, this association seems rare in study area, but according to DESMOTS *et al.* (2015) it must probably be more widespread because misidentified. Following the previous author, it is known in only nine municipalities from Loire-Atlantique, Vendée and Charente-Maritime departments. Among the species that frequently accompany *Zannichellia obtusifolia*, we find *Ranunculus peltatus* subsp. *baudotii*, *Zannichellia pedunculata*, *Callitriche truncata* subsp. *occidentalis*, *Stuckenia pectinata*, *Potamogeton crispus* and *Myriophyllum spicatum* and more rarely also other species of the *Potametea* (DESMOTS *et al.*, 2015). We found a less developed and fragmented sample in a channel from the lower Charente estuary system.

Ruppium maritima association is a submerged bed of *Ruppia* species, *Zannichellia pedicellata*, *Chara* species and even *Tolypella nidifica* (FRÖDE, 1958; FUKAREK, 1961). It is a typical association from brackish waters (sea inlets, estuaries, permanent pools, mud and sand flats, and coastal lagoons) of Atlantic, North Sea and Baltic coasts of boreal and temperate Europe. We found small fragments in the lower Charente estuary.

Zosteretum noltii occupy as vicariant the saltiest portions benefiting of freshwaters influence. It was found in the most maritime estuaries in their salt portions as was for Étrel estuary. The roselières (GÉHU, 2006; SENDER *et al.*, 2017) physiognomic community is characterized by a dominant presence of graminoids, and it is composed by several plant associations distributed along different salt, water, trophic and topographic clines. Most of the association belonging to this physiognomic group belongs to the *Phragmiti australis-*

Magnocaricetea elatae class. This class represent perennial helophytic communities that colonize marsh and lacustrine environments as well as fluvial areas, on eutrophic to meso-oligotrophic soils of brackish and fresh waters. We considered as basis for this community analysis (GÉHU & GÉHU, 1978; GÉHU, 2006d; LANDUCCI, 2013; DELCOIGNE & THÉBAUD, 2018). Between these associations we can underline the *Caricetum ripario – acutiformis*, *Galio palustris – Caricetum ripariae*, *Caricetum acutiformis* that are plant association composing the estuarine fen, in swampy areas, at any estuarine sector if freshwater presence is dominant.

About the associations of the *Phragmitum communis* alliance we have found:

Scirpetum lacustris, only found in highest freshwater dynamical tide portion. The *Glycerietum aquaticae*, *Sparganietum erecti*, *Typhetum angustifoliae*, *Typhetum latifoliae* where found scattered elsewhere especially in the freshwater point from the mesohaline and oligohaline sectors.

The *Phragmitetum communis* merit more specification because it was under some synonyms regrouping some communities describes as different associations with some ecological difference. As example we can find a salty reed bed variant formerly described as *Scirpo compacti-Phragmitetum australis* Bueno et F. Prieto in Bueno 1997, characterized by a strong presence of *Scirpus compactus* Hoffm (= *Bolboschoenus maritimus* subsp. *maritimus*); typically spread even dominant in the high Schorre and more occasionally upper in the major river bed - from the salty to the oligohaline estuarine sectors, mainly in riparian conditions and lesser in marshy conditions. The *Calystegio sepium - Phragmitetum australis* Royer, Thévenin & Didier in Royer et al. 2006 that is very spread as forest mantle, in clearings and in secondary successions, – especially in the uppermost levels: in riparian conditions. We considered this as most secondary and ruderal variant of reed bed.

In marshy condition the *Solano dulcamarae - Phragmitetum australis* (Krausch 1965) Succow 1974 can be found more rarely, especially in sub-salty sectors with a dominance of fresh water intrusion. We considered this as a marshy variant.

We found another salty but driest variant of reed bed, rich in *Elymus athericus* from the high Schorre to up in sandiest conditions; placed in drier and upper conditions if compared to the *Scirpus compactus* variant.

The *Typho domingensis-Phragmitetum maximi* is a novelty for the French Atlantic side. This reed bed association is here characterized by a strong presence even exclusive presence of *Typha domingensis*, often misunderstood for *Thypha angustifolia*. Typical for the marshiest coastal environment more exposed to seawaters if compared to the *Solanum dulcamara* variant of the *Phragmitetum vulgaris* association. The *Iridetum pseudacori* and the *Rorippo sylvestris – Phalaridetum arundinaceae* associations are from marshy areas with a dominance of freshwaters while the second association was notes as most riparian. The association from the *Eleocharido palustris – Sagittarion sagittifoliae* alliance corresponds to marshiest levels from oligohaline to freshwater portions.

The associations from *Bolboschoenetalia maritimi* ordo contains more brackish and salt tolerant associations. Here, the *Scirpetum maritimi* corresponds also to the former *Scirpetum compacti* as synonym.

The *Helosciadetum nodiflori* corresponds to the marshy freshwaters variant position of the *Apio nodiflori – Eleocharidetum amphibiae* placed in the *Scirpion maritimi*.

From the *Molinio-Arrhenatheretea* class associations, the *Dactylido glomeratae – Festucetum arundinaceae* represent a typical estuarine mesic secondary grassland. The *Heracleo sphondylii – Brometum mollis* represent a most nitrophilic aspect; the *Lolio perennis*

– *Plantaginetum majoris* represent a more disturbed and trampled condition; *Lolio perennis* – *Plantaginetum coronopi* a trampled and driest or salty condition.

The *Lysimachio vulgaris* – *Filipenduletum ulmariae* represent a rare and occasional megaphorb community find in largest river estuaries as punctual. Within the *Agrostietea Stoloniferae*, taking as reference DE FOUCAULT (1984) and DE FOUCAULT & CATTEAU (2012): in the *Deschampsietalia cespitosae*, the following associations represents the typical estuarine prairial vegetation of the mesohaline portion with prolongation to the freshwater and to the salty water (where freshwaters inclusions) demonstrating how these associations are more salt tolerant than halophilic. They develop from the Schorre to the high riverbed in moist conditions. The *Eleocharido palustris* – *Oenanthe fistulosae* was not often found in our fieldworks, representing a wet facies together with *Ranunculo ophioglossifolii* – *Oenanthe fistulosae* (often lacking in *Ranunculus ophioglossifolius*). *Senecioni aquatici* – *Oenanthe mediae* is also typical from the wettest points but it could be more dry during summer, as is for the *Junco gerardi* – *Oenanthe fistulosae*. In addition, the *Trifolio maritimi* – *Oenanthe silaifoliae* lives in wet condition that are drier in summer, but its habitats tend to be more salt rich – especially in the driest season. *Oenanthe peucedanifoliae* – *Brometum racemosi* is from more sub-mesic habitats while the *Hordeo secalini* – *Lolietum perennis* is taking place in upper and mesic conditions. *Pulicario dysentericae* – *Juncetum inflexi* and *Mentha longifoliae* – *Juncetum inflexi* are very wet grassland that could often be drier in summer and generally, livestock grazing influence them. The same is for *Alopecuro pratensis* – *Cynosuretum cristati*, *Cirsio palustris* – *Juncetum effuse*, *Junco acutiflori* – *Cynosuretum cristati*, *Lolio perennis* – *Potentilletum anserinae*, *Plantagini majoris* – *Trifolietum resupinati*. These associations are easily flooded pastures (grazed meadows) generally from alkaline type in estuaries, on mesotrophic and short-flooded soils. They are characterized by the presence of *Pulicaria dysenterica* at the edge of all types of watercourses and marshes. They are characteristic of the middle topographic levels, generally at the edge of the watercourses; but they can also be found on slopes, at the level of seeps. These associations are often bistratified. The first level is characterized by monocotyledons while the second layer is characterized by reptant species like *Ranunculus* and *Mentha*. Monocotyledons generally dominate the association, forming quite lank facies consisting in diversified vegetations, dominated by hemicryptophytes belonging to the families of the *Poaceae*, *Cyperaceae* and *Juncaceae*. These associations are dense and closed, rarely exceeding seventy cm in height. The optimal period of observation of short-lived mesotrophic grasslands is especially at the beginning of summer. These meadows gradually lead to the development of megaphorbs (*Filipendulo ulmariae* - *Convolvuletea sepium*), followed by willows thickets. They are part of the dynamics of alluvial (*Alnion incanae*) or swamp forests (*Alnion glutinosae*). These are secondary meadows linked to pastoral practices. In the case of overgrazing, they can tend to the trampled meadows of *Potentillion anserinae*, or by the enrichment of the substrate to meadows of *Molinio caeruleae* – *Juncetea acutiflori*.

As we observed, the *Bidentetea tripartitae* represent association of pioneer annual nitrophilous and hygrophilous vegetation that grows on nitrogen-rich, muddy or silty-pebbly substrates. The vegetation optimum is during the middle/end of summer. Its mainly natural (primary) place is on last discovered surfaces by the summer waterfowl decreasing (reaching the river-estuarine minimum water level). Nevertheless, these associations could be easily found elsewhere following pond and marshes summer dry-out; or (secondary) following crops (especially summer crops like *Zea mays*, *Helianthus annuus* and vegetable gardens).

Ranunculo sardoi – *Myosuretum minimi* has similar behavior but an earlier phenology. It is also rarer in our study area and resulted as favored in pastures thanks to the grass holes due by livestock. About the *Agropyreteea Pungentis* class association we make reference to GÉHU (1968), GÉHU (1979d), GÉHU & WATTEZ (2007), GÉHU (2006c), DEMARTINI (2016). The *Agropyro pungentis-Inuletum crithmoidis*, *Atriplici hastatae-Agropyretum repentis*, *Atriplici prostratae-Elymetum atherici*, *Beto maritimae-Elymetum atherici* association occupies the highest levels of the Schorre and even portions of higher riverbed. The most common and representative association we found is the *Atriplici prostratae-Elymetum atherici*; while the *Beto maritimae-Elymetum atherici* represents more nitrophilic habitats, comprising the woods borders. *Atriplici hastatae-Agropyretum repentis* represents a more ruderal association that could easily occupy urbanized, road margins and cultivated surfaces. *Convolvulo arvensis* – *Elytrigietum repentis* has similar behavior but tends to occupy higher positions as observed to the field. *Filipendulo ulmariae-Convolvuletea sepium* represent the most association of the megaphorb physiognomic community: temperate planitial to mountain meso-eutrophilic communities on wet soils - more or less floodable. These associations are quite dense; the phenology optimum is in summer. These associations are rich in dicotyledons, characterized by the presence of *Epilobium* species, *Filipendula ulmaria*, and *Calystegia sepium*. We used as basic references: GÉHU & GÉHU (1978), GÉHU & GÉHU-FRANCK (1982), DE FOUCAULT (1984), BIRET *et al.* (1995), LAZARE (2006), LAZARE & BIRET (2006), DE FOUCAULT (2011), and CIANFAGLIONE & BIRET (2017). The *Epilobio hirsuti-Convolvuletea sepium* is the most common and widespread of these associations together with the *Urtico dioicae - Convolvuletea sepium* (more nitrophilic and ruderal). The *Phalaridetum arundinaceae* is characterized by dense stands of *Phalaris arundinacea* occurring in complexes of marsh vegetation in river low floodplains. It occurs in shallow depressions, oxbows in an advanced stage of burial, with slow-flowing water or on the banks of flooded sand pits. In contrast to the *Rorippo-Phalaridetum arundinaceae*, the habitats of *Phalaridetum arundinaceae* corresponds more to longer flooded surfaces that remain constantly moist-wet, not directly affected by currents, and growing on fine-grained or silty soils. In fact, the *Phalaridetum arundinaceae* in our estuaries was more commonly found on more mineral and draining (sandy) soils. A strong accumulation of litter contributes to the development of an organic rich soil driving the dynamic in favor of the *Rorippo-Phalaridetum arundinaceae*, which generally occurs in floodplains of middle river courses, where it grows in depressions that are distant from the river channel (CHYTRÝ, 2011). *Calystegio sepium-Angelicetum heterocarphae* and *Cochleario aestuariae - Oenanthetum crocatae* are more endemic associations from the eastern Atlantic French estuaries. The first is more mesophilic and characterized by the presence of *Angelica heterocarpa*, an endemic species of this zone. They are both slightly halo tolerant and specialist association for oligohaline portions along the banks and even more far along the major riverbed where the last salty tides influence occurs. *Valeriano officinalis - Filipenduletum ulmariae*, *Epilobio hirsuti-Filipenduletum ulmariae* like the previously cited *Lysimachio vulgaris - Filipenduletum ulmariae* concern on the most eurosiberian megaphorb communities. Their phenological optimum occurs in summer. They are basically less eutrophic and less disturbed like the previous two oligohaline megaphorb association but vicariant in fresh water portions or accessions. As seen in our fieldworks, between these three associations we can place the second as a slight eutrophic facies; while the *Lysimachio vulgaris - Filipenduletum ulmariae* appear in slightly acidic or turfier conditions in the entire Eurosiberian zone (CIANFAGLIONE, 2009).

Portulaco oleraceae - *Amaranthes deflexi* and *Galio aparines* - *Smyrniolum olusatrum* consist on association of annual, ephemeral, ruderal nitrophilous and sub-nitrophilous weed vegetations, often in crops or crop margins and urbanized places as noted during our fieldworks.

Anthriscetum sylvestris, *Sambucetum ebuli*, *Calystegio sepium* - *Aristolochietum clematitidis*, *Torilidetum japonicae* consists in nitrophilous (biennial, perennial or therophytic vegetations) from wood edges, that is more or less anthropogenic, from mesophilic to hygrophilous habitats, depending on the degree of soil humidity and/or shade; in nitro-ruderalized places and even as forest borders, as observed in our fieldworks.

Sisymbrio officinalis - *Hordeetum murini* and *Hordeetum murini* represents a ruderal vegetation. The first association is from more rich environments, as observed during our fieldworks. Like previous associations, the *Poo annuae* – *Plantaginetum coronopi* develops on ruderal places distinguishing for more compact trampled, and especially sandy soils as observed. *Silybo mariani-Urticetum piluliferae*, *Heracleo sphondylii* - *Rumicetum obtusifolii*, *Arctio lappae* - *Artemisietum vulgaris*, *Melilotetum albo* – *officinalis* have similar behaviour of the previous associations but basically they are more nitro-ruderal. The first is the most ruderal, the second is more linked to eutrophic pastures, the third could be easily found in woody margins and the second in woody margins but often in crop margins as seen after field observations. About the salty associations from the *Asteretea Tripolii* it consists on coastal and halophilic vegetation group of Atlantic salt meadows associations dominated by hemicryptophytes and aerohaline species (BARDAT *et al.*, 2004). Following the littoral vegetation review (DEMARTINI, 2016), *Puccinellietum maritimae*, *Triglochino maritimi-Limonietum humilis*, *Festucetum littoralis*, *Juncetum gerardii*, *Limonietum lychnidifolium* – *dodartii*, *Cochleario anglicae* – *Plantaginetum maritimae*, *Plantagini maritimae* – *Limonietum vulgaris* associations occupy the Schorre level. *Junco maritimi-Caricetum extensae*, *Asterotripolii-Agrostietum stoloniferae*, *Festuco littoralis-Juncetum gerardii*, and *Oenanthe lachenalii-Juncetum maritime* occupy highest Schorre levels and are more rarely spread on the major river as observed. *Beto maritimae-Atriplicetum prostratae*, *Beto maritimae-Raphanetum landrae* occupy the Schorre levels. They occur also in the major riverbed in nitro-ruderal conditions. Scattered *Cakile maritima* specimens was observed in estuarine condition in Charente. Following GÉHU & TÜXEN (1975); GÉHU & DE FOUCAULT (1978), and DEMARTINI (2016), the *Parapholis strigosae-Hordeetum marini* represent a late-vernal to pre-summer association. It occurs in halophilic and sub-nitrophilic situations bordering temporarily flooded areas that are dry in summer. This association is still very poorly known in France and only one of its associations is now listed in Pays de la Loire region and in Baie de Somme (GÉHU & DELAPORTE, 2008). *Puccinellio maritimae-Salicornietum perennis*, *Bostrychio scorpioidis-Halimionetum portulacoidis*, *Agropyro pungentis* – *Suaedetum verae* represents the Cantabro-Atlantic communities of euhaline Schorre (BARDAT *et al.*, 2004; DEMARTINI, 2016), as observed in estuaries, the *Agropyro pungentis* – *Suaedetum verae* corresponds to driest sandy conditions. *Bostrychio scorpioidis-Halimionetum portulacoidis* corresponds to the most widespread association from the estuarine salty Schorre, representing a typical estuarine presence linked to a strong seawaters influence. More rarely in the association it occurs only *Halimione portulacoides* (in slightly disturbed areas), this plant generally appears with others slikke and Schorre species. In lower conditions even mixed with *Spartina* and *Salicornia* s.l. species, while in upper condition even mixed within the reed bed and *Scirpetum maritime*, until the mesohaline sector. *Spartinetum maritimae*, *Spartinetum anglicae*, and *Spartinetum alterniflorae* represent the lowest topographic level of estuarine vegetation, being from the

Schorre in the salty sector. *Spartinetum maritimae* consist in the native European species association, while the two other associations are considered as invasive (DEMARTINI, 2016). *Salicornietum dolichostachyae*, *Salicornietum fragilis*, *Astero tripolii-Suaedetum maritimae*, *Salicornietum obscurae*, *Puccinellio - maritimae-Salicornietum ramosissimae*, *Spergulario mediae – Salicornietum brachystachyae* associations consist of pioneer coastal or continental vegetation of annual *Salicornia* species found in salty to brackish marshes under tidal effect (DEMARTINI, 2016). The *Ulici europaei-Prunetum spinosae* represent one of the first woody association of estuaries, occurring to major riverbed. *Irido foetidissimae - Prunetum spinosae*, *Rubio peregrinae - Prunetum spinosae*, *Rubio peregrinae - Ligustretum vulgaris*, *Hedero heliis - Atriplicetum halimi*, *Hedero heliis - Rhamnetum alatarni* occupy the same levels (mainly major riverbed) while the *Hedero heliis - Atriplicetum halimi* differentiates for its anthropogenic origin (from hedges plantations) and the *Hedero heliis - Rhamnetum alatarni* differentiates for its thermophilic behavior occurring at the edge of pine sandy forests in Loire estuary mainly in estuarine –slope contact zone, and only occasionally touching the upper estuarine bed.

Salicetum albae and *Salicetum fragilis* associations are scattered present from the lowest to highest salt sectors in estuaries; in lowest portions they develop far from the lowest riverbed, while upper they develop closer and closer to the smaller riverbed edges. Basically the first association is more spread from the mesohaline sector up to the freshwaters, while the second association appears in mesohaline sector. The *Salicetum albae* in its upper valley portions tends to enrich considerably of *Populus* or *Fraxinus* species. *Salicetum triandro-viminalis* and *Salicetum purpureae* are the shrubby willows formation linked to the two previous forest willow associations. In most marshy condition some formation of *Salix x rubens* and *Salix atrocinerea* were detected and not attributable to any known plant association right now. *Solano dulcamarae - Tamaricetum gallicae* is another anthropic shrubby association often linked with the *Salicetum fragilis* as observed by our experience. *Filipendulo ulmariae - Alnetum glutinosae* and *Carici remotae - Fraxinetum excelsioris* associations were more rarely detected and occupying upper levels from the longitudinal direction. They also could occupy in lowest levels the lateral portions modified by man activities linked to barrages that block the up tidal dynamics, in substitution to the *Salix atrocinerea* marshy forests. The *Ulmo minori - Fraxinetum angustifoliae*, *Dryopterido affinis - Fraxinetum excelsioris*, *Aro neglecti-Fraxinetum excelsioris*, *Aro neglecti-Ulmetum minoris*, together with some groupments of mesic *Salix atrocinerea* forest, develop often in residual fragmented stands or in disturbed juvenile stages in the mesophilic vegetation from the highest levels of the major riverbed as observed. Often they are represented in *Fraxinus* species plantation or in Bocages (active and abandoned types). These forest tends to have a more or less presence of *Fraxinus angustifolia* (CIANFAGLIONE & BIRET, 2017) specimens more or less scattered and all along the same estuary (i.e.: Loire and Charente) but basically with a tendency to decrease going up in the longitudinal up sectors as observed. Often the distribution and actual presence of these mesic forest is very difficult to understand following the human land modifications and soil uses (in this level very widespread) to do not allow a good opportunity to correctly understand the potential association presence and related distribution limits. The *Holco mollis-Pteridietum aquilini* was found often, especially as mesic forest and shrubby formations borders.

Estuary	Vilaine										Loire											
	Laita		Loire		Laita		Charente		Charente		Loire		Loire		Charente		Loire		Loire			
Association reference	<i>Potamogeton natans</i>		<i>Potamogeton natans</i>		<i>Potamogeton natans</i>		<i>Potamogeton natans</i>		<i>Potamogeton natans</i>		<i>Potamogeton natans</i>		<i>Potamogeton natans</i>		<i>Potamogeton natans</i>		<i>Potamogeton natans</i>		<i>Potamogeton natans</i>			
Site	Haut barrage d'Arzal		Quimperlé (bas riviére Elé)		Paimboeuf - Frossay		Frossay - Le Pellerin		Quimperlé (bas riviére Elé)		Pont suspendu - Le Mung		Fontaine de Lupin - Pont suspendu		Saint Savinien - Saintes		Ingrandes - Angers		Champloceaux - Angers		Ingrandes - Angers	
Surface (m2)	20	10	5	5	10	1	1	1	10	10	10	1	5	10	10	10	10	10	10	10	10	
Total cover (%)	90	80	80	80	80	90	90	90	40	60	60	10	20	80	80	40	60	50	90	90	20	
Rel.n.	V1	A1	L1	L2	A2	C2	C3	C6	L7	L3	L6	C1	L12	A4	A3	L4	L9	L10	C4	C5	C8	
Progressive	17	13	1	2	14	20	21	24	7	3	6	19	12	16	15	4	9	10	22	23	26	
Species per rel.	6	4	3	3	3	3	2	2	2	1	1	6	5	5	4	1	3	3	3	3	3	
	<i>Potamogeton natans</i> f. <i>fluitans</i>	3	4	4	5	5	5	5	5	3	3	3										
	<i>Lemma minor</i>			+	+		1	+	+	+				+								
	<i>Ranunculus peltatus</i> subsp. <i>baudotii</i>																	3	3		2	
	<i>Ceratophyllum demersum</i>													+					1	4		
	<i>Potamogeton pectinatus</i>	+	+			+								2	2							
	<i>Ludwigia</i> cfr <i>peplodes</i>	r			+																+	
	<i>Potamogeton crispus</i>													+	+	3					+	
	<i>Ranunculus sceleratus</i>																	+	+			
	<i>Callitriche</i> cfr <i>stagnalis</i>			1			+							+						1		
	<i>Glyceria fluitans</i>													1								
	<i>Myriophyllum verticillatum</i>		r										r	+					+	+		
	<i>Potamogeton natans</i> f. <i>submersa</i>													2	3							
	<i>Elodea canadensis</i>																					
	<i>Myriophyllum spicatum</i>																		4	2		
	<i>Persicaria amphibia</i>																+	+				
	<i>Ranunculus</i> cfr <i>trichophyllus</i>		+			r																
	<i>Bolboschoenus maritimus</i>													i								
	<i>Hydrocharis morsus-ranae</i>		1																			
	<i>Mentha pulegium</i>																				+	
	<i>Nymphoides peltata</i> f. <i>emersa</i>		1																			
	<i>Nymphoides peltata</i> f. <i>submersa</i>		1																			
	<i>Ruppia</i> cfr <i>maritima</i>													+								
	<i>Stuckenia pectinata</i>													r								
	<i>Zannichellia</i> cfr <i>pedunculata</i>													1								

Tab. 5. - Hydrophytes vegetation

Estuary	Charente		Loire		Loire		Laita	
Site	Fontaine de Lupin - Pont suspendu	Fontaine de Lupin - Pont suspendu	Pont suspendu - Le Mung	Cordemais - Coueron	Z.I - Donges	Frossay - Le Pellerin	Quimperlé (Lothéa - Pl. C. de Gaulle)	Quimperlé (Lothéa - Pl. C. de Gaulle)
Surface (m2)	100	100	100	50	50	50	100	100
Total cover (%)	100	100	100	100	100	100	100	100
Tree cover (%)	90	95	90	90	90	95	95	95
Shrub cover (%)	20	20	0	1	1	1	15	0
Herb cover (%)	90	90	90	85	85	85	90	90
Rel n.	A3	A2	A4	L2	L1	L3	A1	A2
Progressive	7	6	8	2	1	3	4	5
Species per rel.	12	18	16	15	20	16	37	21
Tree layer : 30m								
<i>Salix fragilis</i>	5	5	5		3	4	5	5
<i>Salix atrocinerea</i>		1		5	2	1		
<i>Calystegia sylvatica</i>							r	
<i>Hedera helix</i>							+	
<i>Prunus spinosa</i>				+				
Shrub layer: 5m								
<i>Salix atrocinerea</i>			+	+	+	+		
<i>Salix fragilis</i>					+	+	1	2
<i>Fraxinus excelsior</i>				+			+	
<i>Acer pseudoplatanus</i>								+
<i>Calystegia sylvatica</i>							+	
<i>Fraxinus angustifolia</i>						+		
<i>Hedera helix</i>							+	
<i>Prunus spinosa</i>				+				
Herb layer: 1m								
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	3	1			1		+	+
<i>Dactylis glomerata</i>	+	1			+			r
<i>Lolium arundinaceum</i>	+	3	2	1				
<i>Phalaris arundinacea</i>				1	1	1	r	
<i>Salix atrocinerea</i>				+	+	+	i	
<i>Salix fragilis</i>					+	+	+	+
<i>Urtica dioica</i>					1	1	+	+
<i>Calystegia sepium</i>					1	1	+	
<i>Juncus inflexus</i>	2	+			1			
<i>Oenanthe crocata</i>						1	1	+
<i>Potentilla reptans</i>	+	+	2					
<i>Trifolium repens</i>	+	+					r	
<i>Angelica</i> cfr <i>heterocarpa</i>							+	+
<i>Angelica sylvestris</i>							2	2
<i>Atriplex prostrata</i>					+	1		
<i>Carex otrubae</i>	+					+		
<i>Elymus repens</i>		+	2					
<i>Eupatorium cannabinum</i>							r	r
<i>Geranium rotundifolium</i>		r	r					
<i>Jacobea aquatica</i>							+	1
<i>Lycopus europaeus</i>	+						r	
<i>Oenanthe silaifolia</i>				+	+			
<i>Persicaria amphibia</i>				+		+		
<i>Phragmites australis</i>				1		+		
<i>Ranunculus repens</i>							+	+
<i>Raphanus raphanistrum</i>	+	+						
<i>Reynoutria japonica</i>							r	+
<i>Rumex conglomeratus</i>							r	+
<i>Solanum dulcamara</i>	+	+						
<i>Anthriscus sylvaticus</i>								r
<i>Arum italicum</i> subsp. <i>neglectum</i>		+						

Tab. 9. - *Salicetum fragilis*

Estuary	Loire	Blavet	Villaine	Villaine	Villaine	Charente	Charente	Loire	Loire	Loire	Blavet	Charente	Blavet
Site	Paimboeuf - Frossay	Port Louis - Plouhinez	Penestrin - barrage d'Arzal	Penestrin - barrage d'Arzal	Penestrin - barrage d'Arzal	Ile Madame - Fontaine de Lupin	Ile Madame - Fontaine de Lupin	Paimboeuf	Paimboeuf - Frossay	Frossay - Le Pellerin	Port Louis - Plouhinez	Fontaine de Lupin - Pont suspendu	Port Louis - Plouhinez
Surface (m2)	30	30	70	50	50	20	50	50	70	30	30	100	50
Total cover (%)	100	100	100	100	100	100	100	100	100	100	100	100	100
Shrub cover (%)	80	60	90	90	90	80	80	80	80	80	70	90	60
Herb cover (%)	80	80	90	90	90	100	100	80	90	80	80	100	90
Rel n.	L2	B2	V1	V2	V3	C1	C2	L1	L3	L4	B3	C3	B1
Progressive	2	6	8	9	10	11	12	1	3	4	7	13	5
Species per rel.	8	3	15	22	22	9	15	14	21	21	16	11	17
Shrub layer : 5m													
<i>Tamarix gallica</i>	5	5	5	5	5	5	5	4	4	4	4	4	2
<i>Hedera helix</i>				+	+							+	+
<i>Prunus spinosa</i>					1		1	+		+			
<i>Solanum dulcamara</i>					+			+	+	+			
<i>Rubus fruticosus s.l.</i>									+	+			+
<i>Quercus robur</i>				+									2
<i>Betula alba</i>													+
<i>Cupressus macrocarpa</i>				+									
<i>Laurus nobilis</i>													+
<i>Pinus pinaster</i>				+									
<i>Pinus radiata</i>													+
<i>Populus nigra</i>													+
<i>Salix atrocinerea</i>													1
<i>Salix fragilis</i>												1	
<i>Sambucus nigra</i>												1	
Herb layer: 1m													
<i>Elymus repens</i>	4		4	2	2	5	+	2	+	1	+		+
<i>Chamaeiris foetidissima</i>			2	1	+		1	+		+	+	+	+
<i>Dactylis glomerata</i>			+	1	+			1	1	1	+	1	2
<i>Daucus carota</i>				+	+	+	+	+	1	1	+		
<i>Rubus fruticosus s.l.</i>				1	1	1	1		+	+	+		
<i>Prunus spinosa</i>				+	2		+		1	1	+		
<i>Atriplex prostrata</i>	+		+							+	1		1
<i>Beta vulgaris subsp. maritima</i>				+		+		+			2		+
<i>Convolvulus arvensis</i>				+		+	+			+	+		
<i>Eryngium campestre</i>	+				+			+		+	+		
<i>Hedera helix</i>			+		2				1	+			1
<i>Solanum dulcamara</i>				+	+		+		1	+			
<i>Calystegia sepium var. sepium</i>			+	1	+							r	
<i>Carduus pycnocephalus</i>	+						+		+		1		
<i>Elytrigia acuta</i>	+		+	+		+							
<i>Foeniculum vulgare</i>			+	1					+		+		
<i>Galium aparine</i>			+		1			+		1			
<i>Urtica dioica</i>					+				+		+	1	
<i>Arum italicum subsp. neglectum</i>				+					+		+		
<i>Atriplex halimus</i>			+			1					1		
<i>Avena barbata</i>	+						+		+				
<i>Hordeum murinum</i>					+			2		+			
<i>Oenanthe crocata</i>				+	+								+
<i>Rumex conglomeratus</i>				+					+			+	
<i>Cynodon dactylon</i>	+		+										
<i>Festuca rubra</i>	+	5											
<i>Lactuca saligna</i>					+				+				
<i>Lactuca serriola</i>					+				+				
<i>Pteridium aquilinum</i>				+									1
<i>Ranunculus acris</i>			+						+				
<i>Raphanus raphanistrum</i>							1					2	
<i>Smyrniolum olusatrum</i>						+	2						
<i>Sonchus oleraceus</i>					+			+					
<i>Trifolium repens</i>				+				+					
<i>Ulmus minor</i>					+					+			
<i>Geranium dissectum</i>									+				
<i>Glechoma hederacea</i>								+					
<i>Lolium arundinaceum</i>												1	
<i>Ranunculus sardous</i>			+										
<i>Rapistrum rugosum</i>							+						
<i>Ruscus aculeatus</i>										+			
<i>Silybum marianum</i>							+						
<i>Spergularia maritima</i>			+										
<i>Stellaria media</i>									+				
<i>Torilis japonica</i>										+			
<i>Ulex europaeus</i>										+			

Tab. 14. - *Solano dulcamarae - Tamaricetum gallicae* antropogenic shbrubland

Estuary	Villaine	Villaine	Loire	Loire	Blavet	Loire	Charente	Loire	Loire	Charente	Blavet	Elorn	Loire	Loire	Loire
Date	Persicario hydropiperis - Bidentetum tripartitae														
	Pénestrin - barrage d'Arzal														
	Pénestrin - barrage d'Arzal														
	Le Pellerin - Reze														
	Sainte Luce sur Loire - Ancenis														
	Lanester - Pont scofff														
	Sainte Luce sur Loire - Ancenis														
	Le petit Vergeroux - Tonmay Charente														
	Le Pellerin - Reze														
	Reze - Basse Goulaine														
	Le petit Vergeroux - Tonmay Charente														
	Lanester - Pont scofff														
	Landerneau - Poulquijou (Dirimon)														
	Paimboeuf - Le pellerin														
	Basse Goulaine - Liré														
	Coueron - Nanates														
Surface (m2)	30	20	50	30	50	10	20	40	35	20	10	10	70	50	20
Total cover (%)	80	60	90	80	100	80	600	90	90	70	40	40	80	90	80
Rel n.	V1	VV1	L4	L7	B1	LL1	CC1	L3	L5	C1	BB1	EE1	L1	L6	L2
Species per rel.	7	4	21	21	15	5	5	15	19	12	3	4	13	17	7
Progressive	9	15	4	7	8	11	14	3	5	10	12	13	1	6	2
<i>Bidens tripartita</i>	2	2	1	1	1	1	1	+	+	+	+	+			+
<i>Persicaria hydropiper</i>	2		2	+	2			1	2	1			r	1	
<i>Atriplex prostrata</i>	+	+	+	+	r			r		1			+		
<i>Persicaria lapathifolia</i>		2	+			2	1	r			2	1		+	
<i>Helosciadium nodiflorum</i>					+		+	r	+	+	+			+	
<i>Jacobaea aquatica</i>			+	+	1			+	+	+					
<i>Lycopus europaeus</i>	+			1	+			+	+	+					
<i>Lythrum salicaria</i>			1	1	+			1	2					1	
<i>Persicaria amphibia</i>			1	+				1	+	+			r		
<i>Persicaria maculosa</i>	+	1				1	1					+	+		
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>			+	+	r								r		1
<i>Cardamine hirsuta</i>				+	+			+	+				+		
<i>Poa annua</i>			+	+	+					+			r	+	
<i>Potentilla reptans</i>				r	+				+	+				1	
<i>Rorippa amphibia</i>			r	r				r	+					r	
<i>Veronica anagallis-aquatica</i>			r	+				+	+				+		
<i>Amaranthus albus</i>				+		+		r						+	
<i>Cyperus eragrostis</i>			+	+					+					1	
<i>Juncus effusus</i>			+	1	1			1							
<i>Mentha aquatica</i>					1			r	+					r	
<i>Veronica persica</i>			r	+					+					+	
<i>Beta vulgaris</i> subsp. <i>maritima</i>			r				+	r							
<i>Bidens frondosa</i>			+	+					+						
<i>Geranium robertianum</i>			+	+				1							
<i>Holcus lanatus</i>	+									+		1			
<i>Bidens radiata</i>									r					r	
<i>Epilobium tetragonum</i>													+	+	
<i>Eragrostis pectinacea</i>				+										+	
<i>Galium palustre</i>					+			r							
<i>Myosurus minimus</i>						+							4		
<i>Paspalum distichum</i>				r										+	
<i>Portulaca oleracea</i>			+											r	
<i>Ranunculus sceleratus</i>													+	+	
<i>Solanum nigrum</i>			r											+	
<i>Bolboschoenus maritimus</i>															+
<i>Carex otrubae</i>	+														
<i>Cotula coronopifolia</i>															1
<i>Digitaria sanguinalis</i>				+											
<i>Echinochloa crus-galli</i>									+						
<i>Eleocharis bonariensis</i>			+												
<i>Eleocharis palustris</i>					+										
<i>Galatella pannonica</i>			r												
<i>Ludwigia peploides</i>								r							
<i>Lychnis flos-cuculi</i>													i		
<i>Ranunculus cfr aquatilis</i>															1
<i>Triglochin maritima</i>															+
<i>Veronica serpyllifolia</i>													r		

Tab. 15. - Late summer muds and riverbanks community

Estuary	Loire	Loire	Loire	Loire	Loire	Loire	Loire	Blavet	Laita	Aulne	Aulne	Élorn	Charente	Charente	Loire	Loire	Loire
Association reference	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Phalaridetum arundinaceae</i>	<i>Rorippa sylvestris - Phalaridetum arundinaceae</i>	<i>Rorippa sylvestris - Phalaridetum arundinaceae</i>	<i>Rorippa sylvestris - Phalaridetum arundinaceae</i>
Site	Paimboeuf - Frossay	Lavau et Pipi - Cordemais	Frossay - Le Pellerin	Cordemais - Coueron	Coueron - Nantes	Le Pellerin - Reze	Nantes - Sainte Luce sur Loire	Lanester - Pont Scorff	Pivières (Guidel) - Quimperlé	Pont de Buis-Le Quimerch - Chateaulin	Rosnoen - Pont de Buis-Le Quimerch	Landemau - Poulquijou (Dirinon)	Le petit Vergeroux - Tonmay Charente	Le Mung - Saintes	Reze - Basse Goulaine	Basse Goulaine - Liré	Ancenis - Ingrandes
Surface (m2)	80	20	50	70	80	70	50	20	20	50	50	10	10	30	100	70	100
Total cover (%)	100	90	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100
Rel n.	L1	L2	L3	L4	L5	L6	L7	B1	A1	U1	U2	E1	C1	C2	L8	L9	L10
Progressive	1	2	3	4	5	6	7	11	12	13	14	15	16	17	8	9	10
Species per rel.	5	2	8	5	10	9	11	4	5	4	5	5	5	6	4	6	8
<i>Phalaris arundinacea</i>	4	4	4	4	2	5	4	5	5	5	5	5	5	5	4	5	4
<i>Calystegia sepium</i> var. <i>sepium</i>	2			+		r	+							+		+	
<i>Oenanthe crocata</i>			+		1				+	+				+			1
<i>Urtica dioica</i>		1						+			+	+	+	+			
<i>Phragmites australis</i>	2		2	1											1		+
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	+			+			+								1		
<i>Cirsium arvense</i>	+						+	+							r		
<i>Holcus lanatus</i>							+	+		+							+
<i>Lythrum salicaria</i>					1				+			+	+				
<i>Mentha aquatica</i>						r					+			+			+
<i>Ranunculus repens</i>				r	1	+											+
<i>Xanthium strumarium</i>											+	i	i			+	
<i>Helosciadum nodiflorum</i>												r	r	+			
<i>Jacobaea aquatica</i>			r		+						r						
<i>Lycopus europaeus</i>					+				+	+							
<i>Angelica heterocarpa</i>			+		+												
<i>Dactylis glomerata</i>			+														+
<i>Potentilla reptans</i>							+										+
<i>Pulicaria dysenterica</i>							+		r								
<i>Artemisia verlotiorum</i>							r										
<i>Bellis perennis</i>							r										
<i>Carex acutiformis</i>																	+
<i>Carex otrubae</i>			+														
<i>Deschampsia cespitosa</i>					1												
<i>Elymus caninus</i>						+											
<i>Galatella pannonica</i>			r														
<i>Galium palustre</i>						r											
<i>Glyceria fluitans</i>						1											
<i>Populus nigra</i>																	+
<i>Rumex anguineus</i>					+												
<i>Solanum dulcamara</i>						+											
<i>Symphyotrichum novi-belgii</i>																	+
<i>Symphytum officinale</i>						r											
<i>Taraxacum officinale</i>					r												
<i>Trifolium pratense</i>							+										
<i>Trigonella alba</i>							+										

Tab. 22. - *Phalaris arundinacea* community

Estuary	Charente	Charente	Charente	Charente	Charente
Site	Pointe de la Fumée - Le petit Vergeroux	Fontaine de Lupin - Pont suspendu	Fontaine de Lupin - Pont suspendu	Fontaine de Lupin - Pont suspendu	Fontaine de Lupin - Pont suspendu
Surface (m2)	30	30	30	30	10
Total cover (%)	100	100	100	100	60
Rel n.	C1	C2	C3	C4	C5
Species per rel.	36	8	2	9	1
<i>Silybum marianum</i>	2	1	5	5	4
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	+		1	+	
<i>Dipsacus fullonum</i>	+	+		+	
<i>Urtica dioica</i>	+	3		1	
<i>Artemisia verlotiorum</i>	2			+	
<i>Cirsium arvense</i>		+		+	
<i>Dactylis glomerata</i>	+	r			
<i>Picris hieracioides</i>	1			1	
<i>Rumex conglomeratus</i>	+	1			
<i>Rumex obtusifolius</i>	1	1			
<i>Trifolium campestre</i>	+			+	
<i>Alcea rosea</i>	+				
<i>Avena</i> cfr <i>fatua</i>	r				
<i>Beta vulgaris</i> subsp. <i>maritima</i>	+				
<i>Cichorium intybus</i>	+				
<i>Daucus carota</i>	1				
<i>Elymus repens</i>	+				
<i>Erigeron canadensis</i>	1				
<i>Erigeron sumatrensis</i>	1				
<i>Foeniculum vulgare</i>	+				
<i>Galium aparine</i>	+				
<i>Geranium rotundifolium</i>	r				
<i>Lathyrus pratensis</i>	+				
<i>Lolium perenne</i>				1	
<i>Malva sylvestris</i>	+				
<i>Medicago arabica</i>	1				
<i>Medicago lupulina</i>	+				
<i>Medicago sativa</i>	+				
<i>Mentha longifolia</i>	+				
<i>Mercurialis annua</i>	+				
<i>Pastinaca sativa</i>	+				
<i>Phragmites vulgaris</i>		r			
<i>Plantago coronopus</i>	+				
<i>Plantago lanceolata</i>	+				
<i>Plantago major</i>	+				
<i>Potentilla reptans</i>	+				
<i>Sambucus nigra</i>	i				
<i>Symphytum officinale</i>	+				
<i>Trifolium repens</i>	+				

Tab. 27. - *Silybetum mariani* (Br.-Bl. 1931), Br.-Bl., Gajeswki, Wraber & Walas 1936 corresponding partially to the *Silybo mariani-Urticetum piluliferae*

Estuary	Loire	Laita	Loire	Charente	Charente	Loire	Vilaïne	Loire	Charente	Vilaïne	Loire	Charente
Association reference	<i>Alopecuro pratensis</i> — <i>Cynosuretum cristati</i>	<i>Alopecuro pratensis</i> — <i>Cynosuretum cristati</i>	<i>Lolio perennis</i> — <i>Potentilletum anserinae</i>	<i>Lolio perennis</i> — <i>Potentilletum anserinae</i>	<i>Plantagini majoris</i> — <i>Trifolietum resupinati</i>	<i>Plantagini majoris</i> — <i>Trifolietum resupinati</i>	<i>Cirsio palustris</i> — <i>Juncetum effusi</i>	<i>Cirsio palustris</i> — <i>Juncetum effusi</i>	<i>Cirsio palustris</i> — <i>Juncetum effusi</i>	<i>Junco acutiflori</i> — <i>Cynosuretum cristati</i>	<i>Junco acutiflori</i> — <i>Cynosuretum cristati</i>	<i>Junco acutiflori</i> — <i>Cynosuretum cristati</i>
Site	Coueron - Nantes	Saint Julien - Pont D224	Coueron - Nantes	Le Mung - Saintes	Pointe de la Fumée - Le petit Vergeroux	Paimboeuf - Frossay	Pénestrin - barrage d'Arzal	Coueron - Nantes	Fontaine de Lupin - Pont suspendu	Billers - barrage d'Arzal	Liré - Montjean sur Loire	Le Mung - Saintes
Surface (m2)	30	20	10	10	20	20	10	10	25	10	10	10
Total cover (%)	100	100	100	100	100	100	100	90	100	100	100	100
Rel n.	L1	A1	L4	C3	C4	L5	V1	L2	C1	V2	L3	C2
Progressive	1	6	4	11	12	5	7	2	9	8	3	10
Species per rel.	25	19	8	5	8	8	16	9	14	13	10	15
<i>Lolium perenne</i>	1	1	3	3			1		2	1	1	2
<i>Plantago lanceolata</i>	1	1					1	1	1	2	1	2
<i>Poa annua</i>	+	+				1	+	1		1	1	+
<i>Trifolium repens</i>	+	+	1	+			+		+	+		1
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>			1	+	1		2	1	1		1	
<i>Juncus effusus</i>	1	1						2	2	+	+	+
<i>Ranunculus sardous</i>	+	+				+	+	+		+		+
<i>Ranunculus acris</i>	+	+			+	+	+					+
<i>Rumex acetosa</i>	+	1					+		+	+		1
<i>Silene flos-cuculi</i>	r	+						+	+		+	+
<i>Cynosurus cristatus</i>	2	1								1	1	+
<i>Holcus lanatus</i>	1	+					1		+	1		
<i>Juncus acutiflorus</i>			2	2						+	1	+
<i>Poa trivialis</i>	+	+					+			1		+
<i>Potentilla anserina</i>	+		+	+			+	+				
<i>Prunella vulgaris</i>	+	+					+		+			+
<i>Cerastium</i> sp.	+	+					1			+		
<i>Cirsium palustre</i>	+						+	2	1			
<i>Dactylis glomerata</i>	+	1					1		+			
<i>Festuca rubra</i>		+			+	+				+		
<i>Lathyrus pratensis</i>	r	+							+			+
<i>Alopecurus pratensis</i>	2	2	+									
<i>Anthoxantum odoratum</i>	+		+									+
<i>Centaurea nigra</i>	+	+							+			
<i>Galium palustre</i>	+								+		+	
<i>Plantago coronopus</i>					1	+		+				
<i>Plantago major</i>					1	1					+	
<i>Juncus inflexus</i>					+	1						
<i>Rumex conglomeratus</i>	+						+					
<i>Trifolium resupinatum</i>					2	2						
<i>Mentha pulegium</i>					+							
<i>Poa pratense</i>	+											
<i>Potentilla reptans</i>			+									
<i>Ranunculus repens</i>	+											

Tab. 30. - *Ranunculo repentis* — *Cynosurion cristati* meadows

Estuary	Loire	Loire	Loire	Loire	Charente
Site	Coueron - Nauades	Coueron - Nauades	Le Pellerin - Reze	Nantes - Sainte Luce sur Loire	Saint-Savinien - Saintes
Surface (m2)	20	80	50	20	20
Total cover (%)	100	100	100	100	100
Shrub cover (%)	90	90	95	95	85
Herb cover (%)	80	80	80	80	80
Rel n.	L1	L2	L3	L4	C1
Progressive	1	2	3	4	5
Species per rel.	33	52	26	23	24
Shrub layer					
<i>Salix triandra</i>	2	2	3	4	3
<i>Salix atrocinerea</i>	1		1	1	2
<i>Crataegus monogyna</i>	+	+			1
<i>Salix alba</i>		1	1	1	
<i>Salix fragilis</i>	1	1		1	
<i>Salix viminalis</i>	1	2	2		
<i>Fraxinus angustifolia</i>	1	1			
<i>Hedera helix</i>			+		
<i>Humulus lupulus</i>				+	
<i>Populus alba</i>	1				
<i>Prunus spinosa</i>	1				
<i>Rosa canina</i>	+				
<i>Sambucus nigra</i>				+	
Herb layer					
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	2	1	2	1	2
<i>Hedera helix</i>	+	+	+	+	+
<i>Oenanthe crocata</i>	+	+	+	+	+
<i>Fraxinus angustifolia</i>	+		+	+	+
<i>Holcus lanatus</i>	+	+		1	+
<i>Lolium arundinaceum</i>	1	+		1	+
<i>Calystegia sepium</i> var. <i>sepium</i>	+			+	1
<i>Cardamine pratensis</i>		+	+		+
<i>Cirsium arvense</i>		+		+	1
<i>Dactylis glomerata</i>	1			1	2
<i>Elytrigia repens</i>	2			1	2
<i>Epilobium hirsutum</i>		1	+		+
<i>Galium aparine</i>	+			+	+
<i>Persicaria amphibia</i>		+	+		+
<i>Potentilla reptans</i>		+	+		+
<i>Urtica dioica</i>	+		+		+
<i>Althaea officinalis</i>	+		+		
<i>Arrhenatherum elatius</i>			+	+	
<i>Atriplex prostrata</i>		+		+	
<i>Deschampsia cespitosa</i>	1		1		
<i>Equisetum fluviatile</i>			+		+
<i>Glyceria maxima</i>		1	+		
<i>Lythrum salicaria</i>		1	+		
<i>Mentha aquatica</i>		+		+	
<i>Persicaria hydropiper</i>	+	+			
<i>Phalaris arundinacea</i>	1	1			
<i>Phleum pratense</i>	+	+			
<i>Phragmites australis</i>		1			+
<i>Potentilla anserina</i>	+	+			
<i>Ranunculus repens</i>		+		+	
<i>Rubus caesius</i>		+		1	
<i>Rumex conglomeratus</i>	+				+
<i>Schoenoplectus triqueter</i>		1	1		
<i>Solanum dulcamara</i>		+	+		
<i>Sonchus oleraceus</i>	+		+		
<i>Taraxacum officinale</i>	+				+
<i>Thalictrum flavum</i>		+	+		
<i>Alopecurus pratensis</i>		+			
<i>Angelica heterocarpa</i>		+			
<i>Bidens tripartita</i>					+
<i>Callitriche stagnalis</i>		+			
<i>Carex hirta</i>		+			
<i>Carex remota</i>		+			
<i>Carex riparia</i>		+			
<i>Cyperus eragrostis</i>			+		
<i>Cyperus longus</i>		+			
<i>Dioscorea communis</i>				+	
<i>Dipsacus fullonum</i>	+				
<i>Dysphania ambrosioides</i>	+				
<i>Eleocharis bonariensis</i>		1			
<i>Epipactis helleborine</i>		+			
<i>Equisetum arvense</i>			+		
<i>Galium palustre</i>		+			
<i>Helosciadium nodiflorum</i>		+			
<i>Jacobaea aquatica</i>		+			
<i>Limniris pseudacorus</i>		+			
<i>Ludwigia peploides</i>		+			
<i>Lycopus europaeus</i>		+			
<i>Lysimachia vulgaris</i>		+			
<i>Melissa officinalis</i>	+				
<i>Oenanthe fistulosa</i>		+			
<i>Reynoutria japonica</i>	+				
<i>Rumex sanguineus</i>		+			
<i>Scrophularia auriculata</i>		+			
<i>Symphotrichum lanceolatum</i>		+			
<i>Typha latifolia</i>		+			
<i>Veronica anagallis-aquatica</i>		+			

Tab. 31. - *Salicetum triandro-viminalis* part 1

Estuary	Loire	Loire	Charente
Site	Coueron - Nantès	Le Pellerin - Reze	Saint Savinien - Saines
Surface (m2)	20	20	20
Total cover (%)	100	100	100
Shrub cover (%)	90	90	90
Herb cover (%)	80	80	80
Rel n.	L1	L3	C1
Species per rel.	26	21	25
Shrub layer			
<i>Salix atrocinerea</i>	1	1	3
<i>Crataegus monogyna</i>		1	1
<i>Fraxinus angustifolia</i>	1		1
<i>Prunus spinosa</i>	+		+
<i>Salix purpurea</i>	4	4	
<i>Salix triandra</i>	+		1
<i>Humulus lupulus</i>		+	
<i>Rosa canina</i>	+		
<i>Sambucus nigra</i>	+		
Herb layer			
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	2	1	4
<i>Arrhenatherum elatius</i>	+	+	+
<i>Dactylis glomerata</i>	+	1	1
<i>Elytrigia repens</i>	1	+	+
<i>Oenanthe crocata</i>	1	1	+
<i>Phalaris arundinacea</i>	2	2	+
<i>Bidens tripartita</i>		+	+
<i>Calystegia sepium</i> var. <i>sepium</i>	+		+
<i>Cardamine pratensis</i>	+		+
<i>Cirsium arvense</i>		1	+
<i>Fraxinus angustifolia</i>	+		+
<i>Alopecurus pratensis</i>	+		
<i>Althaea officinalis</i>	+		
<i>Atriplex prostrata</i>	+		
<i>Dioscorea communis</i>		+	
<i>Dipsacus fullonum</i>			+
<i>Galium aparine</i>			+
<i>Galium palustre</i>	+		
<i>Hedera helix</i>		+	
<i>Holcus lanatus</i>			1
<i>Lolium arundinaceum</i>		+	
<i>Lythrum salicaria</i>	+		
<i>Persicaria amphibia</i>		+	
<i>Persicaria hydropiper</i>	+		
<i>Phleum pratense</i>			+
<i>Phragmites australis</i>			1
<i>Potentilla anserina</i>			+
<i>Potentilla reptans</i>	+		
<i>Ranunculus repens</i>		+	
<i>Reynoutria japonica</i>		+	
<i>Rubus caesius</i>		+	
<i>Rumex conglomeratus</i>	+		
<i>Rumex sanguineus</i>			+
<i>Saponaria officinalis</i>		+	
<i>Solanum dulcamara</i>	+		
<i>Sonchus oleraceus</i>			+
<i>Urtica dioica</i>		+	
<i>Deschampsia cespitosa</i>	+		
<i>Epilobium hirsutum</i>			+

Tab. 32. - *Salicetum purpureae*

Site	Le Pellerin - Reze	Le Pellerin - Reze	Le Pellerin - Reze
Surface (m2)	30	30	30
Total cover (%)	100	100	100
Shrub cover (%)	90	90	0
Herb cover (%)	90	90	100
Rel n.	C3	C3	C4
Taxa per rel.	48	27	15
Shrub layer			
<i>Aristolochia clematitis</i>	1	2	
<i>Calystegia sepium</i> var. <i>sepium</i>	+	+	
<i>Fraxinus excelsior</i>	1	2	
<i>Prunus spinosa</i>	1	+	
<i>Salix alba</i>	3	2	
<i>Humulus lupulus</i>	1		
Herb layer			
<i>Aristolochia clematitis</i>	3	2	4
<i>Calystegia sepium</i>	+	+	1
<i>Dactylis glomerata</i>	1	+	+
<i>Daucus carota</i>	+	+	+
<i>Elymus repens</i>	+	1	+
<i>Galium aparine</i>	1	1	1
<i>Geum urbanum</i>	+	+	+
<i>Glechoma hederacea</i>	1	+	+
<i>Urtica dioica</i>	+	+	+
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	+		+
<i>Arctium nemoralis</i>	1	+	
<i>Chaerophyllum temulum</i>	+	+	
<i>Fraxinus excelsior</i>	+	+	
<i>Hedera helix</i>	1		+
<i>Holcus lanatus</i>	1		+
<i>Lolium perenne</i>	+	1	
<i>Oenanthe crocata</i>	+		+
<i>Phalaris arundinacea</i>	+		+
<i>Plantago lanceolata</i>	+	1	
<i>Poa trivialis</i>	+		+
<i>Prunus spinosa</i>	+	1	
<i>Rubus fruticosus</i> s.l.	+	+	
<i>Taraxacum officinale</i>	+	+	
<i>Trigonella alba</i>	1	+	
<i>Anisantha sterilis</i>	+		
<i>Anthriscus sylvestris</i>	+		
<i>Arum italicum</i> subsp. <i>neglectum</i>	+		
<i>Chamaeiris foetidissima</i>	+		
<i>Chelidonium majus</i>	+		
<i>Dioscorea communis</i>		+	
<i>Eupatorium cannabinum</i>	+		
<i>Filipendula ulmaria</i>	+		
<i>Geranium dissectum</i>	+		
<i>Heracleum spondylium</i>		1	
<i>Humulus lupulus</i>	1		
<i>Hypericum perforatum</i>	+		
<i>Lapsana communis</i>	+		
<i>Linaria vulgaris</i>	+		
<i>Parietaria judaica</i>	+		
<i>Ranunculus acris</i>	+		
<i>Rubus caesius</i>	1		
<i>Rumex conglomeratus</i>	+		
<i>Rumex obtusifolius</i>		+	
<i>Salix alba</i>	+		
<i>Scrophularia nodosa</i>		+	
<i>Symphytum officinale</i>	+		

Tab. 33. - *Calystegia sepium* - *Aristolochietum clematitidis*

Estuary	Loire	Blavet	Blavet	Villaine	Villaine	Elorn	Charente	Charente	Charente	Charente	Charente	Charente	Charente	Charente	
Site	St Brevin les Pins - Paimboeuf	Port Louis - Plouhinez	Port Louis - Gavres	Penestrin - barrage d'Arzal	Penestrin - barrage d'Arzal	Rade de brest - La forest Landemau	Ile Madame - Fontaine de Lupin	Ile Madame - Fontaine de Lupin	Ile Madame - Fontaine de Lupin	Ile Madame - Fontaine de Lupin	Ile Madame - Fontaine de Lupin	Ile Madame - Fontaine de Lupin	Ile Madame - Fontaine de Lupin	Pointe de la Fumée - Le petit Vegeeroux	Pointe de la Fumée - Le petit Vegeeroux
Surface (m2)	10	10	20	10	10	5	20	40	30	20	20	10	20	20	
Total cover (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Rel n.	L1	B1	B2	V1	V2	V1	C1	C2	C3	C4	C5	C6	C7	C8	
Progressive	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Species per rel.	17	13	8	18	16	21	5	21	8	11	20	4	4	10	
<i>Atriplex halimus</i>	5	5	4	5	4	3	5	3	5	4	5	4	5	5	
<i>Dactylis glomerata</i>	1	1		1	+	+	+			+	1	1		+	
<i>Elymus repens</i>	+	2	+	1	+	2				2	2	3		2	
<i>Elytrigia acuta</i>	1	+	2		4		3	3	2	+			4		
<i>Foeniculum vulgare</i>		1		+	1	1	+	+		+	+				
<i>Beta vulgaris</i> subsp. <i>maritima</i>	+					+		+	1	+	+			+	
<i>Chamaeiris foetidissima</i>	+			+	+	1		1			1			2	
<i>Fraxinus excelsior</i>	+	+		+	+	+				+	+				
<i>Arum italicum</i> subsp. <i>neglectum</i>	+				+	+		+			1			+	
<i>Atriplex prostrata</i>			+			+		+	1	+	+				
<i>Crithmum maritimum</i>	1			+		+		+		+					
<i>Festuca rubra</i>		1	1	1		1		+							
<i>Hedera helix</i>	1			1		1					2			2	
<i>Rubus ulmifolius</i> s.l.	1			1		+		+			1				
<i>Salix atrocinerea</i>	+	+		+				+			+				
<i>Agrostis stolonifera</i> var. <i>maritima</i>			1			+	+		+						
<i>Eryngium campestre</i>	1	+			1			+							
<i>Prunus spinosa</i>		+		1				+			1				
<i>Quercus robur</i>				+		+		+			+				
<i>Silene uniflora</i>	+			+	+			+							
<i>Tamarix gallica</i>	+					1		+			+				
<i>Taraxacum officinale</i>						+		+			+	+			
<i>Daucus carota</i>										+	1			+	
<i>Ligustrum vulgare</i>		+			+						+				
<i>Ulex europaeus</i>				+		1		+							
<i>Umbilicus rupestris</i>				+		1		+							
<i>Armeria maritima</i>	+							+							
<i>Elaeagnus</i> × <i>submacrophylla</i>		+				1									
<i>Eryngium maritimum</i>					+			+							
<i>Honckenya peploides</i>	+				+										
<i>Picris hieracioides</i>									+		+				
<i>Pinus pinaster</i>				+	+										
<i>Raphanus raphanistrum</i>									+		+				
<i>Smyrniolus olusatrum</i>													+	1	
<i>Sonchus oleraceus</i>										+				+	
<i>Cynodon dactylon</i>									1						
<i>Euonymus japonicus</i>		+													
<i>Orobancha hederac</i>				+											
<i>Prospero autumnale</i>					1										
<i>Quercus ilex</i>						+									
<i>Sedum album</i>					+										
<i>Silybum marianum</i>													+		
<i>Suaeda maritima</i>			1												
<i>Suaeda vera</i>			+												

Tab. 34. - *Hedera helix* - *Atriplicetum halimi*

Estuary	Loire	Loire	Loire	Blavet	Laita	Villaine	Elorn	Charente	Charente	Charente	Charente
Site	Montjean sur Loire - Les Ponts de Cé	Ingrandes - Angers	Basse Goulaine - Champloceaux	Lorient - Pont scorff	Pont D224 - Quimperlé	Penn Lann - Barrage d'Arzal	Rade de brest - La forest Landernau	St.Savinien - Saintes	St.Savinien - Saintes	Saintes - Le Mung	Saintes - Le Mung
Surface (m2)	10	10	10	10	10	10	5	20	20	20	20
Total cover (%)	100	100	100	100	100	100	100	100	100	100	100
Rel n.	L1	L2	L3	B1	A1	V1	V1	C1	C2	C3	C4
Progressive	1	2	3	4	5	6	7	8	9	10	11
Species per rel.	25	19	13	13	8	23	15	17	16	15	23
<i>Heracleum spondylium</i>	2	2		3	3	2	2	1	2	2	1
<i>Holcus lanatus</i>	1		1	1	1	1	+	+	1		2
<i>Lolium perenne</i>	1	+	1	+		1		1		1	+
<i>Plantago lanceolata</i>	+	1		+		1	1	1	+		+
<i>Dactylis glomerata</i>	1	+				1		1	2	1	1
<i>Poa annua</i>		1	1			+	1	+	1	1	
<i>Poa pratensis</i>	+	+				+		+	+	+	+
<i>Ranunculus acris</i>			+	+	+		+	+		+	+
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	+	1				+	+	+			+
<i>Leucanthemum vulgare</i>	1	+				+	+		+		+
<i>Plantago coronopus</i>	+			+	1		+		+	1	
<i>Taraxacum officinale</i>				+		+	1		+	+	1
<i>Achillea millefolium</i>	+	1	+			+					+
<i>Cerastium fontanum</i> subsp. <i>vulgare</i>	+					+	+	+			+
<i>Cynosurus cristatus</i>	+				1	+		+			1
<i>Daucus carota</i>	+			+		+	+				+
<i>Elymus repens</i>	+		1			+		+			1
<i>Jacobea vulgaris</i>	+	+				+		1		+	
<i>Plantago major</i>	+	+				+				+	+
<i>Ranunculus repens</i>	+					+	+		+		+
<i>Rumex acetosa</i>	+		+			+				+	+
<i>Bromus japonicus</i>		+			1			+			+
<i>Galium aparine</i>		+				+	+				+
<i>Galium mollugo</i>	+	+				+					+
<i>Trifolium pratense</i>	+		1	+							+
<i>Anthoxanthum odoratum</i>			+	+	+						
<i>Arrhenatherum elatius</i>				+					+		+
<i>Avena fatua</i>		+							+		+
<i>Bromus hordeaceus</i>	+							+	+		
<i>Bromus racemosus</i>	+	+						+			
<i>Holcus mollis</i>	+							+	+		
<i>Lathyrus pratensis</i>			+			+	1				
<i>Poa trivialis</i>			+		+		1				
<i>Geranium dissectum</i>			+								+
<i>Lotus corniculatus</i>			+								+
<i>Oenanthe crocata</i>		1							+		
<i>Sonchus oleraceus</i>				+					+		
<i>Trifolium repens</i>	+					+					
<i>Urtica dioica</i>		+								+	
<i>Festuca rubra</i>				1							
<i>Geum urbanum</i>	+										
<i>Malva moschata</i>		+									

Tab. 35. - *Heracleo spondylii*-*Brometum mollis*

Estuary	Loire	Blavet	Laita	Villaine	Charente
Site	Ingrandes - Angers	Lorient - Pont-scöff	Pont D224 - Quimperlé	Penn Lann - Barrage d'Arzal	St. Savinien - Saintes
Surface (m2)	10	10	10	10	20
Total cover (%)	100	100	100	100	100
Rel n.	L2	B1	A1	V1	C1
Progressive	1	2	3	4	5
Species per rel.	13	10	11	9	11
Average species number	1	1	1	1	1
Total rel. n.	13	10	11	9	11
<i>Galium aparine</i>	1	1	1	1	1
<i>Heracleum spondylium</i>	2	1	1	2	2
<i>Rumex obtusifolius</i>	1	2	1	1	2
<i>Dactylis glomerata</i>	+	1	1		+
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>			1	+	+
<i>Holcus lanatus</i>		+	+	+	
<i>Holcus mollis</i>	+	+			+
<i>Oenanthe crocata</i>	+	+		+	
<i>Bromus hordeaceus</i>	+				1
<i>Cirsium arvense</i>			+		+
<i>Daucus carota</i>		+			+
<i>Galium mollugo</i>	+		+		
<i>Juncus effusus</i>	1				+
<i>Urtica dioica</i>		1		1	
<i>Bromus japonicus</i>	+				
<i>Elymus repens</i>	+				
<i>Glechoma hederacea</i>			+		
<i>Jacobea vulgaris</i>				+	
<i>Lolium perenne</i>					+
<i>Phalaris arundinacea</i>	+				
<i>Plantago lanceolata</i>		+			
<i>Rumex conglomeratus</i>			+		
<i>Taraxacum officinale</i>				+	
<i>Trifolium repens</i>	1				
<i>Ulmus minor</i>			1		

Tab. 36. - *Heracleo sphondylii - Rumicetum obtusifolii*

Estuary	Loire	Blavet	Laita	Villaine	Elorn	Charente
Site	<i>Dactylido glomeratae - Festucetum arundinaceae</i>	<i>Heracleo sphondylii - Rumicetum obtusifolii</i>	<i>Heracleo sphondylii - Rumicetum obtusifolii</i>	<i>Dactylido glomeratae - Festucetum arundinaceae</i>	<i>Dactylido glomeratae - Festucetum arundinaceae</i>	<i>Heracleo sphondylii - Rumicetum obtusifolii</i>
Site	Basse Goulaine - Champloceaux	Lorient - Pont scöff	Pont D224 - Quimperlé	Penn Lann - Barrage d'Arzal	Rade de brest - La forest Landerneau	St. Savinien - Saintes
Surface (m2)	10	10	10	10	5	20
Total cover (%)	100	100	100	100	100	100
Rel n.	L3	B1	A1	V1	V1	C1
Progressive	1	2	3	4	5	6
Species per rel.	8	5	8	6	6	8
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	2	2	2	2	1	2
<i>Heracleum spondylium</i>	1	2	1	1	2	2
<i>Lolium perenne</i>	1	2	1	2	1	2
<i>Rumex obtusifolius</i>	1	+	1	1	1	+
<i>Urtica dioica</i>	+	1		+	1	1
<i>Dactylis glomerata</i>	1			1	1	
<i>Calystegia sepium</i> var. <i>sepium</i>			1			
<i>Hordeum murinum</i>	+					
<i>Juncus effusus</i>						+
<i>Malva moschata</i>			+			
<i>Phalaris arundinacea</i>						+
<i>Sonchus oleraceus</i>	+					
<i>Taraxacum officinale</i>			+			
<i>Persicaria maculosa</i>						+
<i>Picris hieracoides</i>			+			

Tab. 37. - *Dactylido glomeratae-Festucetum arundinaceae* pasture ad meadows i (right side)

Estuary	Loire	Blavet	Laita	Villaine	Elorn	Charente	Aulne
Site	Basse Goulaine - Champloceaux	Lorient - Pont scoff	Pont D224 - Quimperlé	Penn Lann - Barrage d'Arzal	Rade de brest - La forest Landernau	Le petit Vergeroux - Tonmay Charente	Barrage de Guily Glas
Surface (m2)	5	5	5	5	5	5	5
Total cover (%)	100	100	100	100	100	100	100
Rel n.	L3	B1	A1	V1	V1	C1	U1
Progressive	1	2	3	4	5	6	7
Species per rel.	10	6	7	4	5	7	6
Average species number	1	1	1	1	1	1	1
Total rel. n.	10	6	7	4	5	7	6
<i>Lolium perenne</i>	1	1	+	+	1	2	1
<i>Plantago coronopus</i>	2	4	4	5	4	3	3
<i>Poa annua</i>	1	1	+		+	1	+
<i>Polygonum aviculare</i>	+		+	1	1	1	+
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	1	+		1		1	+
<i>Plantago major</i>	1	+			+	1	1
<i>Trifolium repens</i>	+	+	1				
<i>Juncus bufonius</i>	+					+	
<i>Persicaria maculosa</i>	+		+				
<i>Potentilla reptans</i>	+		+				

Tab. 38. - *Lolium perennis* – *Plantaginetum coronopodis*

Estuary	Loire	Charente
Site	Basse Goulaine - Liré	Fontaine de Lupin - Pont suspendu
Surface (m2)	40	80
Total cover (%)	100	100
Rel n.	L1	C1
Species per rel.	4	2
Average species number	4	2
<i>Cirsium arvense</i>	+	+
<i>Dipsacus fullonum</i>	+	
<i>Persicaria maculosa</i>	+	
<i>Sambucus ebulus</i>	5	5

Tab. 39. - *Sambucetum ebuli*

Estuary	Loire	Blavet	Laita	Villaine	Elorn	Charente	Aulne
Site	Nantes - Basse Goutaine	Lorient - Pont scorff	Pont D224 - Quimperlé	Penn Lann - Barrage d'Arzal	Rade de brest - La forest Landernau	Saintes - Le Mung	Barrage de Guily Glas
Surface (m2)	5	5	5	5	5	5	5
Total cover (%)	100	100	100	100	100	100	100
Rel n.	L3	B1	A1	V1	V1	C1	U1
Progressive	1	2	3	4	5	6	7
Species per rel.	14	7	7	7	6	16	14
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	1	2	2	+	3	1	1
<i>Lolium perenne</i>	1	2	2	2	2	2	1
<i>Plantago major</i>	2	2	1	1	+	2	2
<i>Plantago lanceolata</i>	+	+	+	1		+	+
<i>Poa annua</i>	+	2	2	1		+	1
<i>Plantago coronopus</i>	+	+			+	+	r
<i>Taraxacum officinale</i>	+			+	1	+	+
<i>Trifolium repens</i>	+		+	1		+	+
<i>Daucus carota</i>			+		1	+	r
<i>Bellis perennis</i>	+					+	+
<i>Dactylis glomerata</i>	+					+	+
<i>Juncus bufonius</i>	+					+	+
<i>Persicaria maculosa</i>		+				+	r
<i>Polygonum aviculare</i>	+					+	+
<i>Elymus repens</i>	+					1	
<i>Potentilla reptans</i>	+					+	

Tab. 40. - *Lolium perenne* - *Plantaginietum majoris*

Estuary	Loire	Loire	Loire	Charente
Site	Cordemais - Coueron	Le Pellerin - Reze	Le Pellerin - Reze	Pointe de la Fumée - Le petit Vergeroux
Surface (m2)	10	10	10	30
Total cover (%)	80	80	80	80
Rel n.	L1	L2	L3	C1
Progressive	1	2	3	4
Species per rel.	5	6	5	3
<i>Typha angustifolia</i>	2	4	4	5
<i>Lycopus europaeus</i>	1	+	+	+
<i>Eleocharis cfr palustris</i>			1	r
<i>Bolboschoenus maritimus</i>	+			
<i>Calystegia sepium var. sepium</i>		+		
<i>Glyceria maxima</i>			+	
<i>Helosciadum nodiflorum</i>			+	
<i>Phalaris arundinacea</i>		1		
<i>Phragmites australis</i>	1			
<i>Solanum dulcamara</i>		+		
<i>Typha latifolia</i>	+			
<i>Veronica anagallis-aquatica</i>		+		

Tab. 41. - *Typhetum angustifolii*

Estuary	Loire	Blavet	Charente
Site	Basse Goulaine - Champtoceaux	Lorient - Pont scorff	Saintes - Le Mung
Surface (m2)	10	10	20
Total cover (%)	100	100	100
Rel n.	L3	B1	C3
Average species number	12	3	7
<i>Poa annua</i>	1	+	+
<i>Trigonella alba</i>	3	5	4
<i>Hordeum murinum</i>	+		+
<i>Plantago lanceolata</i>	+		1
<i>Plantago major</i>	+		+
<i>Taraxacum officinale</i>	+		+
<i>Agrostis stolonifera var. stolonifera</i>	1		
<i>Bromus japonicus</i>	+		
<i>Jacobea vulgaris</i>		+	
<i>Lolium perene</i>	+		
<i>Malva sylvestris</i>	1		
<i>Malva moschata</i>			+
<i>Medicago sativa</i>	1		
<i>Trigonella officinalis</i>	1		

Tab. 42. - *Melilotetum albo – officinalis*

Estuary	Loire	Charente
Site	Basse Goulaine - Champocéaux	Saintes - Le Mung
Surface (m2)	10	20
Total cover (%)	100	100
Rel n.	L3	C4
Progressive	1	2
Species per rel.	10	11
<i>Arctium lappa</i>	2	2
<i>Artemisia vulgaris</i>	1	1
<i>Dactylis glomerata</i>	+	+
<i>Lolium perenne</i>	+	+
<i>Rubus ulmifolius</i> s.l.	+	1
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>		1
<i>Fraxinus excelsior</i>		+
<i>Galium aparine</i>		1
<i>Glechoma hederacea</i>		+
<i>Poa annua</i>	1	
<i>Prunus spinosa</i>		+
<i>Quercus robur</i>		+
<i>Salix atrocinerea</i>	+	
<i>Taraxacum officinale</i>	1	
<i>Torilis arvensis</i>	+	
<i>Urtica dioica</i>	+	

Tab. 43. - *Arctio lappae* - *Artemisietum vulgaris*

Estuary	Laita	Laita
Site	Pont D224 - Ruisseau Le Frouit	Pont D224 - Ruisseau Le Frouit
Surface (m2)	100	100
Total cover (%)	100	100
Tree cover (%)	90	90
Shrub cover (%)	50	40
Herb cover (%)	80	80
Rel n.	A1	A2
Tree layer : 10m		
<i>Alnus glutinosa</i>	2	3
<i>Quercus robur</i>	1	
<i>Salix atrocinerea</i>	2	2
Shrub layer: 5m		
<i>Alnus glutinosa</i>		1
<i>Ilex aquifolium</i>	r	
<i>Prunus spinosa</i>	2	
<i>Rubus fruticosus</i> s.l.	+	
<i>Salix atrocinerea</i>	2	3
Herb layer: 1m		
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	1	2
<i>Alnus glutinosa</i>		1
<i>Calystegia sepium</i> var. <i>sepium</i>	+	
<i>Carex paniculata</i>	+	+
<i>Carex remota</i>	+	
<i>Filipendula vulgaris</i>	r	
<i>Hedera helix</i>	+	
<i>Limniris pseudacorus</i>	2	
<i>Lysimachia vulgaris</i>	+	
<i>Phalaris arundinacea</i>	1	+
<i>Phragmites australis</i>	1	
<i>Prunus spinosa</i>	+	+
<i>Rosa canina</i>	+	
<i>Rubia peregrina</i>	+	
<i>Rubus caesius</i>	+	
<i>Salix atrocinerea</i>		2

Tab. 44. - *Alnus glutinosa* forests

Estuary	Loire	Loire	Loire	Loire	Loire	Loire	Charente
Site	Paimboeuf - Frossay	Frossay - Le Pellerin	Frossay - Le Pellerin	Cordemais - Coueron	Coueron - Nanates	Le Pellerin - Reze	Pont suspendu - Le Mung
Surface (m2)	20	40	20	40	30	20	25
Total cover (%)	100	100	100	100	100	100	100
Rel n.	L1	L2	L3	L4	L5	L6	C1
Species per rel.	7	15	9	10	1	8	7
<i>Glyceria maxima</i>	4	2	5	4	5	3	4
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	1			+		2	1
<i>Glyceria fluitans</i>	+	1		+		+	
<i>Limniris pseudacorus</i>		+		1		1	+
<i>Galium palustre</i>		1	r			r	
<i>Lycopus europaeus</i>			+	+		+	
<i>Phalaris arundinacea</i>			+	1		1	
<i>Ranunculus reptans</i>	+			+			1
<i>Helosciadum nodiflorum</i>		+					+
<i>Juncus effusus</i>		1					+
<i>Lysimachia nummularia</i>	+			+			
<i>Ranunculus sceleratus</i>			+	+			
<i>Salix atrocinerea</i>	1		r				
<i>Solanum dulcamara</i>			r			r	
<i>Veronica anagallis-aquatica</i>		+		+			
<i>Veronica beccabunga</i>		2					1
<i>Callitriche</i> cfr <i>stagnalis</i>	+						
<i>Cardamine hirsuta</i>			r				
<i>Fraxinus excelsior</i>		+					
<i>Juncus acutus</i>		1					
<i>Juncus inflexus</i>		+					
<i>Lythrum salicaria</i>		r					
<i>Oenanthe crocata</i>		+					
<i>Persicaria amphibia</i>			r				
<i>Ranunculus sardous</i>		1					
<i>Rosa canina</i>		+					

Tab. 45. - *Glycerietum maximae*

Estuary	Loire	Loire	Loire	Loire	Loire	Charente	Charente
Site	Frossay - Le Pellerin	Cordemais - Coueron	Cordemais - Coueron	Le Pellerin - Reze	Aucenis - Ingrandes	Fontaine de Lupin - Pont suspendu	Pont suspendu - Le Mung
Surface (m2)	20	50	30	20	30	30	30
Total cover (%)	80	100	80	80	95	95	95
Rel n.	L1	L2	L3	L4	L5	C1	C2
Species per rel.	7	6	6	6	5	6	2
<i>Typha latifolia</i>	4	5		4	4	5	5
<i>Lycopus europaeus</i>	1	+			1	+	
<i>Veronica anagallis-aquatica</i>		+	+	+	1		
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>		+			+	+	
<i>Glyceria maxima</i>	+	+		1			
<i>Helosciadum nodiflorum</i>	+	+		+			
<i>Carex acutiformis</i>			+			+	
<i>Carex riparia</i>					+	+	
<i>Lythrum salicaria</i>	+		+				
<i>Potamogeton</i> cfr <i>natans</i>			+				+
<i>Solanum dulcamara</i>	+			+			
<i>Typha angustifolia</i>	+		4				
<i>Callitriche</i> cfr <i>stagnalis</i>			+				
<i>Calystegia sepium</i> var. <i>sepium</i>				+			
<i>Phragmites australis</i>						+	

Tab. 46. - *Typhetum latifoliae*

Estuary	Charente	Charente	Charente
Site	Pointe de la Fumée - Le petit Vergeroux	Pointe de la Fumée - Le petit Vergeroux	Pointe de la Fumée - Le petit Vergeroux
Surface (m2)	50	20	10
Total cover (%)	80	80	80
Rel n.	C1	C2	C3
Species per rel.	3	1	4
<i>Typha domingensis</i>	5	5	3
<i>Calystegia sepium</i> var. <i>sepium</i>	+		
<i>Lycopus europaeus</i>	+		
<i>Phalaris arundinacea</i>			+
<i>Phragmites australis</i>			2
<i>Solanum dulcamara</i>			+

Tab. 47. - *Typho domingensis-Phragmitetum maximi*

Estuary	Loire	Loire	Loire	Loire	Loire	Charente
Site	Paimboeuf - Frossay	Frossay - Le Pellerin	Cordenais - Coueron	Le Pellerin - Reze	Coueron - Nanates	Pont suspendu - Le Mung
Surface (m2)	20	20	20	10	20	20
Total cover (%)	90	90	90	90	90	90
Rel n.	L1	L2	L3	L4	L5	C1
Species per rel.	5	7	4	1	9	3
<i>Sparganium erectum</i>	4	3	3	5	4	4
<i>Helosciadum nodiflorum</i>	+		+		+	+
<i>Solanum dulcamara</i>		+			+	+
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>			1		+	
<i>Calystegia sepium</i> var. <i>sepium</i>		+			+	
<i>Glyceria fluitans</i>		+			+	
<i>Glyceria maxima</i>			1		+	
<i>Limniris pseudacorus</i>		2			+	
<i>Persicaria amphibia</i>	+	1				
<i>Veronica anagallis-aquatica</i>		+			1	
<i>Phalaris arundinacea</i>	1					
<i>Potamogeton</i> cfr <i>natans</i>	+					

Tab. 48. - *Sparganietum erecti*

Estuary	Loire	Loire	Loire	Loire	Loire	Charente
Site	Cordemais - Coueron	Coueron - Namates	Le Pellerin - Reze	Nantes - Sainte Luce sur Loire	Reze - Basse Goulaine	Tonnay Charente- Saint Savinien
Surface (m2)	20	30	30	30	30	10
Total cover (%)	100	90	80	100	100	80
Rel n.	L1	L2	L3	L4	L5	C1
Species per rel.	6	1	2	3	5	3
<i>Limniris pseudacorus</i>	4	5	4	4	4	4
<i>Lycopus europaeus</i>	+				+	+
<i>Lythrum salicaria</i>	1		+		+	
<i>Persicaria amphibia</i>	+				+	+
<i>Glyceria maxima</i>	+			+		
<i>Lysimachia vulgaris</i>	+			+		
<i>Veronica anagallis-aquatica</i>					1	

Tab. 49. - *Iridetum pseudacori*

Estuary	Loire	Loire	Blavet	Blavet	Charente	Charente
Site	Cordemais - Coueron	Le Pellerin - Reze	Queven - Pont Scorff	Caudan - Pont Scorff	Saint Savinien - Saintes	Le Mung - Saintes
Surface (m2)	10	10	30	10	30	10
Total cover (%)	70	100	100	90	100	80
Rel.n.	L1	L2	B1	B2	C1	C2
Species per rel.	1	3	8	8	8	2
<i>Heleocharis palustris</i>	3	3	3	2	4	4
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>			3	r	1	
<i>Galium palustre</i>			1	1	1	
<i>Persicaria amphibia</i>			+	1	+	
<i>Carex paniculata</i>			1		+	
<i>Helosciadium nodiflorum</i>			r	1		
<i>Mentha aquatica</i>					+	+
<i>Persicaria hydropiper</i>			r	+		
<i>Phalaris arundinacea</i>				+	1	
<i>Glyceria fluitans</i>		1				
<i>Glyceria maxima</i>		1				
<i>Lysimachia nummularia</i>					1	
<i>Phragmites australis</i>			+			
<i>Rorippa aquatica</i>				r		

Tab. 50. - *Eleocharito palustris* - *Oenanthe fistulosae*

Estuary	Loire	Loire	Loire	Charente	Charente	Charente
Site	Nantes - Sainte Luce sur Loire	Reze - Basse Goulaine	Basse Goulaine - Liré	Saint Savinien - Saintes	Saint Savinien - Saintes	Saint Savinien - Saintes
Surface (m2)	25	25	25	25	25	25
Total cover (%)	60	50	60	60	50	50
Rel n.	L1	L2	L3	C1	C2	C3
Progressive	1	2	3	4	5	6
Species per rel.	2	2	2	2	1	2
<i>Nunphar lutea</i>	3	2	4	4	3	3
<i>Myriophyllum spicatum</i>		+	+	+		
<i>Ceratophyllum demersum</i>	1					+
<i>Potamogeton natans</i>						+

Tab. 51. - *Nymphaeae albae*-*Nupharetum luteae*

Estuary	Charente	Charente	Charente	Charente	Charente
Site	Fontaine de Lupin - Pont suspendu	Fontaine de Lupin - Pont suspendu	Fontaine de Lupin - Pont suspendu	Fontaine de Lupin - Pont suspendu	Fontaine de Lupin - Pont suspendu
Surface (m2)	15	15	15	15	15
Total cover (%)	80	80	80	80	60
Rel n.	C1	C2	C3	C4	C5
Species per rel.	3	5	3	3	3
<i>Butomus umbellatus</i>	5	4	3	4	4
<i>Galium palustre</i>		+		+	
<i>Carex hirta</i>					+
<i>Carex riparia</i>			1		
<i>Juncus effusus</i>		1			
<i>Limniris pseudacorus</i>					+
<i>Myriophyllum aquaticum</i>	1				
<i>Persicaria amphibia</i>		+			
<i>Phalaris arundinacea</i>	+				
<i>Phragmites australis</i>			1		
<i>Potentilla anserina</i>		+			
<i>Potentilla reptans</i>				1	

Tab. 52. - *Butometum umbellati*

Estuary	Loire	Loire	Blavet	Aulne	Elorn	Elorn	Charente	Charente
Site	Le Fellerin - Reze	Montjean sur Loire - Les Ponts de Cé	Pont D224 - Ruisseau Le Frouit	Chateaulin - Rosconnec	La Forest-Landernau	Menguen - Landernau	Fontaine de Lupin - Pont suspendu	Pont suspendu - Le Mung
Surface (m2)	25	5	10	5	10	10	5	25
Total cover (%)	80	90	100	100	80	80	100	100
Rel.n.	L1	L2	B1	U1	E1	E2	C1	C2
Progressive	1	2	3	4	5	6	7	8
Species per rel.	2	2	6	4	4	5	2	11
<i>Helosciadium nodiflorum</i>	4	5	5	5	3	3	5	4
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	+				1	1	+	1
<i>Lythrum salicaria</i>			+		+	+		
<i>Phalaris arundinacea</i>			+			+		+
<i>Callitriche</i> cfr <i>stgnalis</i>			+	+				
<i>Galium palustre</i>			+	+				
<i>Juncus effusus</i>					+			1
<i>Limniris pseudacorus</i>						+		+
<i>Glyceria fluitans</i>				+				
<i>Glyceria maxima</i>								1
<i>Lycopus europaeus</i>			+					
<i>Persicaria amphibia</i>								r
<i>Persicaria hydropiper</i>								r
<i>Persicaria maculosa</i>		+						
<i>Phragmites australis</i>								+
<i>Ranunculus repens</i>								+
<i>Veronica beccabunga</i>								+

Tab. 53. - *Helosciadetum nodiflori*

Estuary	Loire	Loire	Loire	Loire	Loire
Site	Paimboeuf - Frossay	Paimboeuf - Frossay	Paimboeuf - Frossay	Cordemais - Coueron	Cordemais - Coueron
Surface (m2)	100	10	10	10	10
Total cover (%)	100	80	80	10	80
Rel.n.	L1	L2	L3	L4	L5
Species per rel.	14	6	5	2	6
<i>Myosurus minimus</i>	4	+	1	+	1
<i>Juncus bufonius</i>	r	1	+		+
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	r		3		1
<i>Poa annua</i>	+	1	+		
<i>Ranunculus sceleratus</i>	+	1			+
<i>Veronica anagallis-aquatica</i>	+	1			1
<i>Ranunculus sardous</i>	+				1
<i>Atriplex prostrata</i>	+				
<i>Cardamine parviflora</i>	+				
<i>Epilobium tetragonum</i>		+			
<i>Gnaphalium uliginosum</i>	r				
<i>Persicaria amphibia</i>			1		
<i>Persicaria maculosa</i>	+				
<i>Silene flos-cuculi</i>	r				
<i>Spergula arvensis</i>	r				
<i>Veronica persica</i>				+	
<i>Veronica serpyllifolia</i>	r				

Tab. 54. - *Ranunculo sardoi* – *Myosuretum minimi*

Estuary	Charente	Charente	Charente	Charente	Charente
Site	Pointe de la Fumée - Le petit Vergeroux	Pointe de la Fumée - Le petit Vergeroux	Fontaine de Lupin - Pont suspendu	Le petit Vergeroux - Tonmay Charente	Tonmay Charente- Saint Savinien
Surface (m2)	15	25	25	25	25
Total cover (%)	90	90	90	90	90
Rel n.	C1	C2	C3	C4	C5
Species per rel.	13	13	15	6	13
<i>Galium aparine</i>	+	+	+	+	+
<i>Smyrniium olusatrum</i>	4	5	5	5	5
<i>Geranium molle</i>		1	+	+	+
<i>Dactylis glomerata</i>	1	+	1		
<i>Daucus carota</i>		+	+		+
<i>Plantago lanceolata</i>		+	+		+
<i>Senecio vulgaris</i>	+		+		+
<i>Sonchus oleraceus</i>	+	+	+		
<i>Urtica dioica</i>		+	+		+
<i>Anisantha sterilis</i>	+		+		
<i>Artemisia verlotiorum</i>	+				+
<i>Avena cfr fatua</i>	+				+
<i>Elymus repens</i>	+	+			
<i>Jacobaea vulgaris</i>	+				+
<i>Lolium perenne</i>		+	+		
<i>Medicago arabica</i>		+	+		
<i>Picris hieracioides</i>				+	+
<i>Plantago major</i>				+	+
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>				1	
<i>Arum italicum</i> subsp. <i>neglectum</i>			+		
<i>Beta vulgaris</i> subsp. <i>maritima</i>	1				
<i>Chamaeiris foetidissima</i>			+		
<i>Foeniculum vulgare</i>	+				
<i>Geranium robertianum</i>			+		
<i>Geranium rotundifolium</i>		+			
<i>Raphanus raphanistrum</i>	+				
<i>Silybum marianum</i>					+
<i>Trifolium repens</i>		+			

Tab. 55. - *Galio aparini* - *Smyrnietum olusatri*

Estuary	Loire	Loire	Loire
Association reference	Hordeetum murinum	Sisymbrio officinalis – Hordeetum murinum	Sisymbrio officinalis – Hordeetum murinum
Site	Nantes -Oudon	Le Pellerin - Reze	Reze - Champtoceaux
Surface (m2)	10	10	10
Total cover (%)	100	80	100
Rel.n.	L1	L2	L3
Species per rel.	9	11	5
<i>Hordeum murinum</i>	4	4	4
<i>Plantago major</i>	+	1	+
<i>Poa annua</i>	1	+	1
<i>Polygonum aviculare</i>	+	+	+
<i>Potentilla reptans</i>	+	+	
<i>Senecio vulgaris</i>	+	+	
<i>Sisymbrium officinale</i>		1	1
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>		+	
<i>Cynodon dactylon</i>	+		
<i>Epilobium</i> sp.		+	
<i>Lolium perenne</i>		1	
<i>Plantago coronopus</i>	+		
<i>Sedum album</i>	+		
<i>Urtica dioica</i>		1	

Tab. 56. - *Hordeum murinum* community

Estuary	Loire	Loire	Loire	Cherante
Site	Reze - Champtoceaux	Reze - Champtoceaux	Champlocé - Angers	Le petit Vergeroux - Tonmay Charente
Surface (m2)	10	10	10	10
Total cover (%)	100	80	100	100
Rel.n.	L1	L2	L3	C1
Species per rel.	12	11	7	9
<i>Amaranthus deflexus</i>	1	1	+	2
<i>Portulaca oleracea</i>	1	+	1	+
<i>Senecio vulgaris</i>	+	1	1	1
<i>Brassica nigra</i>	1		+	+
<i>Chenopodium album</i>		+	+	+
<i>Datura inoxia</i>		1	2	1
<i>Atriplex prostrata</i>	+			+
<i>Epilobium</i> sp.	+	+		
<i>Plantago major</i>	1	1		
<i>Poa annua</i>			1	+
<i>Polygonum aviculare</i>	+	1		
<i>Cynodon dactylon</i>				1
<i>Datura stramonium</i>	1			
<i>Lolium perenne</i>		+		
<i>Persicaria maculosa</i>	+			
<i>Plantago coronopus</i>	+			
<i>Potentilla reptans</i>	+			
<i>Sisymbrium officinale</i>		+		
<i>Urtica dioica</i>		+		

Tab. 57. - *Portulaco oleraceae* – *Amarantheum deflexi*

Estuary	Loire	Loire
Site	Coueron - Nantes	Coueron - Nantes
Surface (m2)	5	5
Total cover (%)	100	100
Rel.n.	L1	L2
Species per rel.	7	7
<i>Anthriscus sylvestris</i>	3	2
<i>Arctium nemorosum</i>	1	+
<i>Dactylis glomerata</i>	+	1
<i>Elymus repens</i>	1	
<i>Heracleum spondylium</i>	+	1
<i>Malva sylvestris</i>	+	
<i>Rubus fruticosus</i> s.l.		1
<i>Rubus ulmifolius</i> s.l.		+
<i>Urtica dioica</i>	1	+

Tab. 58. - *Anthriscetum sylvestris*

Estuary	Loire	Loire	Loire
Site	Donges - Cordemais	Donges - Cordemais	Donges - Cordemais
Surface (m2)	10	10	10
Total cover (%)	80	80	80
Rel.n.	L1	L2	L3
Species per rel.	1	2	2
<i>Ranunculus sceleratus</i>	4	4	4
<i>Persicaria hydropiper</i>		+	+

Tab. 59. - *Rumici maritimi-Ranunculetum scelerati*

Estuary	Loire	Loire	Loire	Loire	Loire	Loire	Laita	Blavet	Charente	Charente	Charente	Charente	Charente
Site	Basse goulaine - Liré	Reze - Basse Goulaine	Sainte Luce sur Loire - Ancenis	Ancenis - Ingrandes	Liré - Montjean sur Loire	Montjean sur Loire - Les Ponts de Cé	Saint Julien - Pont D224	Lanester - Hennebont	Pointe de la Fumée - Le petit Vergeroux	Le petit Vergeroux - Rochefort	Pont suspendu- St. Savinien	Tommay Charente - Saintes	Rochefort - Tommay Charente
Surface (m2)	50	50	50	50	50	50	50	50	50	50	50	50	50
Total cover (%)	100	100	100	100	100	100	100	100	100	100	100	100	100
Rel.n.	L9	L10	L11	L12	L13	L14	A1	B1	C1	C2	C3	C3	C4
Progressive	1	2	3	4	5	6	7	8	9	10	11	12	13
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	2	3	1	1	2	+	+	+	+	+	1	+	1
<i>Convolvulus arvensis</i>		1	+	+	+	+	+	+	1	+	+	+	1
<i>Elymus repens</i>	2	2	1	3	1	2	1	1	2	1	1		2
<i>Lolium perenne</i>	1	2	4	2	1	4	3	2	3	1	2		3
<i>Plantago lanceolata</i>	+		1	1	1	1	1	+	+	1	1	2	+
<i>Dactylis glomerata</i>		1		1		+	1	1	+		+		
<i>Deschampsia flexuosa</i>		+			1		+	2	+			1	+
<i>Fraxinus excelsior</i>	+	+		+	1		+			+	+		
<i>Plantago major</i>			+	+				+	+	+	+	+	
<i>Phalaris arundinacea</i>	+		1		+					+	+	1	
<i>Taraxacum officinale</i>				1	+	+	+			1		1	
<i>Atriplex prostrata</i>	+						+	+	+		+		
<i>Daucus carota</i>		+		+			+		+	+			
<i>Juncus inflexus</i>		+				+		1	+		+		
<i>Lotus corniculatus</i>			1	+	+	+			+				
<i>Picris hieracioides</i>			+	+		+				+	+		
<i>Rumex acetosella</i>	r			+	+		+					1	
<i>Urtica dioica</i>			+		+		+			1		1	
<i>Calystegia sepium</i> var. <i>sepium</i>		+			+		+	+					
<i>Capsella bursa-pastoris</i>		+		+						+			+
<i>Oenanthe crocata</i>			+				+				1	+	
<i>Althaea officinalis</i>	+							+	+				
<i>Cynodon dactylon</i>	2									+		+	
<i>Plantago coronopus</i>									+		1	+	
<i>Rumex conglomeratus</i>	+				+		+						
<i>Beta vulgaris</i>								+			2		
<i>Foeniculum vulgare</i>		+		+									
<i>Lactuca saligna</i>		+		+									
<i>Phragmites australis</i>								+			1		
<i>Symphyotrichum novi-belgii</i>	+										+		
<i>Trifolium repens</i>												+	1
<i>Eringium campestre</i>				+									
<i>Xanthium strumarium</i>	+												
<i>Raphanus raphanistrum</i> subsp. <i>landra</i>											+		
<i>Ulex europaeus</i>							+						

Tab. 60. - *Convolvulo arvensis* – *Elytrigietum repentis*

Estuary	Loire	Loire	Loire	Loire	Laita	Blavet	Charente	Charente	Charente
Site	Coueron - Nantes	St. Nazaire - Donges	Donges - Coueron	Frossay - Le Pellerin	Saint Julien - Pont D224	Lanester - Hennebont	Pointe de la Fumée - Le petit Vergeroux	Le petit Vergeroux - Rochefort	Rochefort - Tonmay Charente
Surface (m2)	5	5	5	5	5	5	5	5	5
Total cover (%)	80	80	80	80	80	80	80	80	80
Rel.n.	L1	L2	L3	L4	A1	B1	C1	C2	C3
Progressive	1	2	3	4	5	6	7	8	9
Species per rel.	4	3	3	5	4	4	5	3	4
<i>Plantago coronopus</i>	1	1	2	+	2	1	1	+	2
<i>Poa annua</i>	2	1	2	3	2	2	2	4	2
<i>Polygonum aviculare</i>	+			1	+	1	1	+	+
<i>Senecio vulgaris</i>		1	+	+	+	+	+		
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	1			+			+		+

Tab. 61. - *Poo annuae* – *Plantaginetum coronopodis*

Estuary	Blavet	Blavet	Blavet	Aulne
Site	Lorient - Pont Scorf	Lanester - Pont Scorf	Pont D194 - Hennebont - Tommay Charente	Rosconec - Chateaulin
Surface (m2)	50	50	50	50
Total cover (%)	100	100	100	100
Rel.n.	C3	C3	C4	A1
Taxa per rel.	15	9	5	9
<i>Pteridium aquilinum</i>	4	4	5	5
<i>Daucus carota</i>		+	+	+
<i>Fraxinus excelsior</i>	+	+		+
<i>Holcus mollis</i>	1	1	1	
<i>Lolium perenne</i>	1	+	1	
<i>Agrostis stolonifera</i> var. <i>stolonifera</i>	+			1
<i>Dactylis glomerata</i>	+			1
<i>Juncus inflexus</i>	+			1
<i>Plantago lanceolata</i>	+	1		
<i>Taraxacum officinale</i>	+			+
<i>Ulex europaeus</i>		1		+
<i>Urtica dioica</i>	+			+
<i>Calystegia sepium</i> var. <i>sepium</i>		+		
<i>Deschampsia flexuosa</i>	+			
<i>Elymus repens</i>	+			
<i>Oenanthe crocata</i>	1			
<i>Rubus ulmifolius</i> s.l.			+	
<i>Rumex acetosella</i>	+			
<i>Rumex conglomeratus</i>		+		
<i>Trifolium repens</i>	+			

Tab. 62. - *Holco mollis* – *Pteridietum aquiline*

Estuary	Loire	Loire	Charente
Site	Montjean sur Loire - Les Ponts de Cé	Ingrandes - Angers	St. Savinien - Saintes
Surface (m2)	50	50	50
Total cover (%)	100	100	100
Rel.n.	C3	C3	A1
Taxa per rel.	23	10	17
<i>Dactylis glomerata</i>	+	+	1
<i>Fraxinus excelsior</i>	+	+	+
<i>Holcus lanatus</i>	+	+	+
<i>Prunus spinosa</i>	+	1	1
<i>Torilis japonica</i>	3	2	3
<i>Trigonella alba</i>	+	1	+
<i>Urtica dioica</i>	+	1	1
<i>Daucus carota</i>	+		+
<i>Elymus repens</i>	1		+
<i>Galium aparine</i>	1		1
<i>Geum urbanum</i>	+		+
<i>Glechoma hederacea</i>	+		+
<i>Hedera helix</i>	+		1
<i>Heracleum spondylium</i>	1		1
<i>Hodeum murinum</i>	+		+
<i>Plantago lanceolata</i>	1		+
<i>Rubus fruticosus</i> s.l.		+	+
<i>Anisantha sterilis</i>	+		
<i>Geranium dissectum</i>	+		
<i>Lolium perenne</i>	+		
<i>Oenanthe crocata</i>	+		
<i>Parietaria judaica</i>	+		
<i>Phalaris arundinacea</i>	+		
<i>Poa trivialis</i>	+		
<i>Ranunculus acris</i>		+	
<i>Taraxacum officinale</i>		+	

Tab. 63. - *Torilidietum japonicae*

5.4. Synphytosociology and Geosynphytosociology

5.4.1. Series description

We described series in large sense, grouping all the same associations related in time and spaces to the same geographical and ecological homogenous surfaces (Tessella or Sigmata). We called each series following the head series association. In case of special associations or special series linked to environmental exception (depressions, outcrops, salt or water intrusions...) we linked this series to the main series; especially because their cover is negligible in surface if compared to the others. When in other hand we have some series close and with same or similar ecological features, with an important surface to share (one association is definitively dominating and others are all on negligible surfaces) we considered them as geoseries s.l. Each series, according to the ecological compartment analysis are characterized by some variants; especially an upper and lower type, defined by the salty, water or topography gradients.

The geopermasigmata (or geopermaseries) were named following the most representative association (between the head series ones) in surface and ecology.

The order of synassociation presentation follows the salty vegetation to the forest vegetation, from the wettest to the driest point. At the end, we present the aquatic vegetation (geopermaseries and the corresponding division in salty, brackish and freshwater sections in plant mapping)

The plant association presence composition of our series is often similar, even common in β -biodiversity between series, for that reason is very useful to group them in geo series or linked associations as possible.

The most differential factors that allow us to distinguish the described series are mostly the head series or potential association, and the composition and coverage assembly of the serial associations.

As example *Scirpetum maritimi* and *Phragmitetum vulgaris* (even in its saltier facies) are present all along the estuaries from the salty to the oligohaline portion, but the optimum zone is between the Polyhaline to the Mesohaline portion. *Elymus athericus* is more linked to the salty zones with an optimum between the Euhaline to the Polyhaline, rarer to the Mesohaline. *Halimione portulacoides* has its optimum in similar way but it can develop within the *Scirpetum maritimi* or the *Phragmitetum vulgaris* till the Mesohaline portion. *Salix fragilis* (as species and community) is possible to be found scattered also in some other series, and *vice versa* for *Salix Alba*, *S. Atrociniera*, and for *Fraxinus* species; however, its highest concentration and representativeness is for the related described series. *Salix fragilis* has also a particular status of critical species and poliphytic because very and easily hibridizable and polymorphic (TRIEST *et al.*, 1998) with a wide range of intermediate forms, till to be even hard to distinguish it from the *Salix alba*, or other related species; and also with some forms that not corresponds to the ones described in bibliography. The *Salix alba* and *Salix fragilis* community could even share the same habitats creating a *Salicetum albo fragilis* (Tüxen *ex Moor* 1958) but considered as synonym of *Salicetum albae* (NEUHÄUSLOVÁ & DOUDA, 2013). Ruderal communities does not appear differential in any way, being present in any series following only the human impact. The neo-formation of shrubs *Solano dulcamarae* - *Tamaricetum gallicae* and *Hedero helicis* - *Atriplicetum halimi* resulted useful to discriminate more stalty series, togheder with the *Oenante* species meadows from the *Potentillo anserinae* – *Polygonetalia avicularis* and *Deschampsietalia cespitosae*.

1) *Atriplici prostratae -Elymeto atherici* geopermasigmetum

Diagnosis

Geopermaseries halophilic and sub-halophilic of salt marshes and meadows from eastern French Atlantic estuaries, characterized by *Elymus athericus*

Synphysiognomy

Physiognomy of the characteristic association:

Atriplici prostratae -Elymetum atherici; corresponding to a dense wide grassland dominated by *Elymus athericus*.

Floristic characteristic composition:

Elymus athericus and *Atriplici prostrata*

Physiography and catenal placement:

Landscape characterization:

Salty marshes (muds and meadows) from the slikke to the Schorre. Even in the larger estuarine bed.

Vegetation contacts:

In lower position we have the estuarine algal community; in upper position, in a complete zonation we have the *Salix atrocinerea* estuarine forest groupment.

Ecology

Dominant soil type:

Silty and sandy riparian steps.

Bioclimate:

average thermotype - mesotemperate;

average ombrotype - subhumid.

Chorology

This geopermaseries is frequent in all the studies estuaries, from the salty to brackish sector.

Phytocoenotic composition

This geopermaseries is characterized by a lowest level of *Spartina* sp. pl. and *Salicornia* sp. pl. associations. Upper is characterized mainly by the *Bostrychio scorpioidis-Halimionetum portulacoidis* and upper by grassland (i.e.: *Scirpetum maritimi*, *S. triquetri*, *S. tabernaemontani*) or reed bed (i.e.: *Astero tripolii - Phragmitetum australis*) associations or *Atriplici prostratae -Elymetum atherici*, depending on humidity and soil uses variations. We can make some facies following the salt sectors. Between the Euhaline to Polyhaline portion, the Halophytes presence is more remarkable. Between Mesohaline to Oligohaline, we have less species and fewer communities. In general, these communities corresponds to the same that we can find in upper portions (Schorre) from the saltiest sector; they are composed from the more tolerant and wider ecological amplitude plants, that could tolerate strong salt and freshwaters influences. We can observe some residual formation ascribable to this geopermaseries in lower

Oligohaline portion, generally on the main channel borders or in saltiest soils patches (especially in summer) that generally appear as linear or punctual or in a mosaic distribution. These communities are generally simplified or paucispecific, characterized mainly by *Bolboschoenus maritimus*, *Schoenoplectus triqueter*, *S. tabernaemontani* and *Eleocharis bonariensis*. Generally they potentially are under Willows or *Fraxinus* forest canopy cover and they could be mapped only in very detailed portions, represented at large scale (< 1: 1000).

The geopermaseries is formed mainly by these associations: *Salsolo kali-Suaedetum maritimae*, *Salicornietum dolychostachyae*, *Agropyro pungentis-Suaedetum verae*, *Puccinellio maritimae*, *Salicornietum ramosissimae*, *Salicornietum obscurae*, *Spartinetum alterniflorae*, *Salicornietum fragilis*, *Spartinetum anglicae*, *Spergulario mediae* – *Salicornietum brachystachyae*, *Salicornietum disarticulato-ramosissimae*, *Beto maritimae* - *Agropyretum pungentis*, *Puccinellietum maritimae*, *Bostrychio scorpioidis-Halimionetum portulacoidis*, *Limonietum lychnidifolii-dodartii*, *Ruppium maritimae*, *Zannichellietum obtusifoliae*, *Atriplici hastatae* - *Betetum maritimae*, *Junco maritimi-Schoenetum nigricantis*, *Limonietum lychnidifolii-dodartii*, *Oenanthe peucedanifoliae-Brometum racemose*, *Parapholis strigosae-Hordeetum marini*, *Spartinetum maritimae*, *Typho domingensis-Phragmitetum maximi*, *Cochleario anglicae* - *Plantaginetum maritimae*, *Triglochino maritimi* - *Limonietum humilis*, *Oenanthe lachenalii* - *Juncetum maritime*, *Plantagini maritimae-Limonietum vulgaris*, *Astero tripolii* - *Phragmitetum australis*, *Junco maritimi-Caricetum extensae*, *Silybo mariani-Urticetum piluliferae*, *Gratiolo officinalis* - *Oenanthetum fistulosae*, *Ranunculetum ophioglossifolii*, *Ranunculo ophioglossifolii* — *Oenanthetum fistulosae*, *Scirpetum triquetri*, *Apio nodiflori* – *Eleocharitetum amphibiae*, *Senecioni aquatici* - *Oenanthetum mediae*, *Ranunculetum baudotii*, *Trifolio maritimi*- *Oenanthetum silaifoliae*, *Festuco littoralis-Juncetum gerardii*, *Agropyro pungentis-Inuletum crithmoidis*, *Hordeo secalini* - *Lolietum perennis*, *Beto maritimae-Atriplicetum prostratae*, *Astero tripolium-Agrostietum stoloniferae*, *Festucetum littoralis*, *Juncetum gerardii*, *Astero tripolii* – *Phragmitetum australis*, *Astero tripolium-Suaedetum maritimae*, *Beto maritimae-Raphanetum landrae*, *Scirpetum maritime*, *Atriplici hastatae-Agropyretum repentis*, *Atriplici prostratae* - *Elymetum atherici*. At lowest level in the series belong also some algal communities like the maerl and the “amphibian” tidal algal bed (mainly *Fucus* and *Pelvetia* sp. pl.).

The *Atriplici prostratae* - *Elymeto atherici* geopermasigmetum (or geopermaseries) was called following the *Atriplici prostratae* - *Elymetum atherici* association because it resulted the most representative in surface in studied estuaries. The salty mud and meadows *Tessella* (*Atriplici prostratae* - *Elymeto atherici* geopermasigmetum) is characterized by a lower level richer in *Galatella pannonica*, *Sueda*, *Spartina* and *Salicornia* species, while the upper level is more characterized by *Scirpus maritimus*, *Scirpus triqueter*, *Scirpus tabernaemontani*, *Phragmites australis* (in wettest points) or *Elymus athericus*, *Raphanus raphanistrum*, *Beta vulgaris* subsp. *maritima*, and *Atriplex hastata* (in driest portions).

After disturbance (natural or artificial), this geopermaseries tend to open versus bare substrate, especially in the lower level. Human impact in this geopermaseries tends also to get opportunity for exotic species colonization (i.e.: *Spartina alterniflora* and hybrids). From the *Halimione portulacoides* level to up, the disturbance (i.e: sediment swing, pasture or human trampling) cause the rarefaction of this community in favour of grasslands (mainly from *Puccinellia* species, *Juncus gerardii*, *Agrostis stolonifera*, and even *Festuca rubra*

aggregatum). In highest and moist levels, the vegetation is dominated by *Scirpus maritimus* and *Phragmites vulgaris* (roselière) but after mowing or pasture, we can have some grasslands in substitution. Generally, they are some associations characterized by the presence of some *Oenanthe* species. If the soil use impact increases this community opening (less cover) and they tend to be paucispecific, dominated by *Juncus* species, *Agrostis stolonifera* and others basal species that generally have a larger ecological spectrum and a wider environmental tolerance. In sandier, draining condition, the dominant vegetation is mainly represented by the *Atriplici prostratae* -*Elymetum atherici*, with a remarkable presence of beaches and dunes species. The contact vegetation also influences some variation. The influence (transgression) of dune species increase if the banks are sandy or if some (embryonal) dunes or bars are in contact (i.e.: *Asparagus* species, *Calystegia soldanella*, *Cakile maritima*, *Dactylis glomerata*, *Daucus carota*, *Eryngium campestre*, *E. maritimum*, *Foeniculum vulgare*, *Jacobaea vulgaris*, *Lagurus ovatus*...). In sandy, but less draining condition we have some dune slacks influence and contacts, with a more remarkable presence of *Juncus gerardii*, *J. maritimus*, *Schoenus nigricans*, *Puccinellia maritima*, *Lysimachia maritima*, *Hydrocotyle vulgaris*, *Oenanthe lachenalii*, *Apium graveolens*, *Festuca rubra*, *Carex arenaria*, *Samolus valerandi*, mixing with typical species of slikke, Schorre and upper “salt” marshes (under greater salt influence) or together with “freshwater” marsh species (under less salt influence). This then leave place to the real dune vegetation or the real dune slacks vegetation, out of estuarine dynamics. In the estuarine sandy places, it is more possible to find meadows rich in *Limonium* species. In rocky places and outcrops within this series and association, we can find mixing some species linked to this geomorphological feature, as is the case of *Crithmum maritimum*, *Limbarda crithmoides*, *Silene uniflora*, *Spergularia media*, *Armeria maritima*... These species could be found also in sandy conditions mixed with the others. These two levels are generally not affected by tides (if not in their lower portion, by exceptional events), but in any case they are fully influenced and determined by the estuarine coastal influence – for that reason we linked all to the same geopermaseries under some facies that follows the various geomorphology differences that they could be clearly represented till the middle estuary. Upstream the rocky outcrops and soil cliffs vegetation is gradually replaced by inland vicariant species like *Umbilicus rupestris*, *Sedum* species (more represented here) and rocky ferns.

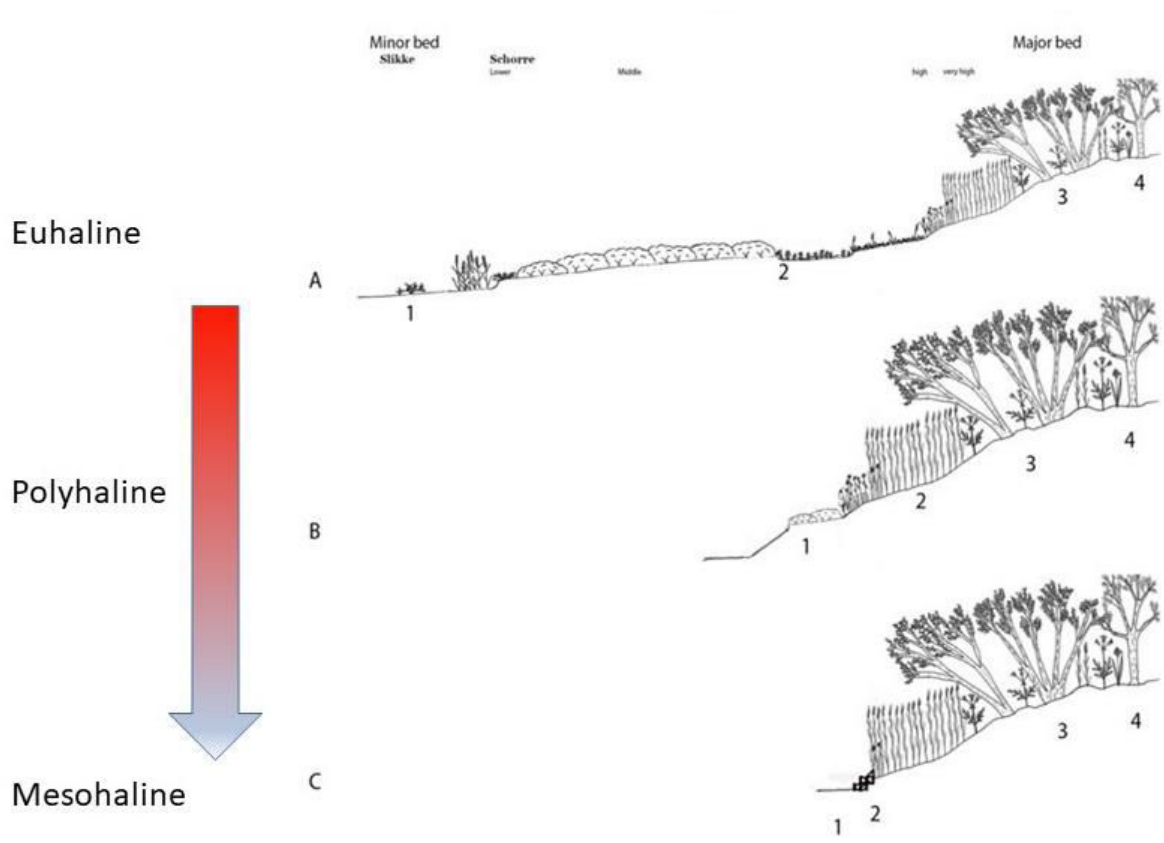


Figure 37. - From 1 to 2 we observe our geopermaseries distribution before the forests in upper levels (3 and 4); within the salt cline (down-up) and the minor to major estuarine-bed cline (right o the left) variations.

In this scheme we can observe the expected ideal differentiation and variations within the three different ecological compartment. In real (mainly between eu- and poly- haline sectors) we have not found any real difference of vegetation if not determined by lateral freshwater accession or by substrate and other geomorphology exceptions. Moving from the Salty to the upper mesohaline portion we observe a simplification in β -biodiversity of our geopermaseries due to the fact that there is also a diminution in species number presence, because the halophytes gradual disappearing in favor of species with a larger ecological elasticity and tolerance (freshwater and salt tolerant species).

2) *Salix atrocinerea* forests geosigmetum

Diagnosis

Geoseries oligo-halotolerant and fresh-waters, of estuarine riparian forests from eastern French Atlantic estuaries, characterized by *Salix atrocinerea*

Synphysiognomy

Physiognomy of the characteristic association:

moist soft woody community corresponding to a megaphorb holigohaline and freshwater herbaceous layer, with a *Salix atrocinerea* dominated forest layer.

Floristic characteristic composition:

Salix atrocinerea, *Oenanthe crocata*, *Limniris pseudacorus*, *Phalaris arundinacea*, *Phragmites vulgaris*, *Scirpus maritimus*, *Scirpus triqueter*, *Calystegia sepium*.

Physiography and catenal placement:

Landscape characterization:

large estuarine bed from riparian to marshy conditions.

Vegetation contacts:

In lower position we have the geopermaseries of salty and sub-salty mud and meadows;

In upper position, in a complete zonation we have the *Fraxinus excelsior* forest groupment

Ecology

Dominant soil type:

Silty riparian and marshy.

Bioclimate:

average thermotype - mesotemperate;

average ombrotype - subhumid.

Chorology

This geopermaseries is frequent in all the studies estuaries, from the salty to brackish sector.

Phytocoenotic composition

This geopermaseries is characterized by a forest marshy community in head series, in substitutional level there are typically, reed bed (*Phragmitetum vulgaris*) grasslands (*Scirpetum maritimae*, *S. triquetri*, *S. taberneamontani*; megaphorb communities, *Carex* communities, and *Oenanthe* sp. pl. humid pastures (mainly from the *Agrostietea Stoloniferae* associations, depending on humidity and soil uses variations. We reattached to this series also the *Epipactido palustris* – *Salicetum atrocinereae* as occasional and punctual presence on marshy sandy draining soils. We find evidence of this association in Aulne, Ruisseau de la baie des Trépassés and lowest Étrel estuaries. We found similar potentiality but for decalcified soils vicariant form, up in Étrel and lower in Aulne (if compared to previous examples of non-decalcified) positions. Generally, this association is coastal –for dune slacks, but it is not to be excluded the

possibly to find it also inland, in marshy sandy draining positions, as is the case of Loire sand alluvial plain.

Following the secondary succession, in the Tessella from grasslands to forest steps we find:

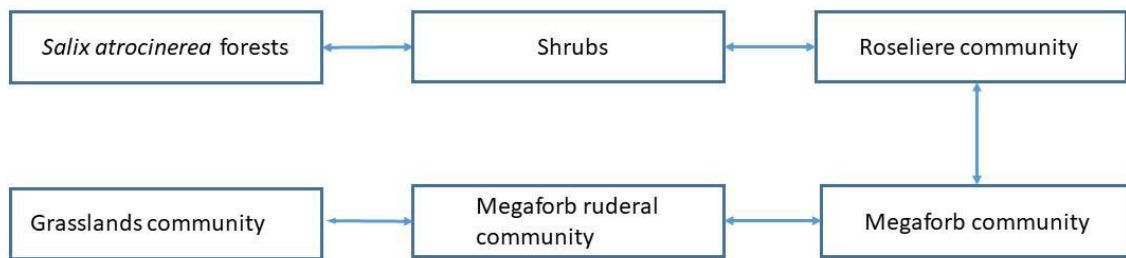


Figure 38. - Physiognomic phytodynamic simplified scheme of the *Salix atrocinerea* forest community.

In this physiognomic phytodynamic scheme we can observe the stages from the forest to the grassland community (Up to down) in substitution, and vice versa (Down up): according to the following list of associations. It is possible to go from one block to another by jumping various stages as a result of environmental or anthropic pressure. From each block is possible to pass to any other, in secondary succession or degeneration/regression directions. If the changes are gradual, ideally the scheme is respected, according to the ecology, behavior, and the biomass development (facilitation or competition phenomena) of the communities present in the various blocks.

- Grasslands community

Gratiolo officinalis - Oenanthe fistulosae, Ranunculo ophioglossifolii — Oenanthe fistulosae, Senecioni aquatici - Oenanthe media, Dactylis glomerata and Daucus carota meadows, Oenanthe peucedanifoliae-Brometum racemose, Heracleo sphondylii-Brometum mollis, Poo annuae – Plantaginetum coronopodis Alopecuro pratensis — Cynosuretum cristati, Convolvulo arvensis – Elytrigietum repentis, Trifolio maritimi- Oenanthe silaifoliae, Festucetum littoralis, Atriplici prostratae -Elymetum atherici, Atriplici hastatae-Agropyretum repentis, Lolio perennis - Plantaginetum majoris, Pulicario dysentericae — Juncetum inflexi, Cirsio palustris — Juncetum effusi, Junco acutiflori — Cynosuretum cristati, Hordeo secalini - Lolietum perennis, Hordeetum murinum, Dactylis glomerata and Daucus carota meadows, Juncus effusus and Agrostis stolonifera meadows.

About grasslands, more the pasture is intensive or more the soil is trampled and more can observe a ruderalization, a simplification and an opening of the soil surface. Last communities (the simplest ones) are consisting in *Agrostis stolonifera, Glyceria fluitans, Cirsium palustris, C. arvensis, G. maxima, Juncus effusus, J. inflexus* and other *Juncus* species

- Megaforb ruderal community

Silybo mariani-Urticetum piluliferae, Galio aparini - Smyrnetum olusatrum, Portulaco oleraceae – Amaranthetum deflexi, Melilotetum albo – officinalis, Sisymbrio officinalis – Hordeetum murinum, Torilidetum japonicae, Heracleo sphondylii - Rumicetum obtusifolii, Apio nodiflori – Eleocharitetum amphibiae, Ranunculo sardoii – Myosuretum minimi, Persicario hydropiperis - Bidentetum tripartitae, Urtico dioicae - Convolvuletum sepium, Beta maritima-Raphanetum landrae.

- Megaforb community

Valeriano officinalis - *Filipenduletum ulmariae*, *Filipendulo ulmariae* – *Alnetum glutinosae*
Sambucetum ebuli, *Lysimachio vulgaris*-*Filipenduletum ulmariae*, *Arctio lappae* -
Artemisietum vulgaris, *Helosciadetum nodiflori*, *Epilobio hirsuti* - *Convolvuletum sepium*
Holco mollis – *Pteridietum aquilini*, *Ranunculetum ophioglossifolii*, *Calystegio sepium*-
Angelicetum heterocarpae, *Rumici maritimi*-*Ranunculetum scelerati*.

- Roselières community

Cypero longi-*Caricetum otrubae*, *Sparganietum erecti*, *Typhetum angustifolii* *Typhetum*
latifoliae, *Caricetum ripariae*, *Caricetum acutiformis*, *Scirpetum lacustris*, *Caricetum ripario* –
acutiformis, *Caricetum acutiformis*, *Eleocharito palustris* - *Oenanthetum fistulosae*
Glycerietum maximae, *Rorippo sylvestris* – *Phalaridetum arundinaceae*,
Dactylido glomeratae - *Festucetum arundinaceae*, *Iridetum pseudacori*, *Phalaridetum*
arundinaceae, *Cochleario aestuarii* – *Scirpetum compacti*, *Junco maritimi*-*Schoenetum*
nigricantis, *Schoenoplectetum tabernaemontani*, *Astero tripolii* – *Phragmitetum australis*,
Scirpetum maritimi, *Phragmitetum communis*.

- Shrubs

Ulici europaei-*Prunetum spinosae* represent the most common natural shrub association in
substional stages, while *Hedero helicis* - *Atriplicetum halimi*, *Solano dulcamarae* -
Tamaricetum gallicae represent the neophytic formation, mainly abandoned or old established
hay.

In marshy areas, where this community could reach a mature development we observe that *Salix*
atrocinerea employ a special strategy of surface colonization. When it reaches a good
dimension it tends to open its polycormon, dressing one or more trunks that continue to grow
and reiterate in some direction spreading the community also where other trees cannot root for
long time (for excessive water presence, salt or anoxic conditions) making a sort of curtain
where trees are not really radicate but just covering with an understory of a normal forest. After
the natural burial if condition is favorable the trunks starts a normal offshoot radication. Same
phenomena but without any radication possibility occurs with *Fraxinus* and *Quercus robur*, that
lay down slowly the branches touching the waters, and in salty portion when they go down to
the tidal waters the leaves and branches are burned by the salt, making a natural pruning of
branches: linearly and all at the same level creating a special “barber aspect” of this curtain of
these forest formations. This curtain often covers the upper belt of the *Atriplici prostratae* -
Elymeto atherici geopermasigmetum opening the upper cenosis that become less dense but
richer in species: creating another special variation within this geopermaseries.

Ecological range (Salinity compartment) Geopermsynecle number Date Site range Surface (ha) Total phanerogamic recovery (%) Average exposition Syntax number Average altitude range (m a.s.l.)	PROGRESSIVE																																																																																																																			Freq. Abs.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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18	O1019	O1020	O1021	O1022	O1023	O1024	O1025	O1026	O1027	O1028	O1029	O1030	O1031	O1032	O1033	O1034	O1035	O1036	O1037	O1038	O1039	O1040	O1041	O1042	O1043	O1044	O1045	O1046	O1047	O1048	O1049	O1050	O1051	O1052	O1053	O1054	O1055	O1056	O1057	O1058	O1059	O1060	O1061	O1062	O1063	O1064	O1065	O1066	O1067	O1068	O1069	O1070	O1071	O1072	O1073	O1074	O1075	O1076	O1077	O1078	O1079	O1080	O1081	O1082	O1083	O1084	O1085	O1086	O1087	O1088	O1089	O1090	O1091	O1092	O1093	O1094	O1095	O1096	O1097	O1098	O1099	O1100	O1101	O1102	O1103	O1104	O1105	O1106	O1107	O1108	O1109	O1110	O1111	O1112	O1113	O1114	O1115	O1116	O1117	O1118	O1119	O1120	O1121	O1122	O1123	O1124	O1125	O1126	O1127	O1128	O1129	O1130	O1131	O1132	O1133	O1134	O1135	O1136	O1137	O1138	O1139	O1140	O1141	O1142	O1143	O1144	O1145	O1146	O1147	O1148	O1149	O1150	O1151	O1152	O1153	O1154	O1155	O1156	O1157	O1158	O1159	O1160	O1161	O1162	O1163	O1164	O1165	O1166	O1167	O1168	O1169	O1170	O1171	O1172	O1173	O1174	O1175	O1176	O1177	O1178	O1179	O1180	O1181	O1182	O1183	O1184	O1185	O1186	O1187	O1188	O1189	O1190	O1191	O1192	O1193	O1194	O1195	O1196	O1197	O1198	O1199	O1200	O1201	O1202	O1203	O1204	O1205	O1206	O1207	O1208	O1209	O1210	O1211	O1212	O1213	O1214	O1215	O1216	O1217	O1218	O1219	O1220	O1221	O1222	O1223	O1224	O1225	O1226	O1227	O1228	O1229	O1230	O1231	O1232	O1233	O1234	O1235	O1236	O1237	O1238	O1239	O1240	O1241	O1242	O1243	O1244	O1245	O1246	O1247	O1248	O1249	O1250	O1251	O1252	O1253	O1254	O1255	O1256	O1257	O1258	O1259	O1260	O1261	O1262	O1263	O1264	O1265	O1266	O1267	O1268	O1269	O1270	O1271	O1272	O1273	O1274	O1275	O1276	O1277	O1278	O1279	O1280	O1281	O1282	O1283	O1284	O1285	O1286	O1287	O1288	O1289	O1290	O1291	O1292	O1293	O1294	O1295	O1296	O1297	O1298	O1299	O1300	O1301	O1302	O1303	O1304	O1305	O1306	O1307	O1308	O1309	O1310	O1311	O1312	O1313	O1314	O1315	O1316	O1317	O1318	O1319	O1320	O1321	O1322	O1323	O1324	O1325	O1326	O1327	O1328	O1329	O1330	O1331	O1332	O1333	O1334	O1335	O1336	O1337	O1338	O1339	O1340	O1341	O1342	O1343	O1344	O1345	O1346	O1347	O1348	O1349	O1350	O1351	O1352	O1353	O1354	O1355	O1356	O1357	O1358	O1359	O1360	O1361	O1362	O1363	O1364	O1365	O1366	O1367	O1368	O1369	O1370	O1371	O1372	O1373	O1374	O1375	O1376	O1377	O1378	O1379	O1380	O1381	O1382	O1383	O1384	O1385	O1386	O1387	O1388	O1389	O1390	O1391	O1392	O1393	O1394	O1395	O1396	O1397	O1398	O1399	O1400	O1401	O1402	O1403	O1404	O1405	O1406	O1407	O1408	O1409	O1410	O1411	O1412	O1413	O1414	O1415	O1416	O1417	O1418	O1419	O1420	O1421	O1422	O1423	O1424	O1425	O1426	O1427	O1428	O1429	O1430	O1431	O1432	O1433	O1434	O1435	O1436	O1437	O1438	O1439	O1440	O1441	O1442	O1443	O1444	O1445	O1446	O1447	O1448	O1449	O1450	O1451	O1452	O1453	O1454	O1455	O1456	O1457	O1458	O1459	O1460	O1461	O1462	O1463	O1464	O1465	O1466	O1467	O1468	O1469	O1470	O1471	O1472	O1473	O1474	O1475	O1476	O1477	O1478	O1479	O1480	O1481	O1482	O1483	O

Saliceto fragilis sigmetum

Diagnosis

Holoserries meso and oligo halotolerant of estuarine riparian forests from eastern French Atlantic estuaries, characterized by *Salix fragilis*

Synphysiognomy

Physiognomy of the characteristic association:

moist soft woody groupment corresponding to a megaphorb holigohaline and freshwater herbaceous layer, with a *Salix fragilis* dominated forest layer.

Floristic characteristic composition:

Salix fragilis, *Oenanthe crocata*, *Limniris pseudacorus*, *Phalaris arundinacea*, *Phragmites vulgaris*, *Scirpus maritimus*, *Scirpus triqueter*.

Physiography and catenal placement:

Landscape characterization:

large estuarine bed from riparian to marshy conditions.

Vegetation contacts:

In lower position we have the geopermaseries of salty and sub-salty mud and meadows;

In upper position, in a complete zonation we have the *Fraxinus excelsior* forest groupment

Ecology

Dominant soil type:

Silty or sandy riparian and marshy.

Bioclimate:

average thermotype - mesotemperate;

average ombrotype - subhumid.

Chorology

This geopermaseries is more frequent in estuaries south to the Laïta.

Phytocoenotic composition

This geopermaseries is characterized by a forest community in head series, in substitutional level there are typically, reed bed (*Phragmitetum vulgaris*) grasslands (*Scirpetum maritimi*, *S. triquetri*, *S. taberneamontani*; megaphorb communities, *Carex* communities, and *Oenanthe* sp. pl. humid pastures (mainly from the *Agrostietea Stoloniferae* associations, depending on humidity and soil uses variations. At the shrub level, in the driest portions we can find more commonly the *Solano dulcamarae* - *Tamaricetum gallicae* (in more anthropogenic surfaces) and the *Ulici europaei-Prunetum spinosae*; the *Salicetum triandro-viminalis* and *Salicetum purpureae* in less salty and wettest portions.

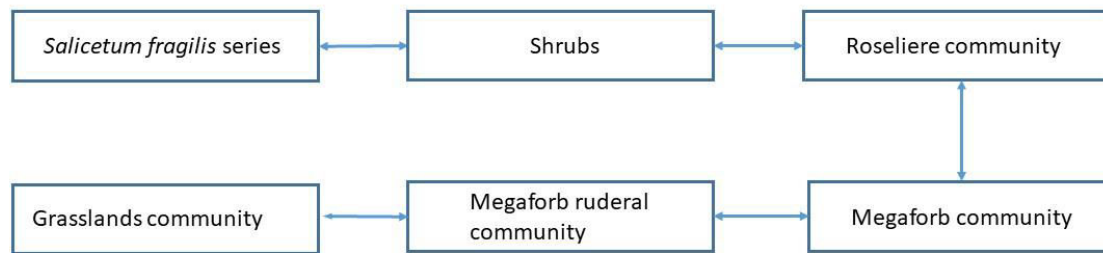


Figure 39. - Physiognomic phytodynamic simplified scheme of the *Salicetum fragilis* series

In this physiognomic phytodynamic scheme we can observe the stages from the forest to the grassland community (Up to down) in substitution, and vice versa (Down up): according to the following list of associations. It is possible to go from one block to another by jumping various stages because of environmental or anthropic pressure. From each block it is possible to pass to any other, in secondary succession or degeneration/regression directions. If the changes are gradual, ideally the scheme is respected, according to the ecology, behavior, and the biomass development (facilitation or competition phenomena) of the communities present in the various blocks.

Following the secondary succession, in the Tessella from grasslands to forest steps we find:

- Grasslands community

Ranunculetum ophioglossifolii, *Gratiolo officinalis* - *Oenanthe fistulosae*, *Ranunculo sardo* - *Myosuretum minimi*, *Ranunculo ophioglossifolii* - *Oenanthe fistulosae*, *Trifolium maritimi* - *Oenanthe silaifoliae*, *Eleocharito palustris* - *Oenanthe fistulosae*, *Juncus acutiflori* - *Cynosuretum cristati*, *Cirsio palustris* - *Juncetum effuse*, *Pulicario dysentericae* - *Juncetum inflexi*, *Oenanthe peucedanifoliae* - *Brometum racemose*, *Senecioni aquatici* - *Oenanthe mediae*, *Poa annuae* - *Plantaginetum coronopodis*, *Alopecuro pratensis* - *Cynosuretum cristati*, *Convolvulo arvensis* - *Elytrigietum repentis*, *Heracleo sphondylii* - *Brometum mollis*, *Hordeetum murinum*, *Hordeo secalini* - *Lolietum perennis*, *Lolio perennis* - *Plantaginetum majoris*, *Dactylis glomerata* and *Daucus carota* meadows, *Juncus effusus* and *Agrostis stolonifera* meadows

- Roselières community

Caricetum ripariariae, *Caricetum ripario* - *acutiformis*, *Caricetum acutiformis*, *Typhetum angustifolii*, *Apio nodiflori* - *Eleocharitetum amphibiae*, *Typhetum latifoliae*, *Glycerietum maximae*, *Iridetum pseudacori*, *Dactylido glomeratae* - *Festucetum arundinaceae*, *Scirpetum maritime*, *Phalaridetum arundinaceae*, *Phragmitetum communis*

- Megaforb ruderal community

Galio aparini - Smyrnetum olusatrum, Arctio lappae - Artemisietum vulgaris, Epilobio hirsuti - Convolvuletum sepium, Torilidetum japonicae, Anthriscetum sylvestris, Heracleo sphondylii - Rumicetum obtusifolii, Rumici maritimi-Ranunculetum scelerati, Silybo mariani-Urticetum piluliferae, Sisymbrio officinalis – Hordeetum murinum, Urtico dioicae - Convolvuletum sepium.

- Megaforb community

Holco mollis – Pteridietum aquilini, Calystegio sepium-Angelictum heterocarpae, Persicario hydropiperis - Bidentetum tripartitae.

- Shrubs

Solano dulcamarae - Tamaricetum gallicae, Ulici europaei-Prunetum spinosae, Salix atrocinerea forests community.

Saliceto albae sigmetum

Diagnosis

Holoserries of freshwater estuarine riparian and marshy forests from eastern French Atlantic estuaries, characterized by *Salix alba*

Synphysiognomy

Physiognomy of the characteristic association:

moist soft woody groupment corresponding to a megaphorb holigohaline and freshwater herbaceous layer, with a *Salix alba* dominated forest layer.

Floristic characteristic composition:

Salix alba, *Oenanthe crocata*, *Limniris pseudacorus*, *Phalaris arundinacea*, *Phragmites vulgaris*.

Physiography and catenal placement:

Landscape characterization:

large estuarine bed from riparian to marshy conditions.

Vegetation contacts:

In lower position we have freshwater - upper oligohaline aquatic vegetation;

In upper position, in a complete zonation we have the *Fraxinus excelsior* forest groupment

Ecology

Dominant soil type:

Silty or sandy riparian and marshy.

Bioclimate:

average thermotype - mesotemperate;

average ombrotype - subhumid.

Chorology

This geopermaseries is more frequent in estuaries south to the Laita.

Phytocoenotic composition

This geopermaseries is characterized by a forest community in head series, in substitutional level there are typically, reed bed (*Phragmitetum vulgaris*) grasslands and megaphorb communities, depending on humidity and soil uses variations. At the shrub level, in the driest portions we can find more commonly the *Ulici europaei-Prunetum spinosae*; while the *Salicetum triandro-viminalis* and *Salicetum purpureae* are more linked to wettest portions.

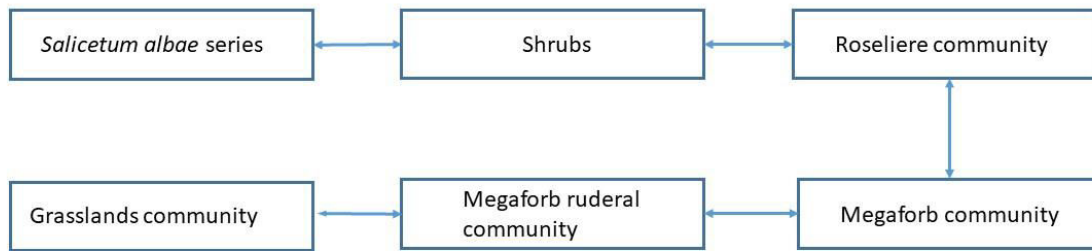


Figure 40. - physiognomic phytodynamic simplified scheme of the *Salicetum albae* series

In this physiognomic phytodynamic scheme we can observe the stages from the forest to the grassland community (Up to down) in substitution, and vice versa (Down up): according to the following list of associations. It is possible to go from one block to another by jumping various stages because of environmental or anthropic pressure. From each block is possible to pass to any other, in secondary succession or degeneration/regression directions. If the changes are gradual, ideally the scheme is respected, according to the ecology, behavior, and the biomass development (facilitation or competition phenomena) of the communities present in the various blocks.

Following the secondary succession, in the Tessella from grasslands to forest steps we find:

- Grasslands community

Ranunculetum ophioglossifolii, *Gratiolo officinalis* - *Oenanthe fistulosae*, *Ranunculo ophioglossifolii* — *Oenanthe fistulosae*, *Eleocharito palustris* - *Oenanthe fistulosae*, *Senecioni aquatici* - *Oenanthe mediae*, *Hordeo secalini* - *Lolietum perennis*, *Junco acutiflori* — *Cynosuretum cristati*, *Pulicario dysentericae* — *Juncetum inflexi*, *Cirsio palustris* — *Juncetum effuse*, *Hordeetum murinum*, *Heracleo sphondylii*-*Brometum mollis*
Oenanthe peucedanifoliae-*Brometum racemose*, *Poo annuae* – *Plantaginetum coronopodis*
Alopecuro pratensis — *Cynosuretum cristati*, *Convolvulo arvensis* – *Elytrigietum repentis*,
Lolio perennis - *Plantaginetum majoris*, *Dactylido glomeratae* - *Festucetum arundinaceae*,
Dactylis glomerata and *Daucus carota* meadows, *Juncus effusus* and *Agrostis stolonifera*
meadows

- Megaforb community

Valeriano officinalis - *Filipenduletum ulmariae*, *Holco mollis* – *Pteridietum aquilini*,
Lysimachio vulgaris-*Filipenduletum ulmariae*, *Persicario hydropiperis* - *Bidentetum tripartitae*,
Calystegio sepium-*Angelicetum heterocarpae*.

- Megaforb ruderal community

Torilidetum japonicae, *Sambucetum ebuli*, *Portulaco oleraceae* – *Amaranthesetum deflexi*, *Helosciadetum nodiflori*, *Melilotetum albo* – *officinalis*, *Heracleo sphondylii* - *Rumicetum obtusifolii*, *Torilidetum japonicae*, *Anthriscetum sylvestris*, *Arctio lappae* - *Artemisietum vulgare*, *Epilobio hirsuti* - *Convolvuletum sepium*, *Sisymbrio officinalis* – *Hordeetum murinum*, *Urtico dioicae* - *Convolvuletum sepium*.

- Roselières community

Cypero longi-*Caricetum otrubae*, *Typhetum angustifolii*, *Typhetum latifoliae*, *Caricetum ripario* – *acutiformis*, *Schoenoplectetum tabernaemontani*, *Sparganietum erecti*, *Caricetum ripariae*, *Scirpetum lacustris*, *Caricetum acutiformis*, *Apio nodiflori* – *Eleocharitetum amphibiae*, *Glycerietum maximae*, *Scirpetum maritime*, *Scirpetum triquetri*, *Phalaridetum arundinaceae*, *Iridetum pseudacori*, *Rorippo sylvestris* – *Phalaridetum arundinaceae*, *Phragmitetum communis*.

- Shrubs

Calystegio sepium - *Aristolochietum clematitidis*, *Ulici europaei*-*Prunetum spinosae*, *Salicetum purpureae*, *Salicetum triandro-viminalis*, *Salix atrocinerea* forests community.

Fraxinus excelsior forest geosigmatum

Diagnosis

Geoseries of highest major riverbed, mesic to hygrophilic forests from eastern French Atlantic estuaries, characterized by *Fraxinus excelsior*

Synphysiognomy

Physiognomy of the characteristic association:

moist soft woody groupment corresponding to a megaphorb mesic to hygrophilic freshwater herbaceous layer, with a *Fraxinus excelsior* dominated forest layer.

Floristic characteristic composition:

Fraxinus excelsior, *Heracleum spondylium*, *Chamaeiris foetidissima*, *Hedera helix*, *Rubus* sp. pl., *Arum* sp. pl., *Dioscorea communis*, and *Bryonia dioica*.

Physiography and catenal placement:

Landscape characterization:

estuarine large bed from riparian to marshy conditions (also dry during summer).

Vegetation contacts:

In lower position, we have all the previous willows series depending on the salty estuarine portion; basically, upper the *Salicetum albae*, middle, the *Salicetum fragilis* and down the *Salix atrocinerea* forests.

In upper position, in a complete zonation we have the *Fraxinus excelsior* forest groupment.

Ecology

Dominant soil type:

Silty or sandy riparian to marshy.

Bioclimate:

average thermotype - mesotemperate;

average ombrotype - subhumid.

Chorology

This geopermaseries is frequent all along the studied estuaries, in the upper vegetation belt.

Phytocoenotic composition

This geoseries is characterized by head series forest community mainly represented by *Fraxinus excelsior* forests. In this geoseries we can find some Associations, characterized mainly by *Fraxinus excelsior* and *Quercus robur* forests. Variations depends especially on soil characteristics and water flooding dynamics. Actually it was not possible to identify all the association and related distribution, because in this geopermaseries surfaces the man impact is still very strong; the forest lacking, or they are too many young, generally with a not good structure or replaced by settlements, cultivations and meadows, or in secondary successions. In this geoseries we can find a pre-forest stage: secondary Elm formations and *Salix atrocinerea* mesic formations that can reach an head series in more exposed to sea winds positions, even as lower (arbustive or dwarf forests) formations. More inland they both represent secondary formations from shrubland to pre-forest type. In this way, is possible to find in this geoseries

also not developed punctual formations of *Populus temula* and *Corylus avellana*. In rare cases, on rocks, pebble's deposits and sand bars the *Prunus spinosa* and *Ulex europaeus* thicket could represent the head series, in poorest soils and exposed to salt conditions (as is for example in the Aulne estuary deposits of the "Le Loc'h" and "Sillon des Anglais". Others substitutional formations are: grasslands (especially represented by *Dactylis glomerata* and *Daucus carota*), others pastures, and megaforb communities in richest and moist conditions. Otherwise, we found *Carex* communities, depending on humidity and soil uses variations. More rarely also the *Phragmitetum vulgaris* and the *Phalaridetum arundinaceae* in more riparian conditions. At the shrub level, in the driest portions we can find more commonly the *Ulici europaei-Prunetum spinosae* and similar shrubby formations. In lowest conditions, the *Fraxinus* forest understory is very similar to the willow forests, showing in one hand a natural forest similar to Willows forests, and a gradient in this direction. In other hand, it could represent a Man alteration of the Willows forests (i.e.: drainage, filling, channeling, embankments artificialization, plantations).

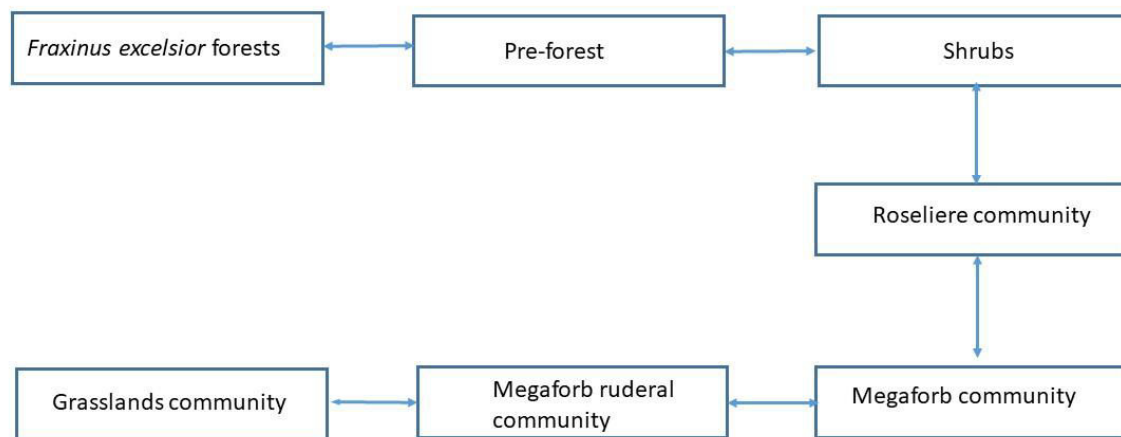


Figure 41. - Physiognomic phytodynamic simplified scheme of the *Fraxinus excelsior* forests

In this physiognomic phytodynamic scheme we can observe the stages from the forest to the grassland community (Up to down) in substitution, and vice versa (Down up): according to the following list of associations. It is possible to go from one block to another by jumping various stages because of environmental or anthropic pressure. From each block is possible to pass to any other, in secondary succession or degeneration/regression directions. If the changes are gradual, ideally the scheme is respected, according to the ecology, behavior, and the biomass development (facilitation or competition phenomena) of the communities present in the various blocks.

Following the secondary succession, in the Tessella we find:

- Roselières community

Caricetum remotae, *Typhetum latifoliae*, *Typhetum angustifolii*, *Rorippo sylvestris* – *Phalaridetum arundinaceae*, *Phalaridetum arundinaceae*, *Phragmitetum communis*

- Grasslands community

Trifolio maritimi- *Oenanthetum silaifoliae*, *Atriplici prostratae* - *Elymetum atherici*, *Atriplici hastatae*-*Agropyretum repentis*, *Senecioni aquatici* - *Oenanthetum mediae*, *Hordeetum*

murinum, *Sisymbrio officinalis* – *Hordeetum murinum*, *Junco acutiflori* — *Cynosuretum cristati*, *Pulicario dysentericae* — *Juncetum inflexi*, *Cirsio palustris* — *Juncetum effuse*, *Hordeo secalini* - *Lolietum perennis*, *Heracleo sphondylii*-*Brometum mollis*, *Oenanthe peucedanifoliae*-*Brometum racemose*, *Poo annuae* – *Plantaginetum coronopodis*, *Alopecuro pratensis* — *Cynosuretum cristati*, *Juncus effusus* and *Agrostis stolonifera* meadows, *Dactylido glomeratae* - *Festucetum arundinaceae*, *Convolvulo arvensis* – *Elytrigietum repentis*, *Lolio perennis* – *Plantaginetum coronopodis*, *Lolio perennis* - *Plantaginetum majoris*, *Dactylis glomerata* and *Daucus carota* meadows

- Megaforb community

Sambucetum ebuli, *Pericario hydropiperis* - *Bidentetum tripartitae*, *Holco mollis* – *Pteridietum aquilini*

- Megaforb ruderal community

Silybo mariani-*Urticetum piluliferae*, *Beto maritimae*-*Raphanetum landrae*, *Galio aparini* - *Smyrnetum olusatri*, *Urtico dioicae* - *Convolvuletum sepium*, *Melilotetum albo* – *officinalis*, *Torilidetum japonicae*, *Heracleo sphondylii* - *Rumicetum obtusifolii*, *Epilobio hirsuti* - *Convolvuletum sepium*, *Arctio lappae* - *Artemisietum vulgaris*

- Pre-forest

Salix atrocinerea mesic formations, which in inland or sheltered could be replaced by *Betula* species forests (mostly *B. pendula* and *B. × aurata*), *Ulmus* species (mainly *U. minor*), *Populus tremula* or *Corylus avellana* formations.

- Shrubs

Hedero heliis - *Atriplicetum halimi*, *Solano dulcamarae* - *Tamaricetum gallicae*, *Aro neglecti*-*Ulmetum minoris*, *Ulici europaei*-*Prunetum spinosae*,

- Forests

In estuarine freshwaters context, *Fraxinus excelsior* forest develops in the most mesophilic portions. In upper condition *Quercus robur* increase in presence. In uppermost condition, we observe a gradient with the closest zonal forest. In more hot and moist conditions, *F. angustifolia* is detectable.

In more riparian conditions, *Fraxinus* forests compete with Willows forests and some mixt formation are detectable. *Fraxinus* species are favored by draining conditions due to natural characteristics (the natural riverbanks drainage, or due to human impact). Willow species could develop mixed in *Fraxinus* forest or making a pre-forest in the succession. In stable conditions, *Fraxinus* species could become dominant due to its development that tend to undercover *Salix* species in these conditions. Less it happens with *Populus* species, mainly if they install before the *Fraxinus* species, because they have the same or greater mass development.

In wettest portions *Fraxinus* forest could be almost pure or mixed with *Salix* and *Populus* species. More to the innerland also *Alnus glutinosa*, *Betula pendula*, *Betula pubescens*, samples could be found. In more mesic conditions, we can observe an increasing in *Quercus robur* presence and also samples of *Tilia* species, *Acer* species, and *Prunus avium*. In uppermost or in driest portions we can observe a gradient with the closest zonal forests and consequently we can find samples of *Quercus petraea*, *Castanea sativa* and *Fagus sylvatica*.

In these forests, often we can distinguish two canopy layers. The highest one made up by tall tress, the second made up but smaller tress maily *Ulmus minor*. Often are still present in this canopy layer trees of *Prunus domestica*, *Prunus x fruticans*, *Carategus monogyna* and *Sambucus nigra*. *Ilex aquifolium*, *Laurus nobilis*, *Juglans regia*, *Carpinus betulus*, *Quercus ilex*, *Q. rubra*, and *Q. cerris* are rare.

According to the field observations, we decided to group these forests within a geoseries because we can presume that the potential vegetation could be easily expressed in various associations even not always described right now. Due to past human impact and actual soil use it is often quite hard to understand Series, Association and related vegetation limits within this *Fraxinus* forests geoseries. We found some variations from the most coastal (even on slopes) portions that generally floristically resembles to the *Aro neglecti-Fraxinetum excelsioris* (in slightly dry soil and air conditions) and the *Dryopterido affinis - Fraxinetum excelsioris* (especially in moister conditions of soil and air). The *Fraxinus* forests have a large and wide potential distribution all along the highest estuarine levels. In saltier sectors it moves away from the riverbed (developing more far or in higher topographic levels, if compared to the main river channel) until to join the minor riverbed borders upstream. In this position, *Fraxinus* forests could be represented by marshy forest in abandoned meanders or is pools (i.e.: *Carici remotae - Fraxinetum excelsioris*, or just in terrace position with an understory similar to *Salix* forests or in more mesic conditions (i.e: *Ulmo minori - Fraxinetum angustifoliae*). Some exceptions were included in the geoseries, as linked series: the related marshiest forest of *Alnus glutinosa* (i.e.: *Filipendulo ulmariae - Alnetum glutinosae*) and the *Salix atrocinerea* marshy forest community exiting surrounded by *Fraxinus* forests. *Alnus* forest generally develops only in inner positions, or in artificial conditions (i.e.: barrages that block the salt-water influence) while in Brackish sectors trhis species presence corresponds to few samples in others forests (mainly willow forests). At this level, the *Salix atrocinera* marshy inner forests could be distinguished to the *Alnus glutinosa* marshy forests by an increasing waterlogged soils. Mesic groupments of *Salix atrocinerea* forest in inner conditions commonly develops in secondary succession as pre-forest, before the *Fraxinus* head series but in more windy or coastal places it could be blocked in head series conditions linked to environment constraints that block this series succession at this stage.

In driest sand dunes conditions, other exceptions were linked into this geoseries. In the Loire mouth left side, the *Fraxinus* forests are replaced by *Quercus ilex* and *Pinus pinaster* forest with more or less scattered *Fraxinus* samples, with a *Rhamnus alaternus* mantle that we also linked to this geoseries as upper and driest thermoxeric facies (the lower levels as transgression) while the upper level is just in contact vegetation, more dry and with lesser species that links with *Fraxinus* forests. This exception could be justified as extrazonal vegetation linked to the dry and poor soil type and by the climatic micro-varation characteristics that are closer to the Mediterranean climate as shown by the ombrotermic diagram elaboration.

Another example of contact vegetation that could transgress to the estuaries border especially in middle and inner confinement phenomena (rocky or ground step outcrops) is the presence of the *Pyro cordatae - Quercetum roboris* Bioret & Magnanon 1993; and *Rubio peregrinae-Quercetum petraeae* Bioret & Gallet 2010 (more rarely, according to BIRET & GALLET, 2010 and CHALUMEAU *et al.*, 2014, 2018) and found only in the Aulne; or the *Rubio peregrinae - Quercetum roboris* Géhu & Géhu-Franck 1988 (more common). These oak forests were considered in contact or even linked to the *Fraxinus* forests depending on the topographic level and depending in their facies. We found facies very rich on *Fraxinus* species samples at their lower level. The same was observed with the *Umbilico rupestris – Quercetum roboris* Géhu &

Bournique 1993, on soil (or rich in soil rocky) outcrops. In fact, in the upper or in the inner outcrops the salty vegetation is replaced by *Umbilico rupestris* - *Asplenietum billotii* B. Foucault 1979 or similar coenoses.

In saltier sectors, the *Fraxinus* forest is primary also in less humid conditions and develops more dwarf and curly facies tendencies, due to the sea wind conditions.

In moist or in less sheltered conditions this forest is primary and it forms an azonal forest; but it could transgress in upper levels, making in this case the pre forest or shrubland of zonal communities (i.e.: *Fagus sylvatica*, *Quercus petraea*, *Castanea sylvatica* forests...).

In more inner conditions, it develops a more humid variant, enriched of marshy and riparian species. When in more dry condition it develops a more typical facies, especially on steep slopes that often could appear richer in ferns. The typical situation already known for coastal cliffs, dominated by ferns that are rooted in cracks and that appreciate the cool and humid atmosphere that prevails in much of the cases. Similarly, it happens with the mesic *Salix atrocinera* forests. In fact, in inner sectors *Fraxinus* species mainly characterize this geoseries expression, while in less sheltered conditions (i.e.: more close to the seacoasts, or in the ravine conditions) *Salix atrocinera* mesophilic forests or *Ulmus* species respectively take place, by disappearing (or reduction) of the upper *Fraxinus* canopy.

In the understory, the vegetation is generally dense and species rich. The neutrocline species are well represented, and generally dominated. The shrub layer is generally characterized by the lowest layer of *Crataegus monogyna*, *Ulmus minor*, *Sambucus nigra*, *Ilex aquifolium*, *Corylus avellana*, *Rubus* and *Prunus* species. Accompanied sometimes by *Ulex europaeus*, *Ligustrum vulgare*, *Clematis vitalba*, *Aristolochia clematidis*, *Euonymus europaeus*, and others species generally from *Rhamno-prunetea*. In wettest and inner conditions, other shrub could be present like *Viburnum opulus*.

The herbaceous layer is typically represented by the presence of *Chamaeiris foetida*, *Arum* (especially *A. italicum* subsp *neglectum*), *Geum urbanum*, *Galium aparine*, *Dactylis glomerata*, *Arctium nemorosus*). Their presence is related to the type of soil; generally consisting in colluviums, neutrophilic to acidiphilic, mesophilic and rich in nutrients. Moss layer is very variable in cover: from almost absent, to very wide covering.

In the series, the forest represents the head series, while *Aro-Ulmetum* the pre-forest and the thicket is represented by *Rhamno-prunetea* species. Herbaceous community of the series are generally represented by *Dactylis glomerata* and *Daucus carota* grasslands with presence of xerophytic species like *Eryngium campestre*, *Hordeum murinum*, *Sedum* species, and *Ononis* species. In moister conditions, the herbaceous community is the same or similar to that accompany the *Salix* species forests.

Lemneto minoris geopermasigmetum

Diagnosis

Geopermaseries of aquatic vegetation from subsalty to fresh waters, from eastern French Atlantic estuaries, characterized submerged and floating vegetation.

Synphysiognomy

Physiognomy of the characteristic association:

Aquatic community characterized by the wide presence of *Lemna* species.

Floristic characteristic composition:

Lemna minor.

Physiography and catenal placement:

Landscape characterization:

estuarine smaller bed, ponds and marshes (not dry during summer).

Vegetation contacts:

From estuary mouth to the freshwater portion,

In lower position, we have salt tolerant or sub-halophyte communities that benefit of freshwater accession or salt leaching. In the salt sectors, the main channel is poorly covered by vegetation (exception or a huge amphibious estuarine algal community, mainly represented by Phaeophyceae and the so called Maerl). Only in lateral pools or freshwater accessions, and lateral confluences we can find phanerophytes communities. In the middle (mesohaline) portion, in the main channel they consist only in microalgal communities; but in pools, secondary or abandoned meanders and freshwater springs, we can find phanerogamic aquatic communities. In upper portion from oligohaline to freshwaters, the geopermaseries is expressed with the larger number of Associations. In largest river estuaries, in contact we typically can find all the previously described willows forests, depending on the salty estuarine portion; basically, upper the *Salicetum albae*, middle, the *Salicetum fragilis* and down the *Salix atrocinerea* forests.

In upper belt position, in a complete zonation we have the *Fraxinus excelsior* geoseries forest groupment.

Ecology

Dominant soil type:

waters.

Bioclimate:

average thermotype - mesotemperate;

average ombrottype - subhumid.

Chorology

This geopermaseries is frequent in all the estuaries.

Phytocoenotic composition

This geoseries is characterized by a common pleustophytic community. By a submerged subsalty community in saltier portions and a submerged community in freshwaters. Always

represented by same possible associations. This geopermaseries is comprised mainly by *Ruppium maritimum*, *Zannichellium obtusifolium*, *Elodea canadensis*, *Ceratophyllum demersum*, *Potamogeton crispus*, *Nymphaea alba*-*Nymphaea lutea*, *Myriophyllum verticillatum*, *Ranunculus baudotii*, *Lemna minor*-*Spirodelos polyrhizus*, *Lemna minor* - *Azolla filiculoides*, *Potamogeton natans*, *Lemna minor*.

5.5. Plant communities' diversity and organization

Analyzing the fieldwork phytosociology and synphytosociology data per estuaries (inter-estuaries) and ecological compartments, we found 123 associations (Tab.72):

Eualine							Polyaline							Mesohaline							Oligohaline							Frashwater						
1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire	Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire	Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire	Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire	Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire
33	33	29	33	22	73	42	0	24	26	21	27	65	73	0	22	23	19	25	61	62	0	15	19	16	26	65	73	0	0	16	17	21	58	60

Tab. 72 . - General plant assooiation numeric distribution

Following the synphytociological method, we can group these 123 plant associations in 2 geopermaseries, 2 geoseries, and 2 holoseries:

Aulne estuary:

Atriplici prostratae -Elymeto atherici geopermasigmetum 21 associations

Salix atrocineria forests community geosigmetum 19 associations

Saliceto fragilis sigmetum 0

Saliceto albae sigmetum 0

Fraxinus excelsior forest geosigmetum 8 associations

Lemneto minoris geopermasigmetum 0

Observer		K Cianfaglione															
Estuary		Aulne															
Departement/Province		Finistere															
Ecological range		A					B				C						
Salinity compartment		Euhaline					Polyhaline				Mesohaline						
Synecle number		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16
Date		1-3-2015	1-3-2015	1-3-2015	2-3-2015	2-3-2015	3-3-2015	3-3-2015	4-3-2015	4-3-2015	5-3-2015	6-3-2015	7-3-2015	8-3-2015	9-3-2015	10-3-2015	11-3-2015
Site range		Iles du Brédy - Hôpital-Camfrout	Hôpital-Camfrout - Le Faou	Le Faou - Pont de Térénez	Pointe de Lomergat (Argol) - Landevenec	Landevenec - Pont de Térénez	Pont de Térénez - Langout	Langout - Rosouën	Pont de Térénez - Treuzelton	Treuzelton - Kerboursard (Daicault)	Kerboursard (Daicault) - Lanvian	Lanvian - E60	E60 - Le Bois du Chap (Dineault)	Rosouën - Logonna-Quimerch	Logonna-Quimerch - Pont de Bois les Quimerch	Pont de Bois-les-Quimerch - E60	E 60 - Kamppoul (Saint-Sigah)
Surface (ha)		30	30	30	10	10	10	10	10	10	20	50	50	40	50	20	50
Total phanerogamic recovery (%)		60	60	80	50	50	50	60	50	60	100	100	100	100	100	100	100
Average exposition		S	SW	NW	NW	W	SW	S	NE	N	N	N	E	S	SE	NW	W
Syntax number		12	15	16	13	11	10	5	11	10	7	6	4	6	4	4	4
Average altitude range (masl)		0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6	0-6
Slakke	<i>Spartinetum alterniflorae</i>	O 1	O 2	O 1													
	<i>Spartinetum anglicae</i>		...r														
	<i>Astero tripolium-Agrostietum stoloniferae</i>			...+			..+		..+								
	<i>Salicornietum fragilis</i>			o+	o+												
	Macroalgal community	O 2	O 2	O 2	O 2	O 2	O 1	...1	O 1	...1							
Lower Shore	<i>Salicornietum disarticulato-ramosissimae</i>			o+													
	<i>Bostrychio scopioidis-Halimionetum portulacoidis</i>	O 1	O 2	O 1	o 1	...r	...r	/1	/..+	...r							
	<i>Puccinellietum maritima</i>	...r		...+	...r	...r											
	<i>Spergulario mediae - Salicornietum brachystachyae</i>			o+	o+												
	Macroalgal community	...1	...1	...1	...1	...1	...1	...1	...1	...1							
Middle Shore	<i>Festucetum littoralis</i>	o+	o 1	o+	..r	...r			...r	...r		...+		...+			
	<i>Festuco littoralis-Juncetum gerardii</i>	...+	...+	...+													
	<i>Juncetum gerardii</i>	...+	...+	...+	...r				...r	...r							
	Macroalgal community	...+	...+	...+	...+	...r	...r	...r	...r	...r	...+						
High shore	<i>Astero tripolium-Suaedetum maritima</i>		...+	...1	...1	...+	...+	...+	...r	...+	...+	...+	...+	...+			
	<i>Junco maritimi-Caricetum extensae</i>					..r			..r								
	<i>Oenantho lachenalii - Juncetum maritimi</i>				or												
	<i>Plantagini maritima-Limonietum vulgaris</i>				or												
Very high shore	<i>Atriplici hastatae-Agropyretum repens</i>		o+	o+						...+	...+	...+	...+	...+	...+	...+	...+
	<i>Atriplici prostratae - Elymetum atherici</i>	/2	/2	/2	/2	/2	/2	/2	/2	/1	/1	/1	/1	/1	/1	/1	/1
	<i>Beto maritima-Raphanetum landrae</i>	...+	...+		...+	...+											
	<i>Junco maritimi-Schoenetum nigricantis</i>							or									
	<i>Scirpetum maritimi</i>	o+	o+	o+				o+	o+	O 2	O 2	O 2	O 2	O 2	O 2	O 2	O 2
	<i>Astero tripolii - Phragmitetum australis</i>	...+	...+					...+	...+	O 3	O 3	O 3	O 3	O 3	O 3	O 3	O 3

Tab. 73. - *Atriplici prostratae -Elymeto atherici* geopermasigmetum

		K Cianfaglione																	
		Aulne																	
		Finistere																	
		A					B				C						D		
		Euhaline					Polyhaline				Mesohaline						Oligohaline		
Ecological range (Salinity compartment)																			
Geopemasysneleve number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Date		1-3-2015	1-3-2015	1-3-2015	2-3-2015	2-3-2015	3-3-2015	3-3-2015	4-3-2015	4-3-2015	5-3-2015	6-3-2015	7-3-2015	8-3-2015	9-3-2015	10-3-2015	11-3-2015	12-3-2015	13-3-2015
Site range		Iles du Bindy – Hôpital-Camfrout	Hôpital-Camfrout – Le Faou	Le Faou – Pont de Térénez	Pointe de Lonerget (Argo) – Landévennec	Landévennec – Pont de Térénez	Pont de Térénez – Langoot	Langoot – Rosnoën	Pont de Térénez – Treuzelom	Treuzelom – Kerbastard (Dineault)	Kerbastard (Dineault) – Lanvian	Lanvian – E60	E60 – Le Bois du Chap (Dineault)	Rosnoën – Logonna-Quimerch	Logonna-Quimerch – Pont de Buis-les Quimerch	Pont de Buis-les Quimerch – E60	E60 – Kamppoull (Saint-Ségal)	Le Bois du Chap (Dineault) – Barrage de Gully Glas	Kamppoull (Saint-Ségal) – Barrage de Gully Glas
Surface (ha)		10	10	10	100	10	10	100	50	100	100	100	100	100	100	100	100	100	
Total phanerogamic recovery (%)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Average exposition		S	SW	NW	NW	W	SW	S	NE	N	N	N	E	S	SE	NW	W	NW	SE
Syntaxa number		10	13	12	9	11	10	9	10	10	10	12	13	14	14	14	14	13	13
Lower major riverbed		Average altitude range (masl)																	
		0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7
Forests		<i>Salix atrocinerea</i> forests community																	
Shrubs		<i>Ulici europaei-Prunetum spinosae</i>																	
Meadows		<i>Astero tripolii – Phragmitetum australis</i>																	
		<i>Atriplici hastatae-Agroropyretum repentis</i>																	
		<i>Atriplici prostratae -Elymetum atherici</i>																	
		<i>Beto maritimae-Raphanetum landrae</i>																	
		<i>Epilobio hirsuti - Convolvuletum sepium</i>																	
		<i>Festucetum littoralis</i>																	
		<i>Helosciadatum nodiflori</i>																	
		<i>Holco mollis – Peridietum aquilini</i>																	
		<i>Junco maritimi-Schoenetum nigricantis</i>																	
		<i>Juncus effusus</i> and <i>Agrostis stolonifera</i> meadows																	
		<i>Lolio perennis - Plantaginatum majoris</i>																	
		<i>Phalaridetum arundinaceae</i>																	
		<i>Phragmitetum communis</i>																	
		<i>Scirpetum maritimi</i>																	
		<i>Urtico dioicae - Convolvuletum sepium</i>																	
		<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows																	
		Others secondary meadows																	
		Cultivated and Urbanised surfaces																	

Tab. 74. - *Salix atrocinerea* forests community geosigmetum

		K Cianfaglione																	
		Aulne																	
		Finistere																	
		A					B				C						D		
		Euhaline					Polyhaline				Mesohaline						Oligohaline		
Ecological range (Salinity compartment)																			
Geopemasysneleve number		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
Date		14-3-2015	14-3-2015	15-3-2015	16-3-2015	16-3-2015	17-3-2015	18-3-2015	18-3-2015	19-3-2015	5-3-2015	6-3-2015	7-3-2015	8-3-2015	9-3-2015	10-3-2015	11-3-2015	12-3-2015	13-3-2015
Site range		Iles du Bindy – Hôpital-Camfrout	Hôpital-Camfrout – Le Faou	Le Faou – Pont de Térénez	Pointe de Lonerget (Argo) – Landévennec	Landévennec – Pont de Térénez	Pont de Térénez – Langoot	Langoot – Rosnoën	Pont de Térénez – Treuzelom	Treuzelom – Kerbastard (Dineault)	Kerbastard (Dineault) – Lanvian	Lanvian – E60	E60 – Le Bois du Chap (Dineault)	Rosnoën – Logonna-Quimerch	Logonna-Quimerch – Pont de Buis-les Quimerch	Pont de Buis-les Quimerch – E60	E60 – Kamppoull (Saint-Ségal)	Le Bois du Chap (Dineault) – Barrage de Gully Glas	Kamppoull (Saint-Ségal) – Barrage de Gully Glas
Surface (ha)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Total phanerogamic recovery (%)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Average exposition		S	SW	NW	NW	W	SW	S	NE	N	N	N	E	S	SE	NW	W	NW	SE
Syntaxa number		9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Upper major riverbed		Average altitude range (masl)																	
		1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12
Forests		<i>Fraxinus excelsior</i> forest community																	
Pre-forests		<i>Salix atrocinerea</i> forests community																	
Shrubs		<i>Ulici europaei-Prunetum spinosae</i>																	
Meadows		<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows																	
		<i>Holco mollis – Peridietum aquilini</i>																	
		<i>Lolio perennis - Plantaginatum majoris</i>																	
		<i>Phragmitetum communis</i>																	
		<i>Lolio perennis – Plantaginatum coronopodis</i>																	
		Others secondary meadows																	
		Cultivated and Urbanised surfaces																	

Tab. 75. - *Fraxinus excelsior* forest geosigmetum

Blavet – Scorff double estuary:

Atriplici prostratae -*Elymeto atherici* geopermasigmetum 23 associations

Salix atrocineria forests community geosigmetum 18 associations

Saliceto fragilis sigmetum 0

Saliceto albae sigmetum 0

Fraxinus excelsior forest geosigmetum 8

Lemneto minoris geopermasigmeto 3

Observer	K Cianfaglione												
Estuary	Blavet-Scorff												
Departement/Province	Morbihan												
Ecological range	A					B				C			
Salinity compartment	Euhaline					Polyhaline				Mesohaline			
Syneleve number	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
Date	08-07-2015	09-07-2015	10-07-2015	11-07-2015	12-07-2015	13-07-2015	14-07-2015	15-07-2015	16-07-2015	18-07-2015	19-07-2015	20-07-2015	21-07-2015
Site range	Gâvres – Port-Louis	Larmor plage – Ploemeur	Ploemeur – Lorient	Port Louis – Pont D194	Lanester – Pont D194	left side (Pont D194 – Pont N 165)	Right side (Pont D194 – Pont N 165)	Lorient – Kercadoret	Laester – Keradelys	Keradelys – Nelhonët	Kercadoret – Pen Mané	Pont N165 – L'hermitage de Hemebont	Pont N 165 – Foret du Hingair
Surface (ha)	30	10	8	20	10	10	10	10	100	10	10	10	10
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100
Average exposition	W	NE	SE	NW	S	SE	NW	NE	SW	W	E	NW	SE
Syntaxa number	22	16	16	16	16	14	12	11	11	9	9	9	9
Average altitude range (masl)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Slikke	<i>Astero tripolium-Agrostietum stoloniferae</i> ...+												
	<i>Salicornietum fragilis</i> ...+												
	Macroalgal community O2 O2 O2 O2 O2 O2 O2 O2 O2 ...+ ...+ ...+ ...+												
Lower Shore	<i>Salicornietum disarticulato-ramosissimae</i> ...+												
	<i>Bostrychio scorpioidis-Halimionetum portulacoidis</i> ...1 ...1 ...1 ...1 ...1 ...+ ...+ ...+ ...+												
	<i>Puccinellietum maritima</i> ...+ ...+ ...+ ...+												
	<i>Spergulario mediae – Salicornietum brachystachyae</i> ...+ ...+ ...+ ...+												
	Macroalgal community ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1												
Middle Shore	<i>Festucetum littoralis</i> ...+ ...+ ...+ ...+												
	<i>Festuco littoralis-Juncetum gerardii</i> ...+ ...+ ...+ ...+												
	<i>Astero tripolium-Suaedetum maritima</i> ...+ ...+ ...+ ...+												
	<i>Cochleario anglicae - Plantaginetum maritima</i> ...+ ...+ ...+ ...+												
	Macroalgal community ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+												
High shore	<i>Junco maritimi-Caricetum extensa</i> ...+ ...+ ...+ ...+												
	<i>Juncetum gerardii</i> ...+ ...+ ...+ ...+												
	<i>Oenanthe lachenalii - Juncetum maritimi</i> ...+ ...+ ...+ ...+												
	<i>Plantagini maritima-Limonietum vulgaris</i> ...+ ...+ ...+ ...+												
	<i>Limonietum lychnidifolii-dodartii</i> ...+ ...+ ...+ ...+												
	Macroalgal community ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+												
Very high shore	<i>Agropyro pungentis-Inuletum crithmoidis</i> ...+ ...+ ...+ ...+												
	<i>Agropyro pungentis-Suaedetum verae</i> /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1												
	<i>Astero tripolii – Phragmitetum australis</i> ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1 ...1												
	<i>Atriplici hastatae-Agropyretum repentis</i> /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1												
	<i>Atriplici prostratae -Elymetum atherici</i> /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1 /1												
	<i>Beto maritima - Agropyretum pungentis</i> /+ /+ /+ /+ /+ /+ /+ /+ /+ /+ /+ /+ /+												
	<i>Beto maritima-Raphanetum landrae</i> ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+ ...+												
	<i>Junco maritimi-Schoenetum nigricantis</i> ...+ ...+ ...+ ...+												
	<i>Scirpetum maritimi</i> ...+ ...+ /1 /1 /1 o1 o3 o3 o3 o3												

Tab. 76. - *Atriplici prostratae* -*Elymeto atherici* geopermasigmetum

	Observer	K Cianfaglione																				
	Estuary	Blavet-Scorff																				
	Departement/Province	Finistère																				
	Ecological range (Salinity compartment)	A					B				C				D				E			
Geopernasynele number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Date	08-07-2015	09-07-2015	10-07-2015	11-07-2015	12-07-2015	13-07-2015	14-07-2015	15-07-2015	16-07-2015	18-07-2015	19-07-2015	20-07-2015	21-07-2015	22-07-2015	23-07-2015	24-07-2015	25-07-2015	26-07-2015	27-07-2015	29-07-2015	30-07-2015	
Site range	Gâvres – Port-Louis	Larmor plage – Ploemeur	Ploemeur – Lorient	Port Louis – Pont D194	Lanester – Pont D194	left side (Pont D194 – Pont N 165)	Right side (Pont D194 – Pont N 165)	Lorient – Keradoret	Lanester – Keraddeys	Keraddeys – Nelhouët	Keradoret – Pen Mané	Pont N165 – L'hermitage de Hembout	Pont N 165 – Forêt du Hingair	Forêt du Hingair – Inzinzac-Lochrist	L'hermitage de Hembout – Inzinzac-Lochrist	Nelhouët – Pont Scorff	Pen Mané – Pont Scorff	Pont Scorff - Le moulin de St Yves (right side)	Pont Scorff - Le moulin de St Yves (left side)	Inzinzac-Lochrist - Kervarh	Inzinzac-Lochrist - Kervars	
Surface (ha)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1	1	1	1	1	1	1	1	1	1	1	1	
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Average exposition	W	NE	SE	NW	S	SE	NW	NE	SW	W	E	NW	SE	NW	SE	W	E	E	W	SE	NW	
Syntax number	12	11	9	9	9	10	10	10	10	9	10	11	11	11	10	8	7	8	8	8	8	
Average altitude range (m asl)	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	
Lower major riverbed	Average altitude range (m asl)																					
Forests	<i>Salix atrocinerea</i> forests community																					
Shrubs	<i>Ulici europaei-Prunetum spinosae</i>																					
Meadows	<i>Astero tripoli – Phragmitetum australis</i>																					
	<i>Atriplici hastatae-Agropyretum repentis</i>																					
	<i>Atriplici prostratae -Elymetum atherici</i>																					
	<i>Beto maritima-Raphanetum landrae</i>																					
	<i>Epilobio hirsuti - Convolvuletum sepium</i>																					
	<i>Festucetum littoralis</i>																					
	<i>Helosciadetum nodiflori</i>																					
	<i>Holco mollis – Pteridietum aquilini</i>																					
	<i>Junco maritimi-Schoenetum nigricantis</i>																					
	<i>Juncus effusus and Agrostis stolonifera meadows</i>																					
	<i>Lolium perennis - Plantagnetum majoris</i>																					
	<i>Phalaridetum arundinaceae</i>																					
	<i>Phragmitetum communis</i>																					
	<i>Scirpetum maritimi</i>																					
	<i>Urtica dioicae - Convolvuletum sepium</i>																					
	<i>Dactylis glomerata and Daucus carota meadows</i>																					
	Others secondary meadows																					
	Cultivated and Urbanised surfaces																					

Tab. 77. - *Salix atrocinerea* forests community geosigmetum

	Observer	K Cianfaglione																				
	Estuary	Blavet-Scorff																				
	Departement/Province	Finistère																				
	Ecological range (Salinity compartment)	A					B				C				D				E			
Geopernasynele number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Date	08-07-2015	09-07-2015	10-07-2015	11-07-2015	12-07-2015	13-07-2015	14-07-2015	15-07-2015	16-07-2015	18-07-2015	19-07-2015	20-07-2015	21-07-2015	22-07-2015	23-07-2015	24-07-2015	25-07-2015	26-07-2015	27-07-2015	29-07-2015	30-07-2015	
Site range	Gâvres – Port-Louis	Larmor plage – Ploemeur	Ploemeur – Lorient	Port Louis – Pont D194	Lanester – Pont D194	left side (Pont D194 – Pont N 165)	Right side (Pont D194 – Pont N 165)	Lorient – Keradoret	Lanester – Keraddeys	Keraddeys – Nelhouët	Keradoret – Pen Mané	Pont N165 – L'hermitage de Hembout	Pont N 165 – Forêt du Hingair	Forêt du Hingair – Inzinzac-Lochrist	L'hermitage de Hembout – Inzinzac-Lochrist	Nelhouët – Pont Scorff	Pen Mané – Pont Scorff	Pont Scorff - Le moulin de St Yves (right side)	Pont Scorff - Le moulin de St Yves (left side)	Inzinzac-Lochrist - Kervarh	Inzinzac-Lochrist - Kervars	
Surface (ha)	1	1	1	1	1	3	3	3	3	30	30	30	30	30	30	30	30	30	30	30	30	
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Average exposition	W	NE	SE	NW	S	SE	NW	NE	SW	W	E	NW	SE	NW	SE	W	E	E	W	SE	NW	
Syntax number	6	6	6	6	7	7	9	7	9	10	10	10	10	10	10	9	9	9	9	9	9	
Average altitude range (m asl)	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	
Upper major riverbed	Average altitude range (m asl)																					
Forests	<i>Fraxinus excelsior</i> forest community																					
Pre-forests	<i>Salix atrocinerea</i> forests community																					
Shrubs	<i>Ulici europaei-Prunetum spinosae</i>																					
Meadows	<i>Dactylis glomerata and Daucus carota meadows</i>																					
	<i>Holco mollis – Pteridietum aquilini</i>																					
	<i>Lolium perennis - Plantagnetum majoris</i>																					
	<i>Phragmitetum communis</i>																					
	<i>Lolium perennis - Plantagnetum coronopodis</i>																					
	Others secondary meadows																					
	Cultivated and Urbanised surfaces																					

Tab. 78. - *Fraxinus excelsior* forest geosigmetum

	Observer	K Cianfaglione				
	Estuary	Blavet-Scorff				
	Departement/Province	Finistère				
	Ecological range	E				
	Salinity compartment	Fresh water				
	Syneleve number	18	19			
	Date	26-07-2015	27-07-2015			
	Site range	Pont Scorff - Le moulin de St Yves (right side)	Pont Scorff - Le moulin de St Yves left side)			
	Surface (ha)	30	30			
	Total phanerogamic recovery (%)	100	100			
	Average exposition	E	W			
	Syntaxa number	3	3			
	Average altitude range (m asl)	1 - 12	1 - 12	Freq. Abs.	Freq. Rel.	Σ
Small riverbed	<i>Lemnetum minoris</i>	... 1	... 1	2,00	40,00	
	<i>Potametum natantis</i>	... 1	... 1	2,00	40,00	
	<i>Potametum crispum</i>	... 1	... 1	2,00	40,00	

Tab. 79. - *Lemnetum minoris* geopermasigmetum

Charente estuary:

Atriplici prostratae - *Elymeto atherici* geopermasigmetum 31

Salix atrocineria forests community geosigmetum 57

Saliceto fragilis sigmetum 43

Saliceto albae sigmetum 49

Fraxinus excelsior forest geosigmetum 39

Lemnetum minoris geopermasigmetum 11

Observer	K Cianfaglione									
Estuary	Charente									
Departement/Province	Charente maritime									
Ecological range	A				B				C	
Salinity compartment	Euhaline				Polyhaline				Mesohaline	
Syneleve number	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Date	7-10-2015	8-10-2015	9-10-2015	10-10-2015	11-10-2015	12-10-2015	13-10-2015	14-10-2015	15-10-2015	16-10-2015
Site range	Ile Madame - Fort Lupin	Pointe de la Funée - La basse roche	Fort Lupin - South Anse D137	La basse roche - North Anse D137	N Anse D 137 LE petit Vergeroux	S Anse D 137 - Soubise	Soubise - St. Hyppolite	Petit Vergeroux - Tonmay Charente	St. Hyppolite - Pont D118	Tonmay Charente - Pont D 118
Surface (ha)	300	100	100	100	300	200	60	100	10	10
Total phanerogamic recovery (%)	30	30	20	90	90	90	90	90	90	90
Average exposition	NE	SW	NW	SE	W	E	N	S	NE	SW
Syntaxa number	14	28	18	25	14	15	12	8	9	7
Average altitude range (m asl)	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
Slikke	<i>Spartinetum maritima</i>									
	.r									
	<i>Spartinetum anglica</i>									
	... +									
	Macroalgal community									
	O2	O2	O1	... +						
Lower Shore	<i>Astero tripolium-Suaedetum maritima</i>									
	... +	... +	... +	... +	... r	... r	... r			
	<i>Bostrychio scorpioidis-Halimionetum portulacoidis</i>									
	... +	... +	... +	... +	... +	... +				
	Macroalgal community									
	... +	... +	... +	... +	... +	... +	... +	... +		
Middle Shore	<i>Puccinellietum maritima</i>									
	... +	... +		... +						
	<i>Puccinellio maritima</i> - <i>Salicornietum ramosissimae</i>									
		... +		... +						
	<i>Puccinellio maritima</i> - <i>Salicornietum perennis</i>									
		... +		... +						
	<i>Salicornietum obscurae</i>									
		... +		... +						
	<i>Trifolio maritimi</i> - <i>Oenanthetum silaifolia</i>									
		... 1		... +						
	Macroalgal community									
	... +	... +	... +	... +	... +	... +	... +	... +	... +	
High shore	<i>Astero tripolium-Agrostietum stoloniferae</i>									
	... +	... +	... +	... +	... +	... +				
	<i>Festucetum littoralis</i>									
					... +	... +	... +			
	<i>Festuco littoralis</i> - <i>Juncetum gerardii</i>									
					... +	... +				
	<i>Juncetum gerardii</i>									
	... +	... +	... +	... +	... +	... +	... +			
	<i>Junco maritimi</i> - <i>Caricetum extensae</i>									
				... +						
	<i>Limonietum lychnidifolii</i> - <i>dodartii</i>									
	... +			... +						
	<i>Oenanthe lachenalii</i> - <i>Juncetum maritimi</i>									
				... +						
	<i>Parapholis strigosae</i> - <i>Hordeetum marini</i>									
		... +	... +							
	<i>Salicornietum disarticulato</i> - <i>ramosissimae</i>									
	... +									
	<i>Salicornietum dolychostachyae</i>									
	... +			... +						
Very high shore	<i>Agropyro pungentis</i> - <i>Inuletum crithmoidis</i>									
	... +	... +	... +	... +						
	<i>Astero tripolii</i> - <i>Phragmitetum australis</i>									
	O2	O2	O2	O2	O2	O1	O1	... +	... +	... +
	<i>Atriplici hastatae</i> - <i>Agropyretum repentis</i>									
	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Atriplici prostratae</i> - <i>Elymetum atherici</i>									
	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Beto maritima</i> - <i>Atriplicetum prostratae</i>									
	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Beto maritima</i> - <i>Raphanetum landrae</i>									
			... +			... +	... +		... +	
	<i>Hordeo secalini</i> - <i>Lolietum perennis</i>									
	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Ranunculetum baudotii</i>									
		... +	... +	... +						
	<i>Ruppium maritima</i>									
				... +						
	<i>Scirpetum maritimi</i>									
	... +	... +	...1	...1	...1	...1	... +	... +	... +	... +
	<i>Scirpetum triquetri</i>									
									... +	... +
	<i>Typho domingensis</i> - <i>Phragmitetum maximi</i>									
		o 1	... +							
	<i>Silybo mariani</i> - <i>Urticetum piluliferae</i>									
	... +	... +								

Tab. 80. - *Atriplici prostratae* -*Elymeto atherici* geopermasigmetum

Observer	K Cianfaglione															
Estuary	Charente															
Departement/Province	Charente maritime															
Ecological range	A				B				C		D				E	
Salinity compartment	Euhaline				Polyhaline				Mesohaline		Oligohaline				Fresh water	
Syneleve number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Date	7-10-2015	8-10-2015	9-10-2015	10-10-2015	11-10-2015	12-10-2015	13-10-2015	14-10-2015	15-10-2015	16-10-2015	17-10-2015	18-10-2015	19-10-2015	20-10-2015	21-10-2015	25-10-2015
Site range	Île Madame - For Lupin	Pointe de la Fumée - La basse	Fort Lupin - Soudif Anse D137	La basse roche - North Anse D137	N Anse D 137 LE petit Vergeroux	S Anse D 137 - Soubise	Soubise - St. Hippolite	Petit Vergeroux - Tommay Charente	St. Hippolite - Pont D118	Tommay Charente - Pont D118	Pont D118 - St. Savinien	Pont D118 - Pont D18	St. Svinien - Taillebourg	Pont D18 - Pont D127	Taillebourg - Saintes West	Pont D127 - Saintes East
Surface (ha)	10	10	10	10	10	10	10	10	1	1	1	1	1	1	1	1
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Average exposition	NE	SW	NW	SE	W	E	N	S	NE	SW	S	N	SW	NE	W	E
Syntaxa number	25	29	28	32	33	33	32	35	34	38	38	39	40	32	34	29
Lower major riverbed	Average altitude range (m asl)															
	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	2-10
Forests	<i>Salix atrocinerea</i> forests community															
Shrubs	<i>Solano dulcamarae</i> - <i>Tamaricetum gallicae</i>															
	<i>Ulici europaei-Prunetum spinosae</i>															
	<i>Hedero helices</i> - <i>Atriplicetum halimi</i>															
Meadows	<i>Sparganietum erecti</i>															
	<i>Alopecuro pratensis</i> — <i>Cynosuretum cristati</i>															
	<i>Arctio lappae</i> - <i>Artemisietum vulgaris</i>															
	<i>Atriplici hastatae-Agropyretum repentis</i>															
	<i>Atriplici prostratae</i> - <i>Elymetum atherici</i>															
	<i>Beto maritimae-Raphanetum landrae</i>															
	<i>Calystegio sepium-Angelicetum heterocarpae</i>															
	<i>Caricetum acutiformis</i>															
	<i>Caricetum ripariae</i>															
	<i>Caricetum ripario</i> – <i>acutiformis</i>															
	<i>Convolvulo arvensis</i> – <i>Elytrigietum repentis</i>															
	<i>Dactylido glomeratae</i> - <i>Festucetum arundinaceae</i>															
	<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows															
	<i>Eleocharis palustris</i> - <i>Oenanthetum fistulosae</i>															
	<i>Epilobio hirsuti</i> - <i>Convolvuletum sepium</i>															
	<i>Glycerietum maximae</i>															
	<i>Gratiolo officinalis</i> - <i>Oenanthetum fistulosae</i>															
	<i>Helosciadatum nodiflori</i>															
	<i>Heracleo sphondylii</i> - <i>Rumicetum obtusifolii</i>															
	<i>Heracleo sphondylii</i> - <i>Brometum mollis</i>															
	<i>Holco mollis</i> – <i>Preridietum aquilini</i>															
	<i>Hordeetum murinum</i>															
	<i>Hordeo secalini</i> - <i>Lolietum perennis</i>															
	<i>Iridetum pseudacori</i>															
	<i>Juncus effusus</i> and <i>Agrostis stolonifera</i> meadows															
	<i>Lolio perennis</i> - <i>Plantaginetum majoris</i>															
	<i>Lysimachio vulgaris</i> - <i>Filipenduletum ulmariae</i>															
	<i>Melilotetum albo</i> - <i>officinalis</i>															
	<i>Oenantho peucedanifoliae</i> - <i>Brometum racemosi</i>															
	<i>Pericario hydropiperis</i> - <i>Bidentetum tripartitae</i>															
	<i>Phalaridetum arundinaceae</i>															
	<i>Phragmitetum communis</i>															
	<i>Poo annuae</i> – <i>Plantaginetum coronopodis</i>															
	<i>Ranunculetum ophioglossifolii</i>															
	<i>Ranunculo ophioglossifolii</i> — <i>Oenanthetum fistulosae</i>															
	<i>Rorippo sylvestris</i> – <i>Phalaridetum arundinaceae</i>															
	<i>Rumici maritimi</i> - <i>Ranunculetum scelerati</i>															
	<i>Sambucetum ebuli</i>															
	<i>Schoenoplectetum tabernaemontani</i>															
	<i>Scirpetum lacustris</i>															
	<i>Scirpetum maritimi</i>															
	<i>Senecioni aquatici</i> - <i>Oenanthetum mediae</i>															
	<i>Sisymbrio officinalis</i> – <i>Hordeetum murinum</i>															
	<i>Torilidietum japonicae</i>															
	<i>Trifolio maritimi</i> - <i>Oenanthetum silaifoliae</i>															
	<i>Typhetum angustifolii</i>															
	<i>Typhetum latifoliae</i>															
	<i>Urtico dioicae</i> - <i>Convolvuletum sepium</i>															
	<i>Valeriano officinalis</i> - <i>Filipenduletum ulmariae</i>															
	<i>Junco acutiflori</i> — <i>Cynosuretum cristati</i>															
	<i>Pulicario dysentericae</i> — <i>Juncetum inflexi</i>															
	<i>Cirsio palustris</i> — <i>Juncetum effusi</i>															
	<i>Galio aparini</i> - <i>Smyrniyetum olusatri</i>															
	Others secondary meadows															
	Cultivated and Urbanised surfaces															

Tab. 81. - *Salix atrocinerea* forests community geosigmetum

	Observer	K Cianfaglione											
	Estuary	Charente											
	Departement/Province	Charente maritime											
	Ecological range	A				B				C		D	
	Salinity compartment	Euhaline				Polyhaline				Mesohaline		Oligohaline	
	Syneleve number	1	2	3	4	5	6	7	8	9	10	11	12
	Date	7-10-2015	8-10-2015	9-10-2015	10-10-2015	11-10-2015	12-10-2015	13-10-2015	14-10-2015	15-10-2015	16-10-2015	17-10-2015	18-10-2015
	Site range	Ile Madame - Fort Lupin	Pointe de la Fumée - La basse roche	Fort Lupin - South Anse D137	La basse roche - North Anse D137	N Anse D 137 LE petit Vergeroux	S Anse D 137 - Soubise	Soubise - St. Hippolite	Petit Vergeroux - Tonmay Charente	St. Hippolite - Pont D118	Tonmay Charente - Pont D 118	Pont D118 - St. Savinten	Pont D118 - Pont D18
	Surface (ha)	1	1	10	10	10	10	10	10	10	10	10	10
	Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100
	Average exposition	NE	SW	NW	SE	W	E	N	S	NE	SW	S	N
	Syntaxa number	21	21	22	22	27	24	23	27	27	25	20	19
Lower major riverbed	Average altitude range (masl)	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
Forests	<i>Salicetum fragilis</i>	...+	...+	...1	...1	...1	...1	...1	...1	...1	...1	...+	...+
Pre-forests	<i>Salix atrocinerea</i> forests community	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
Shrubs	<i>Solano dulcamarae - Tamaricetum gallica</i>	...+	...+										
	<i>Ulici europaei-Prunetum spinosae</i>	...+	...+	...+	...+								
Meadows	<i>Alopecuro pratensis — Cynosuretum cristati</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Anthriscetum sylvestris</i>			...+	...+								
	<i>Arctio lappae - Artemisietum vulgare</i>									...+	...+		
	<i>Calystegio sepium-Angelicetum heterocarpha</i>							...+	...+	...+	...+		
	<i>Caricetum acutiformis</i>									...+	...+	...+	
	<i>Caricetum ripariae</i>									...+	...+		
	<i>Caricetum ripario – acutiformis</i>									...+	...+		...+
	<i>Convolvulo arvensis – Elytrigietum repentis</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Dactylido glomeratae – Festucetum arundinaceae</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Dactylis glomerata and Daucus carota meadows</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Eleocharito palustris - Oenanthetum fistulosae</i>					...+	...+						
	<i>Epilobio hirsuti - Convolvuletum sepium</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Glycerietum maximae</i>							...+	...+				
	<i>Gratiolo officinalis - Oenanthetum fistulosae</i>										...+		
	<i>Heracleo sphondylii - Rumicetum obtusifolii</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Heracleo sphondylii-Brometum mollis</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Hordeetum murinum</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Hordeo secalini - Lolietum perennis</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Iridetum pseudacori</i>										...+		
	<i>Juncus effusus and Agrostis stolonifera meadows</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Lolio perennis - Plantaginetum majoris</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Oenanthe peucedanifoliae-Brometum racemosi</i>					...+	...+	...+	...+				
	<i>Pericario hydropiperis - Bidentetum tripartitae</i>					...+	...+	...+	...+	...+	...+		
	<i>Phalaridetum arundinaceae</i>					...+	...+	...+	...+	...+	...+		
	<i>Phragmitetum communis</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Poo annuae – Plantaginetum coronopodis</i>	...+	...+	...+	...+	...+	...+						
	<i>Ranunculo ophioglossifolii — Oenanthetum fistulosae</i>					...+	...+						
	<i>Rumici maritimi-Ranunculetum scelerati</i>					...+	...+						
	<i>Scirpetum maritimi</i>							...+	...+	...+			
	<i>Senecioni aquatici - Oenanthetum mediae</i>					...+	...+	...+	...+	...+			
	<i>Sisymbrio officinalis – Hordeetum murinum</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Torilidetum japonicae</i>											...+	
	<i>Trifolio maritimi- Oenanthetum silaifoliae</i>	...+	...+	...+	...+	...+							
	<i>Urtico dioicae - Convolvuletum sepium</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Junco acutiflori — Cynosuretum cristati</i>			...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Pulicario dysentericae — Juncetum inflexi</i>			...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Cirsio palustris — Juncetum effusi</i>			...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Galio aparini - Smyrnetum olusatrum</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	Others secondary meadows	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	Cultivated and Urbanised surfaces	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1

Tab. 82. - *Saliceto fragilis sigmetum*

	Observer	K Cianfaglione					
	Estuary	Charente					
	Departement/Province	Charente maritime					
	Ecological range	D				E	
	Salinity compartment	Oligohaline				Fresh water	
	Syneleve number	11	12	13	14	15	16
	Date	17-10 2015	18-10 2015	19-10 2015	20-10 2015	21-10 2015	25-10 2015
	Site range	Pont D18 - St. Savinien	Pont D18 - Pont D18	St. Svinien - Tailllebourg	Pont D18 - Pont D127	Tailllebourg - Saintes West	Pont D127 - Saintes East
	Surface (ha)	100	200	200	200	200	200
	Total phanerogamic recovery (%)	100	100	100	100	100	100
	Average exposition	S	N	SW	NE	W	E
	Syntaxa number	2	2	3	3	5	4
Lower major riverbed	Average altitude range (m asl)	4- 10	4- 10	4- 10	4- 10	4- 10	4- 10
Forests	<i>Salicetum albae</i>	o1	o1	o2	o2	O2	O2
Pre-forests	<i>Salix atrocinerea</i> forests community	...+	...+	...+	...+	...+	...+
Shrubs	<i>Salicetum purpureae</i>					...+	...+
	<i>Salicetum triandro-viminalis</i>				...+	...+	
Meadows	<i>Sparganietum erecti</i>					...+	...+
	<i>Alopecuro pratensis</i> — <i>Cynosuretum cristati</i>	o1	o1	o1	o1	o1	o1
	<i>Anthriscetum sylvestris</i>			...+			
	<i>Arctio lappae</i> - <i>Artemisietum vulgaris</i>				...+	...+	
	<i>Calystegio sepium</i> - <i>Angelicetum heterocarphae</i>	...+	...+				
	<i>Caricetum acutiformis</i>				...+	...+	...+
	<i>Caricetum ripariae</i>					...+	
	<i>Caricetum ripario – acutiformis</i>				...+		
	<i>Convolvulo arvensis</i> – <i>Elytrigietum repentis</i>	o1	o1	o1	o1	o1	o1
	<i>Dactylido glomeratae</i> - <i>Festucetum arundinaceae</i>	...+	...+	...+	...+	...+	...+
	<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows	...+	...+	...+	...+	...+	...+
	<i>Eleocharito palustris</i> - <i>Oenanthetum fistulosae</i>	...+	...+		...+	...+	...+
	<i>Epilobio hirsuti</i> - <i>Convolvuletum sepium</i>	...+	...+	...+	...+	...+	...+
	<i>Glycerietum maximae</i>		...+		...+	...+	
	<i>Gratiolo officinalis</i> - <i>Oenanthetum fistulosae</i>	...+					
	<i>Helosciadetum nodiflori</i>				...+	...+	...+
	<i>Heracleo sphondylii</i> - <i>Rumicetum obtusifolii</i>	o1	o1	o1	...+	...+	...+
	<i>Heracleo sphondylii</i> - <i>Brometum mollis</i>	o1	o1	o1	o1	o1	o1
	<i>Holco mollis</i> – <i>Pteridietum aquilini</i>			...+	...+	...+	...+
	<i>Hordeetum murinum</i>			...+			...+
	<i>Hordeo secalini</i> - <i>Lolietum perennis</i>			...+	...+	...+	
	<i>Iridetum pseudacori</i>		...+	...+	...+	...+	...+
	<i>Juncus effusus</i> and <i>Agrostis stolonifera</i> meadows	o1	o1	o1	o1	o1	o1
	<i>Lolio perennis</i> - <i>Plantaginetum majoris</i>	...+	...+	...+	...+	...+	...+
	<i>Lysimachio vulgaris</i> - <i>Filipenduletum ulmariae</i>			...+	...+	...+	
	<i>Melilotetum albo</i> - <i>officinalis</i>	...+	...+	...+	...+	...+	...+
	<i>Oenantho peucedanifoliae</i> - <i>Brometum racemosi</i>	...+	...+	...+	...+	...+	...+
	<i>Phalaridetum arundinaceae</i>	o1	o1	o1	o1	o1	o1
	<i>Phragmitetum communis</i>	o2	o2	o2	o2	o2	o2
	<i>Poo annuae</i> – <i>Plantaginetum coronopodis</i>	...+	...+				
	<i>Ranunculo ophioglossifolii</i> — <i>Oenanthetum fistulosae</i>	...+					
	<i>Rorippo sylvestris</i> – <i>Phalaridetum arundinaceae</i>	...+	...+	...+	...+	o1	o1
	<i>Sambucetum ebuli</i>	...+	...+				
	<i>Schoenoplectetum tabernaemontani</i>	...+					
	<i>Scirpetum lacustris</i>					...+	...+
	<i>Scirpetum maritimi</i>	...+					
	<i>Scirpetum triquetri</i>	...+	...+				
	<i>Senecioni aquatici</i> - <i>Oenanthetum mediae</i>	...+	...+	...+			
	<i>Sisymbrio officinalis</i> – <i>Hordeetum murinum</i>	...+	...+	...+	...+	...+	...+
	<i>Torilidetum japonicae</i>				...+		
	<i>Urtico dioicae</i> - <i>Convolvuletum sepium</i>	o1	o1	o1	o1	o1	o1
	<i>Valeriano officinalis</i> - <i>Filipenduletum ulmariae</i>					...+	
	<i>Junco acutiflori</i> — <i>Cynosuretum cristati</i>			...+	...+	...+	
	<i>Pulicario dysentericae</i> — <i>Juncetum inflexi</i>			...+	...+	...+	
	<i>Cirsio palustris</i> — <i>Juncetum effusi</i>			...+	...+	...+	
	Others secondary meadows	o1	o1	o1	o1	o1	o1
	Cultivated and Urbanised surfaces	o1	o1	o1	o1	o1	o1

Tab. 83. - *Saliceto albae* sigmetum

Observer	K Cianfaglione															
Estuary	Charente															
Departement/Province	Charente maritime															
Ecological range	A				B				C		D				E	
Salinity compartment	Euhaline				Polyhaline				Mesohaline		Oligohaline				Fresh water	
Syneleve number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Date	7-10-2015	8-10-2015	9-10-2015	10-10-2015	11-10-2015	12-10-2015	13-10-2015	14-10-2015	15-10-2015	16-10-2015	17-10-2015	18-10-2015	19-10-2015	20-10-2015	21-10-2015	25-10-2015
Site range	Ile Madame - Fort Lupin	Pointe de la Fumée - La basse roche	Fort Lupin - South Anse D137	La basse roche - North Anse D137	N Anse D 137 LE petit Vergeroux	S Anse D 137 - Soubise	Soubise - St. Hyppolite	Petit Vergeroux - Tommay Charente	St. Hyppolite - Pont D118	Tommay Charente - Pont D 118	Pont D118 - St. Svinien	Pont D118 - Pont D18	St. Svinien - Taillebourg	Pont D18 - Pont D127	Taillebourg - Saintes West	Pont D127 - Saintes East
Surface (ha)	50	50	50	50	50	50	50	50	50	100	100	200	200	100	200	200
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Average exposition	NE	SW	NW	SE	W	E	N	S	NE	SW	S	N	SW	NE	W	E
Syntaxa number	28	28	33	33	32	31	30	30	32	31	29	30	27	28	29	27
Average altitude range (masl)	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
Lower major riverbed																
Forests	<i>Fraxinus excelsior</i> forest community															
Pre-forests	<i>Salix atrocinerea</i> forests community															
Shrubs	<i>Solano dulcamarae - Tamaricetum gallicae</i>															
	<i>Ulici europaei-Prunetum spinosae</i>															
	<i>Aro neglecti-Ulmetum minoris</i>															
Meadows	<i>Alopecuro pratensis - Cynosuretum cristati</i>															
	<i>Arctio lappae - Artemisietum vulgaris</i>															
	<i>Atriplici hastatae-Agropyretum repentis</i>															
	<i>Atriplici prostratae - Elymetum atherici</i>															
	<i>Beto maritima-Raphanetum landrae</i>															
	<i>Convolvulo arvensis - Elytrigietum repentis</i>															
	<i>Dactylido glomeratae - Festucetum arundinaceae</i>															
	<i>Dactylis glomerata and Daucus carota meadows</i>															
	<i>Epilobio hirsuti - Convolvuletum sepium</i>															
	<i>Heracleo sphondylii - Rumicetum obtusifolii</i>															
	<i>Heracleo sphondylii-Brometum mollis</i>															
	<i>Holco mollis - Pteridietum aquilini</i>															
	<i>Hordeetum murinum</i>															
	<i>Hordeo secalini - Lolietum perennis</i>															
	<i>Juncus effusus and Agrostis stolonifera meadows</i>															
	<i>Lolio perennis - Plantaginetum majoris</i>															
	<i>Melilotetum albo - officinalis</i>															
	<i>Oenantho peucedanifoliae-Brometum racemosi</i>															
	<i>Phalaridetum arundinaceae</i>															
	<i>Phragmitetum communis</i>															
	<i>Poo annuae - Plantaginetum coronopodis</i>															
	<i>Rorippo sylvestris - Phalaridetum arundinaceae</i>															
	<i>Sambucetum ebuli</i>															
	<i>Senecioni aquatici - Oenanthetum mediae</i>															
	<i>Sisymbrio officinalis - Hordeetum murinum</i>															
	<i>Torilidetum japonicae</i>															
	<i>Trifolio maritimi- Oenanthetum silaifoliae</i>															
	<i>Typhetum angustifolii</i>															
	<i>Typhetum latifoliae</i>															
	<i>Urtico dioicae - Convolvuletum sepium</i>															
	<i>Juncus acutiflori - Cynosuretum cristati</i>															
	<i>Pulicario dysentericae - Juncetum inflexi</i>															
	<i>Cirsio palustris - Juncetum effusi</i>															
	<i>Gallo aparini - Smyrnetum olusatris</i>															
	Others secondary meadows															
	Cultivated and Urbanised surfaces															

Tab. 84. - *Fraxinus excelsior* forest geosigmetum

Observer																
Estuary																
Departement/Province																
Ecological range	A				B				C		D				E	
Salinity compartment	Euhaline				Polyhaline				Mesohaline		Oligohaline				Fresh water	
Syneleve number	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Date	8-10-2015	9-10-2015	10-10-2015	11-10-2015	12-10-2015	13-10-2015	14-10-2015	15-10-2015	16-10-2015	17-10-2015	18-10-2015	19-10-2015	20-10-2015	21-10-2015	25-10-2015	
Site range	Poinée de la Fumée - La basse roche	Fort Lanin - South Anse D137	La basse roche - North Anse D137	N Anse D 137 LE petit Vergeroux	S Anse D 137 - Sombise	Sombise - St. Hippolite	Petit Vergeroux - Tommay - Charente	St. Hippolite Pont D118	Tommay Charente - Pont D 118	Pont D118 - St. Savinien	Pont D118 - Pont D18	St. Svinien - Taillebourg	Pont D18 - Pont D127	Taillebourg - Saintes West	Pont D127 - Saintes East	
Surface (ha)	50	50	50	50	50	50	50	50	100	100	200	200	200	200	200	
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Average exposition	SW	NW	SE	W	E	N	S	NE	SW	S	N	SW	NE	W	E	
Syntaxa number	6	2	2	2	2	6	6	6	6	5	5	7	7	8	8	
Average altitude range (m asl)	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	1 - 12	
Small riverbed	<i>Ceratophyllum demersi</i>												...+	...+	...+	
	<i>Elodeetum canadensis</i>														...+	
	<i>Lemnetum minoris-Spirodeletum polyrhizae</i>	...+				...+	...+	...+	...+	...+	...+	...1	...1	...1	...1	
	<i>Lemnetum minoris</i>	...+				...+	...+	...+	...+	...+	...+	...1	...1	...1	...1	
	<i>Lemnetum minoris - Azolletum filiculoidis</i>	...+				...+	...+	...+	...+	...+	...+	...1	...1	...1	...1	
	<i>Myriophyllum verticillati</i>					...+	...+	...+	...+	...+	...+	...1	...1	...1	...1	
	<i>Nymphaea albae-Nupharetum luteae</i>											...1	...1	...1	...1	
	<i>Potametum crispum</i>														...+	
	<i>Potametum natantis</i>	...+	...+	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	
	<i>Ranunculetum baudotii</i>	...1	...1	...1	...1	...1	...1	...+	...+	...+	...+					
	<i>Ruppium maritima</i>	...+														

Tab. 85. - *Lemnetum minoris* geopermasigmetum

Elorn estuary:

Atriplici prostratae - Elymeto atherici geopermasigmetum 23

Salix atrocinerea forests geosigmetum 18

Saliceto fragilis sigmetum 0

Saliceto albae sigmetum 0

Fraxinus excelsior forest geosigmetum 8

Lemnetum minoris geopermasigmetum 0

	Observer	K Cianfaglione							
	Estuary	Elorn							
	Departement/Province	Finistere							
		A				B		C	
	Ecological range (Salinity compartment)	Euhaline				Polyhaline		Mesohaline	
	Geopermasyneleve number	E1	E2	E3	E4	E5	E6	E7	E8
	Date	14-6-2015	15-6-2015	16-6-2015	17-6-2015	18-6-2015	19-6-2015	22-6-2015	23-6-2015
	Site range	Brest – Pont N165	Traouidian – Pont N165	Pont N165 – Kermeur St Yves	Pont N165 – St. Jean	Kermeur St Yves – La Forest Landernau	St. Jean – Mesnot Dirinon	La Forest Landernau - Pont D712	Mesnot Dirinon - Pont D712
	Surface (ha)	1	1	1	1	1	1	1	1
	Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100
	Average exposition	SE	NW	SE	NW	SE	NW	SE	NW
	Syntaxa number	6	7	16	16	15	14	10	8
	Average altitude range (masl)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Slikke	<i>Spartinetum alterniflorae</i>			...r					
	<i>Spartinetum anglicae</i>			...l					
	<i>Astero tripolium-Agrostietum stoloniferae</i>	...r	...r	...+	...+	...+	...+		
	<i>Salicornietum fragilis</i>			...+					
	Macroalgal community	O2	O2	O2	O2	O1	O1	...+	...+
Lower Shore	<i>Salicornietum disarticulato-ramosissimae</i>			...+	...+				
	<i>Bostrychio scorpioidis-Halimionetum portulacoidis</i>			/1	/1	/1	/1		
	<i>Salicornietum obscurae</i>			...+					
	<i>Puccinellietum maritimae</i>		...r	...+	...+				
	<i>Spergulario mediae – Salicornietum brachystachyae</i>			...+	...+				
Middle Shore	<i>Festucetum littoralis</i>				...+	...+	...+	...+	...+
	<i>Festuco littoralis-Juncetum gerardii</i>					...+	...+	...+	
	<i>Juncetum gerardii</i>						...+	...+	
High shore	<i>Astero tripolium-Suaedetum maritimae</i>	...r	...r	...r	...+	...l	...l	...r	...r
	<i>Triglochino maritimi - Limonietum humilis</i>			...+	...+	...+			
	<i>Junco maritimi-Caricetum extensae</i>				...+	...+			
Very high shore	<i>Agropyro pungentis-Inuletum crithmoidis</i>	...+	...+	...+	...+	...r	...r		
	<i>Astero tripolii – Phragmitetum australis</i>				...+	...+	...+		
	<i>Atriplici hastatae - Betetum maritimae</i>			...+	...+				
	<i>Atriplici hastatae-Agropyretum repentis</i>	...1	...1	...1	...1	...1	...1	...+	...+
	<i>Atriplici prostratae -Elymetum atherici</i>	...+	...+	...1	...1	...1	...1	...1	...1
	<i>Beto maritimae-Atriplicetum prostratae</i>					...+	...+	...+	...+
	<i>Beto maritimae-Raphanetum landrae</i>					...+	...+	...+	...+
<i>Scirpetum maritimi</i>				...+	...l	...l	o4	o4	

Tab. 86. - *Atriplici prostratae -Elymeto atherici* geopermasigmatum

Observer		K Cianfaglione											
Estuary		Eln											
Departement/Province		Finistere											
Ecological range (Salinity compartment)		A				B		C		D		E	
Geopermsyneleve number		Euhaline				Polyhaline		Mesohaline		Oligohaline		Fresh water	
Date		1	2	3	4	5	6	7	8	9	10	11	12
Site range		14-6-2015	15-6-2015	16-6-2015	17-6-2015	18-6-2015	19-6-2015	22-6-2015	23-6-2015	24-6-2015	25-6-2015	26-06-2015	28-6-2015
Surface (ha)		Brest – Pont N165	Traouidian – Pont N165	Pont N165 – Kermeur St Yves	Pont N165 – St. Jean	Kermeur St Yves – La Forest Landernau	St. Jean – Mesnot Dirinon	La Forest Landernau - Pont D712	Mesnot Dirinon - Pont D712	Pont D712 - Landrenau (left side)	Pont D712 - Landrenau (right side)	Landernau - Penallen (Left side)	Landernau - Penallen (Right side)
Total phanerogamic recovery (%)		0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Average exposition		SE	NW	SE	NW	SE	NW	SE	NW	SE	NW	SW	NW
Syntaxa number		4	4	4	4	5	6	11	11	14	14	11	11
Lower major riverbed		Average altitude range (m asl)											
Forests		0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7
Forests	<i>Salix atrocinerea</i> forests community	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
Shrubs	<i>Ulici europaei-Prunetum spinosae</i>	...2	...2	...2	...2	...1	...1	...1	...1	...1	...1	...1	...1
Meadows	<i>Astero tripolii – Phragmitetum australis</i>						...+	..					
	<i>Atriplici hastatae-Agrophyretum repentis</i>	...2	...2	...2	...2	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Atriplici prostratae -Elymetum atherici</i>					...1	...1						
	<i>Beto maritima-Raphanetum landrae</i>							...1	...1	...1	...1		
	<i>Epilobio hirsuti - Convolvuletum sepium</i>									...1	...1	...1	...1
	<i>Festucetum littoralis</i>							...1	...1	...1	...1		
	<i>Helosciadetum nodiflori</i>									...+	...+	...+	...+
	<i>Holco mollis – Pteridietum aquilini</i>							...+	...+	...+	...+	...+	...+
	<i>Junco maritimi-Schoenetum nigricantis</i>								...+				
	<i>Juncus effusus</i> and <i>Agrostis stolonifera</i> meadows							...1	...1	...1	...1	...1	...1
	<i>Lolio perennis - Plantaginetum majoris</i>							...+	...+	...+	...+	...+	...+
	<i>Phalaridetum arundinaceae</i>									...+	...+	...+	...+
	<i>Phragmitetum communis</i>							...+	...+	...1	...1	...1	...1
	<i>Scirpetum maritimi</i>					...+	...+	...1	...1	...+	...+		
	<i>Urtico dioicae - Convolvuletum sepium</i>									...+	...+	...+	...+
	<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows					...+	...+	...+	...+	...+	...+	...+	...+
	Others secondary meadows												
	Cultivated and Urbanised surfaces	O1	O1	O1	O1	O1	O1	O1	O1	o1	o1	O1	O1

Tab. 87. - *Salix atrocinerea* forests community geosigmetum

Observer		K Cianfaglione											
Estuary		Eln											
Departement/Province		Finistere											
Ecological range (Salinity compartment)		A				B		C		D		E	
Geopermsyneleve number		Euhaline				Polyhaline		Mesohaline		Oligohaline		Fresh water	
Date		1	2	3	4	5	6	7	8	9	10	11	12
Site range		14-6-2015	15-6-2015	16-6-2015	17-6-2015	18-6-2015	19-6-2015	22-6-2015	23-6-2015	24-6-2015	25-6-2015	26-06-2015	28-6-2015
Surface (ha)		Brest – Pont N165	Traouidian – Pont N165	Pont N165 – Kermeur St Yves	Pont N165 – St. Jean	Kermeur St Yves – La Forest Landernau	St. Jean – Mesnot Dirinon	La Forest Landernau - Pont D712	Mesnot Dirinon - Pont D712	Pont D712 - Landrenau (left side)	Pont D712 - Landrenau (right side)	Landernau - Penallen (Left side)	Landernau - Penallen (Right side)
Total phanerogamic recovery (%)		1	1	1	1	1	1	1	1	1	1	1	1
Average exposition		SE	NW	SE	NW	SE	NW	SE	NW	SE	NW	SW	NW
Syntaxa number		8	8	9	9	9	9	10	10	10	10	10	10
Upper major riverbed		Average altitude range (m asl)											
Forests		1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12
Forests	<i>Fraxinus excelsior</i> forest community	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
Pre-forests	<i>Salix atrocinerea</i> forests community			...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
Shrubs	<i>Ulici europaei-Prunetum spinosae</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
Meadows	<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Holco mollis – Pteridietum aquilini</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Lolio perennis - Plantaginetum majoris</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Phragmitetum communis</i>					...+	...+	...+	...+	...+	...+	...+	...+
	<i>Lolio perennis – Plantaginetum coronopodis</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	Others secondary meadows	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	Cultivated and Urbanised surfaces	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1

Tab. 88. - *Fraxinus excelsior* forest geoseries

Laita estuary:

Atriplici prostratae -*Elymeto atherici* geopermasigmetum 13

Salix atrocineria forests community geosigmetum 23

Saliceto fragilis sigmetum 16

Saliceto albae sigmetum 10

Fraxinus excelsior forest geosigmetum 10

Lemneto minoris geopermasigmetum 3

Observer	K Cianfaglione							
Estuary	Laita							
Departement/Province	Finistere							
Ecological range	A		B				C	
Salinity compartment	Euhaline		Polyhaline				Mesohaline	
Syneleve number	L1	L2	L3	L4	L5	L6	L7	L8
Date	9-08-2015	10-08-2015	11-08-2015	12-08-2015	13-08-2015	14-08-2015	15-08-2015	16-08-2015
Site range	Pointe du Chemin du Mât Ploze (Clohars-Carnoët) – Kernou	Guidel-Plages – Kerbrest	Kernou – St. Germain	St. Germain – St. Maurice	Kerbrest – Pont D 224	Pont D 224 – Kerhoat Bénoal	Kerhoat Bénoal – Pivières	St. Maurice – Ruisseau du Front
Surface (ha)	3	3	3	3	3	2	5	6
Total phanerogamic recovery (%)	30	40	50	70	50	50	100	100
Average exposition	E	SW	E	E	W	W	NE	SW
Syntaxa number	14	14	11	11	11	10	4	4
Average altitude range (m asl)	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6	0 - 6
Slikke	<i>Astero tripolium</i> - <i>Agrostietum stoloniferae</i>							
	...+	...+						
	Macroalgal community							
	...2	...1	O1	O1	O1	O1		
Lower Shore	<i>Bostrychio scorpioidis</i> - <i>Halimionetum portulacoidis</i>							
	...2	...2						
	Macroalgal community							
	...1	...1	O1	O1	O1	O1		
Middle Shore	<i>Festucetum littoralis</i>							
	...+	...+	...+	...+	...+	...+		
	<i>Festuco littoralis</i> - <i>Juncetum gerardii</i>							
	...r	...r	...+	...+	...+	...+		
	<i>Juncetum gerardii</i>							
	...r	...r	...+	...+	...+	...+		
	Macroalgal community							
	...r	...r						
High shore	<i>Plantagini maritimae</i> - <i>Limonietum vulgaris</i>							
	...r	...r	...+	...1	...1	...+		
	<i>Junco maritimi</i> - <i>Caricetum extensae</i>							
	...r	...r	...r	...r	...r			
Very high shore	<i>Atriplici hastatae</i> - <i>Agropyretum repentis</i>							
	o1	o1	o+	o+	o+	o+	O1	O1
	<i>Atriplici prostratae</i> - <i>Elymetum atherici</i>							
	/1	/1	/2	/2	/2	/2	...+	...+
	<i>Scirpetum maritimi</i>							
	...+	...+	...+		...+		O3	O3
	<i>Astero tripolii</i> – <i>Phragmitetum australis</i>							
	...+	...+		...+		...+	o1	o1
	<i>Agropyro pungentis</i> - <i>Inuletum crithmoidis</i>							
	...+	...+		...+	...+	...+		
	<i>Cochleario anglicae</i> - <i>Plantagetum maritimae</i>							
			...+					
	<i>Beto maritimae</i> - <i>Raphanetum landrae</i>							
	...+	o1		...+				

Tab. 89. - *Atriplici prostratae* -*Elymeto atherici* geopermasigmetum

Observer	K Cianfaglione															
Estuary	Laïta															
Departement/Province	Finistère	Morbihan	Finistère	Finistère	Morbihan	Morbihan	Morbihan	Finistère	Morbihan	Finistère	Morbihan	Finistère	Finistère	Finistère	Finistère	Finistère
Ecological range	A		B				C		D				E			
Salinity compartment	Euhaline		Polyhaline				Mesohaline		Oligohaline				Fresh water			
Syneleve number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Date	9-08-2015	10-08-2015	11-08-2015	12-08-2015	13-08-2015	14-08-2015	15-08-2015	16-08-2015	17-08-2015	18-08-2015	19-08-2015	20-08-2015	22-08-2015	23-08-2015	28-08-2015	29-08-2015
Site range	Poite du Chemin du Mât Flotte (Cohars-Carnot) - Kerrou	Gaël-Plages - Kerbrest	Kerrou - St. Germain	St. Germain - St. Maurice	Kerbrest - Pont D 224	Pont D 224 - Kerboat Bémol	Kerboat Bémol - Pvières	St. Maurice - Ruisseau du Froul	Pvières - Locmaria	Ruisseau du Froul - Route forestière du Château	Locmaria - Quimperlé	Route forestière du Château - Quimperlé	Quimperlé - Moulin de Billiguet	Moulin de Billiguet - Quimperlé	Quimperlé - Le Moulin de la Motte	Le Moulin de la Motte - Quimperlé
Surface (ha)	0,1	2	0,2	0,2	0,2	1	5	6	2	2	0,5	0,5	0,1	0,1	0,1	0,1
Total phanerogame recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Average exposition	S	SW	SW	S	NE	N	NE	SW	NW	SE	SW	NE	NW	SE	NW	SE
Syntax number	10	12	14	14	14	14	6	11	12	14	11	11	8	8	8	8
Average altitude range (masl)	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	2-10	2-10	2-10	2-10	3-10	3-10	3-10	3-10
Lower major riverbed																
Forests	<i>Salix atrocinerea</i> forests community															
	...	...	o 1	o 1	o 1	o 1	...	...	o 2	o 2	o 2	o 2	o 2	o 2	o 2	o 2
	<i>Filipendulo ulmariae - Ainetum glutinosae</i>															
Shrubs	o 3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Meadows	<i>Atriplici hastatae-Agropyretum repentis</i>															
	...	...	/2	...	/2	...	...	...	...	...	...	...	...	...	...	...
	<i>Atriplici prostratae-Elymetum atherici</i>															
	...	o 2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	<i>Beto mariumae-Raphanetum landrae</i>															

	<i>Epilobio hirsuti - Convolvuletum sepium</i>															

	<i>Helosciadatum nodiflori</i>															

	<i>Holco mollis - Pteridietum aquilini</i>															

	<i>Juncus effusus and Agrostis stolonifera meadows</i>															

	<i>Lolium perennis - Plantaginetum majoris</i>															

	<i>Phalaridetum arundinaceae</i>															

	<i>Phragmitetum communis</i>															
	...	...	...	o 2	...	o 2	o 3	o 3	o 3	o 3	o 3	o 3	...	...	...	...
	<i>Rorippo sylvestris - Phalaridetum arundinaceae</i>															
	...	...	...	...	...	...	o 2	o 2	/1	/1	...	...	...	...	...	...
	<i>Scirpetum maritimi</i>															

	<i>Urtico dioicae - Convolvuletum sepium</i>															

	<i>Daecylis glomerata and Daucus carota meadows</i>															

	<i>Cochleario aestuarii - Scirpetum compacti</i>															

	<i>Ranunculetum ophioglossifoli</i>															

	<i>Lysimachio vulgaris-Filipenduletum ulmariae</i>															

	<i>Valeriano officinalis - Filipenduletum ulmariae</i>															

	<i>Persicario hydropiperis - Bidentetum tripartitae</i>															

	<i>Caricetum acutiformis</i>															

	Others secondary meadows															
	...	...	...	...	...	...	...	...	...	...	...	...	o 2	o 2	...	...
	Cultivated and Urbanised surfaces															
	O 1	O 1	...	...	...	...	...	...	...	...	...	...	O 2	O 2	O 2	O 1

Tab. 90. - *Salix atrocinerea* forests community geosigmetum

	Observer	K Cianfaglione									
	Estuary	Laïta									
Departement/Province	Morbihan	Finistère	Morbihan	Finistère	Morbihan/ Finistère	Finistère	Finistère	Finistère	Finistère	Finistère	Finistère
Ecological range	C		D				E				
Salinity compartment	Mesohaline		Oligohaline				Fresh water				
Syneleve number	7	8	9	10	11	12	13	14	15	16	
Date	15-08-2015	16-08-2015	17-08-2015	18-08-2015	19-08-2015	20-08-2015	22-08-2015	23-08-2015	28-08-2015	29-08-2015	
Site range	Kerhoat Bénéol – Pivières	St. Maurice – Ruisseau du Front	Pivières – Locmaria	Ruisseau du Front – Route forestière du Chateau	Locmaria – Quimperlé	Route forestière du Chateau – Quimperlé	Quimperlé – Moulin de Hilliguet	Moulin de Hilliguet – Quimperlé	Quimperlé – Le Moulin de la Mothe	Le Moulin de la Mothe – Quimperlé	
Surface (ha)	0,1	0,1	1	1	10	10	0,2	0,2	0,2	0,2	
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	
Average exposition	NE	SW	NW	SE	SW	NE	NW	SE	NW	SE	
Syntaxa number	15	15	3	3	3	3	3	3	3	3	
Average altitude range (masl)	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	0-7	
Lower major riverbed											
Forests	<i>Salicetum fragilis</i>										
Pre-forest	<i>Salix atrocinerea</i> forests community										
Shrubs	<i>Ulici europaei-Prunetum spinosae</i>										
Meadows	<i>Epilobio hirsuti - Convolvuletum sepium</i>										
	<i>Holco mollis - Pteridietum aquilini</i>										
	<i>Juncus effusus</i> and <i>Agrostis stolonifera</i> meadows										
	<i>Lolium perennis - Plantaginatum majoris</i>										
	<i>Phalaridetum arundinaceae</i>										
	<i>Rorippo sylvestris - Phalaridetum arundinaceae</i>										
	<i>Persicario hydropiperis - Bidentetum tripartitae</i>										
	<i>Phragmitetum communis</i>										
	<i>Scirpetum maritimi</i>										
	<i>Urtico dioicae - Convolvuletum sepium</i>										
	<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows										
	<i>Pulicario dysentericae - Juncetum inflexi</i>										
	<i>Cirsio palustris - Juncetum effusi</i>										
	Others secondary meadows										
	Cultivated and Urbanised surfaces										

Tab. 91. - *Saliceto fragilis* sigmetum

	Observer	K Cianfaglione															
	Estuary	Laïta															
Departement/Province	Finistère	Morbihan	Finistère	Finistère	Morbihan	Morbihan	Morbihan	Finistère	Morbihan	Finistère	Morbihan/ Finistère	Finistère	Finistère	Finistère	Finistère	Finistère	
Ecological range	A		B				C		D				E				
Salinity compartment	Euhaline		Polyhaline				Mesohaline		Oligohaline				Fresh water				
Syneleve number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Date	9-08-2015	10-08-2015	11-08-2015	12-08-2015	13-08-2015	14-08-2015	15-08-2015	16-08-2015	17-08-2015	18-08-2015	19-08-2015	20-08-2015	22-08-2015	23-08-2015	28-08-2015	29-08-2015	
Site range	Pointe du Chemin de Mat Plage – Kerrou	Gaudez-Plages – Kerbrest	Kerrou – St. Germain	St. Germain – St. Maurice	Kerbrest – Pont D 224	Pont D 224 – Kerhoat Bénéol	Kerhoat Bénéol – Pivières	St. Maurice – Ruisseau du Front	Pivières – Locmaria	Ruisseau du Front – Route forestière du Chateau	Locmaria – Quimperlé	Route forestière du Chateau – Quimperlé	Quimperlé – Moulin de Hilliguet	Moulin de Hilliguet – Quimperlé	Quimperlé – Le Moulin de la Mothe	Le Moulin de la Mothe – Quimperlé	
Surface (ha)	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,5	2	5	60	50	0,1	0,1	0,1	0,1	
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Average exposition	S	SW	SW	S	NE	N	NE	SW	NW	SE	SW	NE	NW	SE	NW	SE	
Syntaxa number	8	5	5	5	6	6	6	6	7	5	8	7	9	8	8	8	
Average altitude range (masl)	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	
Upper major riverbed																	
Forests	<i>Fraxinus excelsior</i> forest community																
Pre-forests	<i>Salix atrocinerea</i> forests community																
Shrubs	<i>Ulici europaei-Prunetum spinosae</i>																
Meadows	<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows																
	<i>Holco mollis - Pteridietum aquilini</i>																
	<i>Lolium perennis - Plantaginatum majoris</i>																
	<i>Lolium perennis - Plantaginatum coronopidis</i>																
	<i>Phragmitetum communis</i>																
	<i>Pulicario dysentericae - Juncetum inflexi</i>																
	<i>Cirsio palustris - Juncetum effusi</i>																
	Others secondary meadows																
	Cultivated and Urbanised surfaces																

Tab. 92. - *Fraxinus excelsior* forest geosigmetum

	Observer	K Cianfaglione			
	Estuary	Laïta			
	Departement/Province	Finistère			
	Ecological range	E			
	Salinity compartment	Fresh water			
	Syneleve number	13	14	15	16
	Date	22-08-2015	23-08-2015	28-08-2015	29-08-2015
	Site range	Quimperlé – Moulin de Hilliguet	Moulin de Hilliguet – Quimperlé	Quimperlé – Le Moulin de la Mothe	Le Moulin de la Mothe – Quimperlé
	Surface (ha)	1	1	1	1
	Total phanerogamic recovery (%)	40	40	60	60
	Average exposition	NW	SE	NW	SE
	Syntaxa number	3	3	3	3
	Average altitude range (m asl)	1 - 12	1 - 12	1 - 12	1 - 12
Small riverbed	<i>Lemnetum minoris</i>	... 1	... 1	... 1	... 1
	<i>Potametum natantis</i>	... 1	... 1	o 1	o 1
	<i>Potametum crispum</i>	... 1	... 1	o 1	o 1

Tab. 93. - *Lemnetum minoris* geopermasigmetum

Loire estuary:

Atriplici prostratae -*Elymeto atherici* geopermasigmetum 26

Salix atrocineria forests community geosigmetum 61

Saliceto fragilis sigmetum 47

Saliceto albae sigmetum 59

Fraxinus excelsior forest geosigmetum 40

Lemnetum minoris geopermasigmetum 12

Observer	K Cuanflagione														
Estuary	Loire														
Departement/Province	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique
Ecological range	A			B					C						
Salinity compartment	Euhaline			Polyhaline					Mesohaline						
Syneleve number	Lo1	Lo2	Lo3	Lo4	Lo5	Lo6	Lo7	Lo8	Lo9	Lo10	Lo11	Lo12	Lo13	Lo14	Lo15
Date	16/04-2015	17/04-2015	18/04-2015	19/04-2015	20/04-2015	21/04-2015	22/04-2015	22/04-2015	23/04-2015	24/04-2015	25/04-2015	26/04-2015	27/04-2015	28/04-2015	29/04-2015
Site range	Poite St. Gilles - St. Michel Chef - Chef	St. Michel Chef - Pont D213	Pointe de Chemoulin - St. Nazaire	St. Nazaire - Danges	Danges - Layon sur Loire	Layon sur Loire - Rohars	Pont D213 - Paimboeuf	Paimboeuf - La Cramaudais	Rohars - Cordemais	Cordemais - L'Angle	L'Angle - Eter de la Guepette	Eter de la Guepette - Eter de la Musee	La Cramaudais - Le Migron	Le Migron - Ile de Massereau	Ile de Massereau - Canal du Buzay
Surface (ha)	15	15	20	15	700	450	50	40	70	40	30	200	350	300	150
Total phanerogamic recovery (%)	30	30	20	90	90	90	90	90	90	90	90	90	90	90	90
Average exposition	NW	NW	SE	SE	SW	SW	NW	NE	SE	SW	SW	SW	NW	NE	NE
Syntaxa number	8	7	5	13	18	13	10	16	0	0	0	0	0	0	0
Average altitude range (masl)	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
Slikke	<i>Spartinetum maritima</i>														
	<i>Spartinetum anglicae</i>														
	Macroalgal community														
Lower Shore	<i>Bostrychio scorpioidis-Halimionetum portulacoidis</i>														
	Macroalgal community														
Middle Shore	<i>Juncetum gerardii</i>														
	<i>Gratiolo officinalis - Oenanthetum fistulosae</i>														
	<i>Oenanthe peucedanifoliae-Brometum racemosi</i>														
	<i>Ranunculetum ophioglossifolii</i>														
	<i>Ranunculo ophioglossifolii - Oenanthetum fistulosae</i>														
	<i>Senecioni aquatici - Oenanthetum mediae</i>														
	<i>Trifolio maritimi - Oenanthetum silaifoliae</i>														
	<i>Aptio nodiflori - Eleocharitetum amphibiae</i>														
	Macroalgal community														
High shore	<i>Juncetum maritimi-Caricetum extensa</i>														
	<i>Oenanthe lachenalii - Juncetum maritimi</i>														
	<i>Festuco littoralis-Juncetum gerardii</i>														
	<i>Festucetum littoralis</i>														
	<i>Astero tripolium-Agrostietum stoloniferae</i>														
Very high shore	<i>Atriplici prostratae - Elymetum atherici</i>														
	<i>Beto maritima - Agropyretum pungentis</i>														
	<i>Beto maritima-Raphanetum landrae</i>														
	<i>Beto maritima-Atriplicetum prostratae</i>														
	<i>Atriplici hastatae-Agropyretum repentis</i>														
	<i>Hordeo secalini - Lolietum perennis</i>														
	<i>Scirpetum maritimi</i>														
	<i>Astero tripolii - Phragmitetum australis</i>														
	<i>Scirpetum triquetri</i>														
	<i>Ranunculetum bandorii</i>														
	<i>Zannichelletum obtusifoliae</i>														

Tab. 94. - *Atriplici prostratae - Elymeto atherici* geopermasigmetum

Observer		K Cianfaglione																
Estuary		Loire																
Departement/Province		Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	
Ecological range		A		B				C						D				
Salinity compartment		Euhaline		Polyhaline				Mesohaline						Oligohaline				
Syneleve number		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Date		18-04-2015	19-04-2015	20-04-2015	21-04-2015	22-04-2015	22-04-2015	23-04-2015	24-04-2015	25-04-2015	26-04-2015	27-04-2015	28-04-2015	29-04-2015	30-04-2015	1-05-2015	3-05-2015	5-05-2015
Site range		Pointe de Chénouin - St Nazaire	St Nazaire - Donges	Donges - Lavau sur Loire	Lavau sur Loire - Rohars	Pont D213 - Paimboeuf	Paimboeuf - La Craudais	Rohars - Cordemais	Cordemais - L'Angle	L'Angle - Etier de la Giquelais	Etier de la Giquelais - Etier de la Musée	La Craudais - Le Migron	Le Migron - Ile du Massereau	Ile du Massereau - Canal du Buzay	Canal du Buzay - Le Pellerin	Etier de la Musée - Couëron	Couëron - Nantes	Le Pellerin - Rezé
Surface (ha)		10	100	200	100	1	1	100	100	100	100	200	200	100	100	10	1	0,1
Total phanerogamic recovery (%)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Average exposition		SE	SE	SW	SW	NW	NE	SE	SW	SW	SW	NW	NE	NE	NE	SW	S	N
Syntax number		11	10	12	14	12	12	14	14	14	15	14	14	14	14	14	14	15
Lower major riverbed		Average altitude range (masl)		0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	2-10	2-10	2-10	2-10
Forests	<i>Salicetum fragilis</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
Pre-forests	<i>Salix atrocinerea</i> forests community	...+	O1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...+
Shrubs	<i>Solano dulcamarae - Tamaricetum gallicae</i>	...+																
	<i>Ulici europaei-Prunetum spinosae</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
Meadows	<i>Alopecuro pratensis — Cynosuretum cristati</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Anthriscetum sylvestris</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Apio nodiflori – Eleocharitetum amphibiae</i>												...+	...+	...+	...+	...+	...+
	<i>Arctio lappae - Artemisietum vulgare</i>				...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Calystegio sepium-Angelicetum heterocarphae</i>				...+				...+		...+	...+	...+	...+	...+	...+	...+	...+
	<i>Caricetum acutiformis</i>			...+														...+
	<i>Caricetum ripariae</i>																	...+
	<i>Caricetum ripario – acutiformis</i>										...+							
	<i>Convolvulo arvensis – Elytrigietum repentis</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Dactylido glomeratae - Festucetum arundinaceae</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Dactylis glomerata and Daucus carota meadows</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Eleocharito palustris - Oenanthetum fistulosae</i>			...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Epilobio hirsuti - Convolvuletum sepium</i>								...+									
	<i>Glycerietum maximae</i>				...+		...+	...+	...1	...1	...1	...1	...1	...+	...+	...1	...+	...1
	<i>Gratiolo officinalis - Oenanthetum fistulosae</i>						...+							...+	...+	...1	...+	...1
	<i>Heracleo sphondylii - Rumicetum obtusifolii</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Heracleo sphondylii-Brometum mollis</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Hordeetum murinum</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Hordeo secalini - Lolietum perennis</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Iridetum pseudacori</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Juncus effusus and Agrostis stolonifera meadows</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Lolio perennis - Plantaginetum majoris</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Oenanthe peucedanifoliae-Brometum racemosi</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Persicario hydropiperis - Bidentetum tripartitae</i>		...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Phalaridetum arundinaceae</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Phragmitetum communis</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Poo annuae – Plantaginetum coronopidis</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Ranunculetum ophioglossifolii</i>																	
	<i>Ranunculo ophioglossifolii – Oenanthetum fistulosae</i>									...+								
	<i>Ranunculo sardoii – Myosuretum minimi</i>									...+	...+							
	<i>Rumici maritimi-Ranunculetum scelerati</i>				...+													
	<i>Scirpetum maritimi</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Senecioni aquatici - Oenanthetum mediae</i>	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Sisymbrio officinalis – Hordeetum murinum</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Torilidetum japonicae</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Trifolio maritimi- Oenanthetum silaifoliae</i>		...+	...+			...+											
	<i>Typhetum angustifolii</i>							...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Typhetum latifoliae</i>							...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Urtico dioicae - Convolvuletum sepium</i>	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Junco acutiflori – Cynosuretum cristati</i>									...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Pulicario dysentericae – Juncetum inflexi</i>									...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Cirsio palustris – Juncetum effusi</i>									...+	...+	...+	...+	...+	...+	...+	...+	...+
	Others secondary meadows																	
	Cultivated and Urbanised surfaces	O1	O1	O1	O1	O1	O1	O2	O2	O1	O1	O1	O1	O1	O1	O1	O2	O2

Tab. 95. - *Salix atrocinerea* forests community geosigmetum

Observer	K Canfaghone													
	Loire													
Estuary	Loire													
Departement/Province	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Maine et Loire	Loire-Atlantique	Loire-Atlantique	Maine et Loire	Loire-Atlantique	Maine et Loire	Maine et Loire	Maine et Loire	Maine et Loire	Maine et Loire
Ecological range	D							E						
Salinity compartment	Oligohaline							Fresh water						
Syneleve number	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Date	5-05-2015	5-05-2015	6-05-2015	7-05-2015	8-05-2015	9-05-2015	10-05-2015	11-05-2015	12-05-2015	13-05-2015	14-05-2015	3-06-2015	3-06-2015	3-06-2015
Site range	Confrom - Nantes	Le Pellerin - Rezé	Rezé - Vertou	Vertou - Basses-Goulaines	Basses-Goulaines - La Varenne	Nantes - Le Cellier	Le Cellier - Ancenis	La Varenne - Liré	Ancenis - Ingrandes	Liré - St Florent le Vieil	St Florent le Vieil - Mouton sur Loire	Mouton sur Loire - Murs - Erigné	Ingrandes - Lac de Maine	Les Ponts de Cé - La Baumette (Angers)
Surface (ha)	10	10	1	1	10	20	10	10	10	10	10	10	10	10
Total phanerogamic recovery (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Average exposition	S	N	NE	SW	NW	SE	SE	NW	SE	NW	NW	NW	SE	E
Syntaxa number	5	7	6	4	4	4	6	7	7	7	6	6	4	4
Lower major riverbed	Average altitude range (masl)													
	2-10	2-10	3-10	4-10	5-10	6-10	3-10	3-10	3-10	3-10	4-10	5-10	6-10	8-10
Forests	<i>Salicetum albae</i>	O 2	O 2	/4	/4	O 2	O 1	O 2	O 3	O 3	O 2	O 3	O 2	O 1
Pre-forests	<i>Salix atrocinerea</i> forests community	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1
	<i>Salicetum purpureae</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
Shrubs	<i>Salicetum triandro-viminalis</i>	... 1	... 1	... 1	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Ulici europaei-Prunetum spinosae</i>						... +	... +	... +	... +	... +	... +	... +	... +
	<i>Calystegio sepium - Aristolochietum clematitidis</i>		... 1	... 1										
Meadows	<i>Portulaco oleraceae - Amaranthetum deflexi</i>						... +	... +	... +	... +				
	<i>Sparganietum erecti</i>		... +											
	<i>Alopecuro pratensis - Cynosuretum cristati</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Anthriscetum sylvestris</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Apio nodiflori - Eleocharitetum amphibiae</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Arctio lappae - Artemisietum vulgaris</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Calystegio sepium-Angelicetum heterocarphae</i>	... +	... +											
	<i>Caricetum acutiformis</i>	... +	... +											
	<i>Caricetum ripariae</i>		... +					... +						
	<i>Caricetum ripario - acutiformis</i>									... +				
	<i>Convolvulo arvensis - Elytrigietum repentis</i>	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1
	<i>Cypero longi-Caricetum otrubae</i>		... +											
	<i>Dactylido glomeratae - Festucetum arundinaceae</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Dactylis glomerata and Daucus carota meadows</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Eleocharito palustris - Oenanthetum fistulosae</i>	... +	... +											
	<i>Epilobio hirsuti - Convolvuletum sepium</i>	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1
	<i>Glycerietum maximae</i>	... +	... +						... +					
	<i>Gratiolo officinalis - Oenanthetum fistulosae</i>	... +	... +											
	<i>Helosciadetum nodiflori</i>		... +											
	<i>Heracleo sphondylii - Rumicetum obtusifolii</i>								... +	... +	... +	... +	... +	... +
	<i>Heracleo sphondylii-Brometum mollis</i>					... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Holco mollis - Pteridietum aquilini</i>								... +	... +	... +	... +	... +	... +
	<i>Hordeetum murinum</i>					... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Hordeo secalini - Lolietum perennis</i>					... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Iridetum pseudacori</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Juncus effusus and Agrostis stolonifera meadows</i>	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1
	<i>Lolio perennis - Plantaginetum majoris</i>	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1
	<i>Lysimachio vulgaris-Filipenduletum ulmariae</i>	... +	... +					... +	... +	... +	... +	... +	... +	... +
	<i>Melilotetum albo - officinalis</i>		... +					... +	... +	... +	... +	... +	... +	... +
	<i>Oenanthe peucedanifoliae-Brometum racemosi</i>	... +	... +					... +	... +	... +	... +	... +	... +	... +
	<i>Persicario hydropiperis - Bidentetum tripartitae</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Phalaridetum arundinaceae</i>	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1
	<i>Phragmitetum communis</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Poo annuae - Plantaginetum coronopidis</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Portulaco oleraceae - Amaranthetum deflexi</i>						... +	... +	... +	... +	... +	... +	... +	... +
	<i>Ranunculetum ophioglossifolii</i>		... +											
	<i>Ranunculo ophioglossifolii - Oenanthetum fistulosae</i>	... +												
	<i>Rorippo sylvestris - Phalaridetum arundinaceae</i>		... +	... +	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1
	<i>Sambucetum ebuli</i>		... +											
	<i>Schoenoplectetum tabernaemontani</i>		... +											
	<i>Scirpetum lacustris</i>													... +
	<i>Scirpetum maritimi</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Scirpetum triquetri</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Senecioni aquatici - Oenanthetum mediae</i>	... 1	... +					... +	... +	... +	... +	... +	... +	... +
	<i>Sisymbrio officinalis - Hordeetum murinum</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Torilidetum japonicae</i>	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	<i>Typhetum angustifolii</i>	... +	... +											
	<i>Typhetum latifoliae</i>	... +	... +											
	<i>Urtico dioicae - Convolvuletum sepium</i>	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1	... 1
	<i>Valeriano officinalis - Filipenduletum ulmariae</i>		... +											
	Others secondary meadows	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +	... +
	Cultivated and Urbanised surfaces	O 2	O 2	O 1	O 1	O 3	O 2	O 1	... 1	... 1	... 1	... 1	O 2	O 2
	<i>Juncus acutiflori - Cynosuretum cristati</i>				... +	... +			... +	... +	... +	... +	... +	... +
	<i>Pulicario dysentericae - Juncetum inflexi</i>				... +	... +			... +	... +	... +	... +	... +	... +
	<i>Cirsio palustris - Juncetum effusi</i>				... +	... +			... +	... +	... +	... +	... +	... +

Tab. 97. - *Salicetum albae sigmetum*

Observer		K Canfigliere																												
Estuary		Loire																												
Department/Province		Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Loire-Atlantique	Maine et Loire	Loire-Atlantique	Loire-Atlantique	Maine et Loire	Loire-Atlantique	Maine et Loire	Maine et Loire	Maine et Loire	Maine et Loire		
Ecological range		A			B					C					D					E										
Salinity compartment		Euhaline		Polyhaline					Mesohaline					Oligohaline					Fresh water											
Synechro number		3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Date		18-04-2015	19-04-2015	20-04-2015	21-04-2015	22-04-2015	23-04-2015	24-04-2015	25-04-2015	26-04-2015	27-04-2015	28-04-2015	29-04-2015	30-04-2015	1-05-2015	3-05-2015	5-05-2015	6-05-2015	7-05-2015	8-05-2015	9-05-2015	10-05-2015	11-05-2015	12-05-2015	13-05-2015	14-05-2015	3-08-2015	3-08-2015	3-08-2015	
Site range		Pointe de Chémoulin – St. Nazaire	St. Nazaire – Donges	Donges – Lavau sur Loire	Lavau sur Loire – Rohars	Paimboeuf – La Craudaudais	Rohars – Cordemais	Cordemais – L'Angle	L'Angle – Eter de la Giquedais	Eter de la Giquedais – Eter de la Musse	La Craudaudais – Le Migron	Le Migron – Ile du Massereau	Ile du Massereau – Canal du Buzay	Canal du Buzay – Le Pellerin	Eter de la Musse – Couëron	Couëron – Nantes	Le Pellerin – Rezé	Rezé – Vertou	Vertou – Basse-Goulaine	Basse-Goulaine – La Varenne	Nantes – Le Cellier	Le Cellier – Ancenis	La Varenne – Liré	Ancenis – Ingrandes	Liré – St. Florent le Vieil	St. Florent le Vieil – Montjean sur Loire	Montjean sur Loire – Murs Erigine	Ingrandes – Lac de Maine	Les Ponts de Cé – La Baumette (Angers)	
Surface (ha)		0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	1	1	1	1	1	1	1	1	1	1	1	
Total phanerogamic recovery (%)		20	20	40	+	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	60	60	60	60	60	60	60	
Average exposition		SE	SE	SW	SW	NE	SE	SW	SW	NW	NE	NE	NE	SW	S	N	NE	SW	NW	SE	SE	SE	SE	NW	SE	NW	SE	SE	E	
Syntaxa number		3	3	5	5	6	5	5	5	5	5	5	5	5	5	0	0	0	1	6	6	2	5	2	2	5	3	5		
Average altitude range (masl)		1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	1-12	
Small riverbed	<i>Ceratophyllum demersi</i>																													
	<i>Elodea canadensis</i>																													
	<i>Lemnetum minoris-Spirodeletum polyrhizae</i>	...1	...1	...1	...+	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Lemnetum minoris</i>	...1	...1	...1	...+	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Lemnetum minoris - Azolletum filiculoidis</i>	...1	...1	...1	...+	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1
	<i>Myriophyllum verticillatum</i>																													
	<i>Nymphaea alba-Nuphar lutea</i>																													
	<i>Potamogeton crispus</i>																													
	<i>Potamogeton natans</i>			...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Ranunculetum baudotii</i>			...1	...+	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...1	...+	...+	...+	...+	...+	...+	...+	...+	...+
	<i>Ruppium maritimum</i>																													
	<i>Zannichellium obtusifolium</i>					..+																								

Tab. 99. - *Lemnetum minoris* geopermasigmetum

Vilaine:

Atriplici prostratae -Elymeto atherici geopermasigmetum 16

Salix atrocinnerea forests community geosigmetum 19

Saliceto fragilis sigmetum 0

Saliceto albae sigmetum 0

Fraxinus excelsior forest geosigmetum 8

Lemneto minoris geopermasigmeto 0

	Observer	K Cianfaglione			
	Estuary	Vilaine			
	Departement/Province	Morbihan			
	Ecological range	A			
	Salinity compartment	Euhaline			
	Syneleve number	V1	V2	V3	V4
	Date	15-09-2015	16-09-2015	17-09-2015	20-09-2015
	Site range	Penn Lann – Bourgerel	Pointe du Halignen – Tréguier	Tréguier – Barrahe d'Arzal	Bourgerel – Barrage d'Arzal
	Surface (ha)	30	30	30	30
	Total phanerogamic recovery (%)	80	80	80	80
	Average exposition	W	NE	SE	NW
	Syntaxa number	16	13	16	13
	Average altitude range (masl)	0 - 5	0 - 5	0 - 5	0 - 5
Slikke	<i>Astero tripolium-Agrostietum stoloniferae</i>	...+	...+	...+	
	<i>Salicornietum fragilis</i>	...+			
	Macroalgal community	O2	O2	O2	O2
Lower Shore	<i>Salicornietum disarticulato-ramosissimae</i>	...+			
	<i>Bostrychio scorpioidis-Halimionetum portulacoidis</i>	...1	...1	...1	...1
	<i>Puccinellietum maritimae</i>	...+	...+	...+	...+
	Macroalgal community	O1	O1	O1	O1
Middle Shore	<i>Festucetum littoralis</i>			...+	...+
	<i>Festuco littoralis-Juncetum gerardii</i>			...+	...+
	<i>Juncetum gerardii</i>				...+
	<i>Astero tripolium-Suaedetum maritimae</i>	...+	...+	...+	...+
	Macroalgal community	...+	...+	...+	
Very high shore	<i>Agropyro pungentis-Inuletum crithmoidis</i>	...+	...+	...+	
	<i>Agropyro pungentis-Suaedetum verae</i>	/1			
	<i>Astero tripolii – Phragmitetum australis</i>			...+	...+
	<i>Atriplici hastatae-Agropyretum repentis</i>	/1	/1	/1	/1
	<i>Atriplici prostratae -Elymetum atherici</i>	/1	/1	/1	/1
	<i>Beto maritimae - Agropyretum pungentis</i>	/+	/+	/+	
	<i>Beto maritimae-Raphanetum landrae</i>	...+	...+	...+	...+
	<i>Scirpetum maritimi</i>	...1	...1	/1	...1

Tab. 100. - *Atriplici prostratae -Elymeto atherici* geopermasigmetum

	Observer	K Cianfaglione			
	Estuary	Vilaine			
	Departement/Province	Morbihan			
	Ecological range (Salinity compartment)	A			
		Euhaline			
	Geopermasyneleve number	V1	V2	V3	V4
	Date	15-9-2015	16-09-2015	17-09-2015	20-09-2015
	Site range	Penn Lann – Bourgerel	Pointe du Halignen – Tréguier	Tréguier – Barrahe d'Arzal	Bourgerel – Barrage d'Arzal
	Surface (ha)	1	1	1	1
	Total phanerogamic recovery (%)	100	100	100	100
	Average exposition	SW	NE	S	N
	Syntaxa number	17	20	17	13
Lower major riverbed	Average altitude range (masl)	1 - 12	1 - 12	1 - 12	1 - 12
Forests	<i>Salix atrocinerea</i> forests community	...+	...+	...+	...+
Shrubs	<i>Ulici europaei-Prunetum spinosae</i>	...1	...1	...1	...1
Meadows	<i>Astero tripolii – Phragmitetum australis</i>	...r	...r		
	<i>Atriplici hastatae-Agropyretum repentis</i>	...1	...1	...1	...1
	<i>Atriplici prostratae -Elymetum atherici</i>	...+	...+	...+	...+
	<i>Beto maritimae-Raphanetum landrae</i>	...+	...+	...+	
	<i>Festucetum littoralis</i>	...+	...+	...+	...+
	<i>Holco mollis – Pteridietum aquilini</i>	...+	...+	...+	...+
	<i>Junco maritimi-Schoenetum nigricantis</i>			...+	
	<i>Juncus effusus</i> and <i>Agrostis stolonifera</i> meadows	...+	...+	...+	...+
	<i>Lolio perennis - Plantaginetum majoris</i>	...+	...+	...+	...+
	<i>Phalaridetum arundinaceae</i>	...+	...+	...+	
	<i>Phragmitetum communis</i>	...1	...1	...1	...1
	<i>Scirpetum maritimi</i>	...1	...1	...1	...1
	<i>Urtico dioicae - Convolvuletum sepium</i>	...1	...1	...1	
	<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows	...+	...1	...1	...1
	<i>Junco acutiflori – Cynosuretum cristati</i>		...+		
	<i>Pulicario dysentericae – Juncetum inflexi</i>		...+		
	<i>Cirsio palustris – Juncetum effusi</i>		...+		
	Others secondary meadows	...+	...+	...+	...+
	Cultivated and Urbanised surfaces	o1	...+	...+	...+

Tab. 101. - *Salix atrocinerea* forests community geosigmetum

	Observer	K Cianfaglione			
	Estuary	Vilaine			
	Departement/Province	Morbihan			
		A			
	Ecological range (Salinity compartment)	Euhaline			
	Geopermasyneleve number	V1	V2	V3	V4
	Date	15-09-2015	16-09-2015	17-09-2015	20-09-2015
	Site range	Penn Lann – Bourgerel	Pointe du Halguen – Tréfiguier	Tréfiguier – Barrahe d'Arzal	Bourgerel – Barrage d'Arzal
	Surface (ha)	1	1	1	1
	Total phanerogamic recovery (%)	100	100	100	100
	Average exposition	SW	NE	S	N
	Syntaxa number	8	8	10	9
Upper major riverbed	Average altitude range (m asl)	1 - 12	1 - 12	1 - 12	1 - 12
Forests	<i>Fraxinus excelsior</i> forest community	...+	...+	...1	...1
Pre-forests	<i>Salix atrocinerea</i> forests community	...+	...+	...+	...+
Shrubs	<i>Ulici europaei-Prunetum spinosae</i>	...1	...1	...1	...1
Meadows	<i>Dactylis glomerata</i> and <i>Daucus carota</i> meadows	...2	...2	...2	...2
	<i>Holco mollis – Pteridietum aquilini</i>			...1	...1
	<i>Lolio perennis - Plantaginetum majoris</i>	...+	...+	...+	...+
	<i>Phragmitetum communis</i>			...1	
	<i>Lolio perennis – Plantaginetum coronopodis</i>	...1	...1	...+	...+
	Others secondary meadows	...1	...1	...1	...1
	Cultivated and Urbanised surfaces	...1	...1	...1	...1

Tab. 102 . - *Fraxinus excelsior* forest geosigmetum

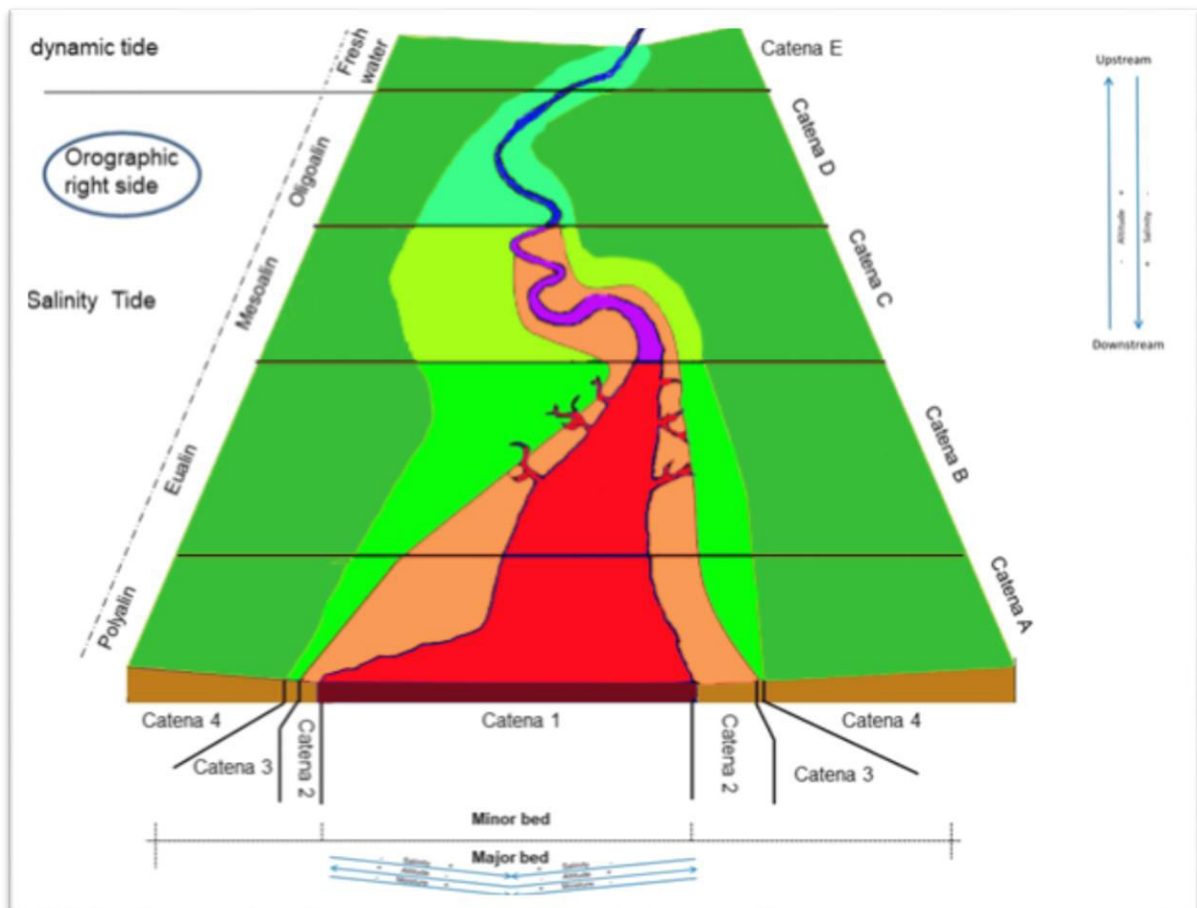


Figure 42 - The theoretical generic ecological compartments (Tessellas) scheme per geo-hydro-morphology sectors adapted to our phytosociological and synphytosociological elaboration.

We propose a second hypothesis scheme (Fig. 42). The scheme show how the previous plant association presence appears if organized following the classification and generalization with synphytosociological criteria.

Series code	Community type	Up-down range																																				
		Eualine							Polyaline							Mesohaline							Oligohaline							Frashwater								
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7		
		Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire	Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire	Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire	Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire	Vilaine	Aulne	Elorn	Blavet-Scorff	Laita	Charente	Loire		
<i>Atriplici hastatae-Agropyretum repentis geopermasigmetum</i>																																						
A, B, C	<i>Salicornietum dolychostachyae</i>						X																															
A, B, C	<i>Agropyro pungentis-Suaedetum verae</i>	X			X																																	
A, B, C	<i>Puccinellio maritimae Salicornietum ramosissimae</i>						X																															
A, B, C	<i>Salicornietum obscurae</i>			X			X																															
A, B, C	<i>Spartinetum alterniflorae</i>		X	X																																		
A, B, C	<i>Salicornietum fragilis</i>	X	X	X	X																																	
A, B, C	<i>Spartinetum anglicae</i>		X	X			X	X								X																						
A, B, C	<i>Spergulario mediae – Salicornietum brachystachyae</i>	X	X	X	X																																	
A, B, C	<i>Salicornietum disarticulato-ramosissimae</i>	X	X	X	X		X																															
A, B, C	<i>Beto maritimae - Agropyretum pungentis</i>	X	X	X	X		X								X																							
A, B, C	<i>Puccinellietum maritimae</i>	X	X	X	X		X		X																													
A, B, C	<i>Bostrychio scorpioidis-Halimionetum portulacoidis</i>	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X		X																	
A, B, C	Macroalgal community	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X		X																		
A, B, C	<i>Limonietum lychnidifolii-dodartii</i>				X																																	
A, B, C	<i>Ruppium maritimae</i>						X																															
A, B, C	<i>Zannichellietum obtusifoliae</i>															X																						
A, B, C	<i>Atriplici hastatae - Betetum maritimae</i>			X																																		
A, B, C	<i>Junco maritimi-Schoenetum nigricantis</i>				X				X																													
A, B, C	<i>Limonietum lychnidifolii-dodartii</i>						X																															
A, B, C	<i>Oenantho peucedanifoliae-Brometum racemosi</i>															X																						
A, B, C	<i>Parapholis strigosae-Hordeetum marini</i>						X																															
A, B, C	<i>Spartinetum maritimae</i>						X	X																														
A, B, C	<i>Typho domingensis-Phragmitetum maximi</i>						X																															
A, B, C	<i>Cochleario anglicae - Plantagnetum maritimae</i>											X	X																									
A, B, C	<i>Triglochino maritimi - Limonietum humilis</i>			X							X																											
A, B, C	<i>Oenantho lachenalii - Juncetum maritimi</i>		X		X		X																															
A, B, C	<i>Plantagini maritimae-Limonietum vulgaris</i>		X		X	X									X																							
A, B, C	<i>Astero tripolii - Phragmitetum australis</i>						X								X												X											
A, B, C	<i>Junco maritimi-Caricetum extensae</i>		X	X	X	X	X		X	X	X	X	X	X	X																							
A, B, C	<i>Silybo mariani-Urticetum piluliferae</i>						X																															
A, B, C	<i>Gratiolo officinalis - Oenanthetum fistulosae</i>															X																						
A, B, C	<i>Ranunculetum ophioglossifolii</i>																																					
A, B, C	<i>Ranunculo ophioglossifolii — Oenanthetum fistulosae</i>															X																						
A, B, C	<i>Scirpetum triquetri</i>																										X	X										
A, B, C	<i>Apio nodiflori – Eleocharitetum amphibiae</i>															X																						
A, B, C	<i>Senecioni aquatici - Oenanthetum mediae</i>															X																						
A, B, C	<i>Ranunculetum baudotii</i>						X								X																							
A, B, C	<i>Trifolio maritimi- Oenanthetum silaifoliae</i>						X								X																							
A, B, C	<i>Agropyro pungentis-Inuletum crithmoidis</i>	X		X	X	X	X				X	X																										
A, B, C	<i>Hordeo secalini - Lolietum perennis</i>						X								X	X																						
A, B, C	<i>Beto maritimae-Atriplicetum prostratae</i>						X	X			X				X	X			X																			
A, B, C	<i>Astero tripolium-Agrostietum stoloniferae</i>	X	X	X	X	X	X			X	X				X	X																						
A, B, C	<i>Festucetum littoralis</i>	X	X	X	X	X	X	X		X	X			X	X	X		X	X																			
A, B, C	<i>Juncetum gerardii</i>	X	X	X	X	X	X			X	X	X	X	X	X		X																					
A, B, C	<i>Astero tripolii – Phragmitetum australis</i>	X	X	X	X					X	X	X	X	X	X		X		X	X																		
A, B, C	<i>Astero tripolium-Suaedetum maritimae</i>	X	X	X	X		X			X	X	X	X	X	X		X	X																				
A, B, C	<i>Beto maritimae-Raphanetum landrae</i>	X	X		X	X	X	X		X	X	X	X	X	X		X	X		X																		
A, B, C	<i>Scirpetum maritimi</i>	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
A, B, C	<i>Atriplici hastatae-Agropyretum repentis</i>	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
A, B, C	<i>Atriplici prostratae -Elymetum atherici</i>	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Tab. 108. - Table of association presence/absence distribution in estuaries per series and ecological compartment (part 4)

In the previous tables, the plant association distribution along estuaries was analyzed by fixing the presence/absence ratio in order to underline the frequency and the placement in the estuarine ecologic compartment. Following this type of elaboration we can represent a zonation of our series and geoseries in transects as follow:

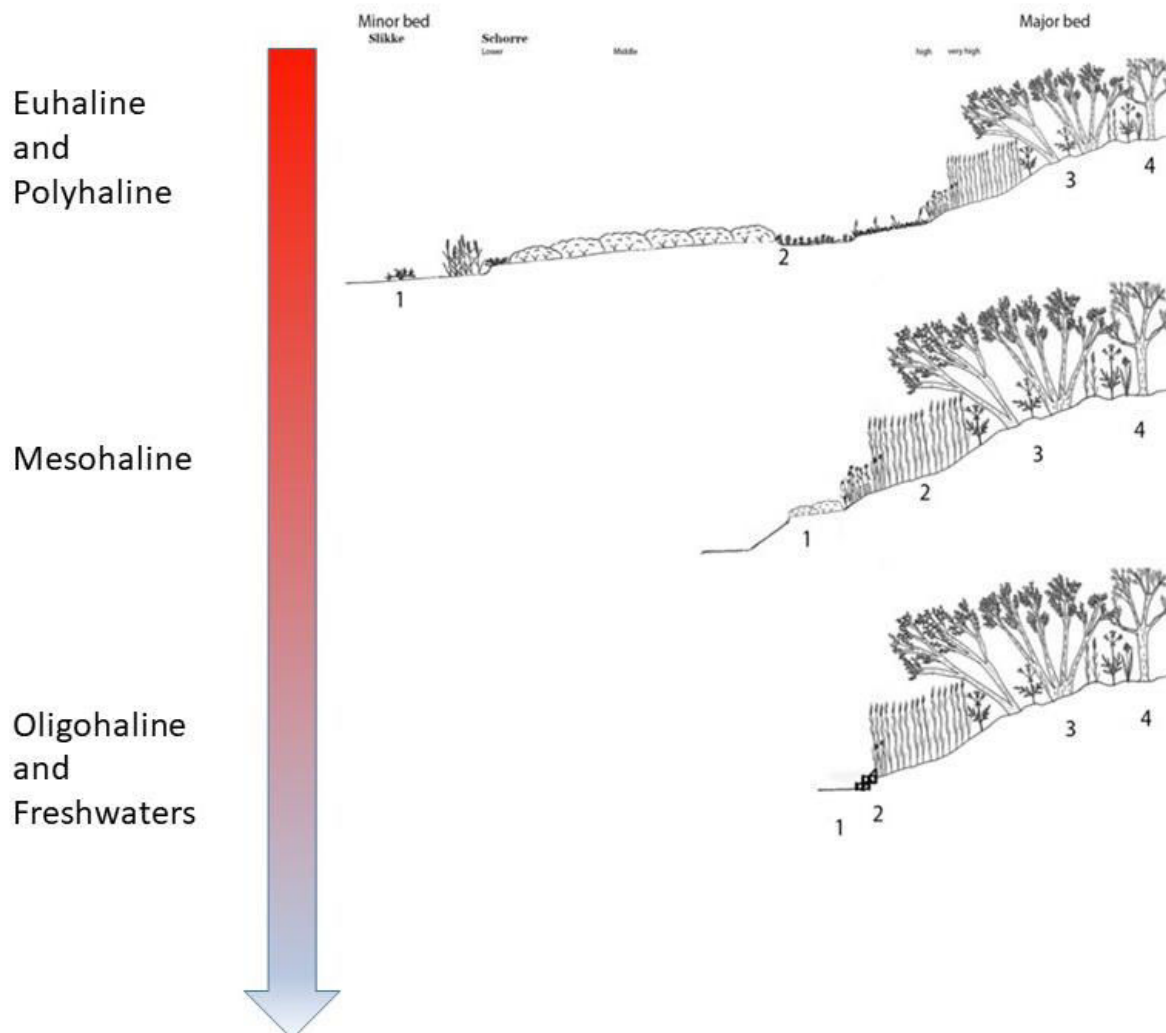


Figure 43. - Series and geoseries transversal distribution variation per salty sector

Following the synphytosociology characteristics, we can group together the salty levels. The mesohaline sector is placed halfway: its lowest level is attributable to the salty vegetation as upper limit. Up, the forest (*Salicetum fragilis*) corresponds to its own series. Uppermost we find the *Fraxinus* forests zone as happening at same level in each sector. In oligohaline and freshwaters in 1 and 2 levels we find the vicariant vegetation as already described, that generally is very linear and linked to the willow forest.

Num ref	Series and geoseries name	Soil type occurrence	Bio-indicator species	Salt compartments
1,2	<i>Atriplici prostratae -Elymeto atherici</i> geopermasigmetum	Mud, sand, pebble, rocks	<i>Atriplex prostrata</i> , <i>Elymus athericus</i> , <i>Scirpus maritimus</i> , <i>Halimione portulacoides</i> , <i>Suaeda maritima</i> , <i>Galatella pannonica</i>	Eu-, poly-, meso-haline
3	<i>Salix atrocinerea</i> forests geosigmetum	Silty to sandy	<i>Salix atrocinerea</i> , <i>Oenanthe crocata</i> , (for marshy facies) <i>Chamaeiris foetida</i> (for mesic facies)	Eu-, poly-, meso-haline
3	<i>Saliceto fragilis</i> sigmetum	Silty to sandy	<i>Salix fragilis</i> , <i>Oenanthe crocata</i>	Meso-, oligo-haline
3	<i>Saliceto albae</i> sigmetum	Silty to sandy	<i>Salix alba</i> , <i>Oenanthe crocata</i>	Oligohaline and Freshwaters
4	<i>Fraxinus excelsior</i> forests geosigmetum	Silty, sandy and stony	<i>Fraxinus excelsior</i> , <i>Ulex europaeus</i> , <i>Daucus carota</i> , <i>Heracleum sphondylium</i> , <i>Arum</i> sp. pl., <i>Chamaeiris foetida</i>	Eu-, poly-, meso-oligo-haline and freswaters
1,2, 3,4	<i>Lemneto minoris</i> geopermasigmetum	Waters	<i>Lemna minor</i> , <i>Azolla</i> sp. pl.	In any sector with ant freshwater accession

Tab. 109. - Table of series and geoseries summarized per abiotic factors and flag species

The previous table (Tab. 109) represents series and geoseries related to soil variations, bio-indicator species and salt compartments. As observed, the soil is not a main factor determining the vegetation expression, as it is known for azonal vegetation. However, the topographic level, the salt and water contents are the main determining factors. The soil or the substrate type is anyway an important influential factor that determines some exceptions (variants) following geomorphological variations.

5.6. Vegetation models

5.6.1. Vegetation Series maps

Following the previous vegetation tables, we provide a synphytosociological mapping of Aulne, Laita, and Loire estuaries looking to provide a more accurate vegetation series spatialization. These estuaries have been chosen as study samples for that purposes, because of their geographical, geomorphological, bioclimatological and synphytosociological representativeness as seen during our chapters up to here. In one hand, these estuaries have some important natural characteristics, and in other hand, they shows a remarkable human impact on vegetation series expression in larges surfaces.

Aulne estuary represents a good example in size for small estuaries, and for it geomorphology (mainly mud type) and hydro-dynamics. This estuary represent also a good example of north

estuary for its climatic and bioclimatic characteristics, and a good sample about plant association diversity and distribution.

Laïta estuary for the same reasons represent a good example, but it is from sandy type, it represent a good sample for its central placement and for the confinement observations by rocky outcrops.

Loire estuary represent a good example of large estuary. About climatic issues, it represent a good example of hottest and drier condition. In the geographical placement, the Loire delimits the southern portion of the Armorican peninsula (and massif).

The patches that corresponds to series and geoseries represent the land surfaces (Tessellas) where statistically we have the most possibility to find out the expected vegetation potential and related sigma combinations. This is mainly remarkable in mobile substrate conditions like in water, banks, slikke and Schorre conditions - where vegetation settlement is often fragmented, discontinuous and variable depending on seasons and yearly: representing in any case a potential surface, even if the possibility to find vegetation is lesser and the bare soil (substrate) opportunity is higher.

Estuary	Hectares
Elorn	492
Étel	3940
Blavet-Scorff	3652
Aulne	3266
Loire	70706
Laïta	461
Charente	14453
Vilaine	1345
Total	98315

Tab. 110 - Surface of fieldworks per each studied estuaries.

Series, geoseries and waters vegetation	Aulne		Loire		Laïta	
	ha	%	ha	%	ha	%
1 Salty waters	2341	71.7	13747	19.4	186	40.3
2 Brackish waters	154	4.7	1279	1.8	33	7.2
3 Freshwaters	18	0.6	3680	5.2	28	6.1
4 <i>Atriplici prostratae</i> - <i>Elymetum aterici</i> geopermaseries	662	20.3	2553	3.6	91	19.7
5 <i>Salicetum albae</i> holoseries	-	-	4437	6.3	-	-
6 <i>Salix atrocineria</i> forests geoseries	91	2.8	4519	6.4	50	10.8
7 <i>Salicetum fragilis</i> holoseries	-	-	4929	7.0	73	15.8
8 <i>Fraxinus excelsior</i> forests geoseries	168	5.1	35562	50.3	132	28.6
Part. tot.	3266		70706		461	TOT. 74433

Tab. 111 - Surface of vegetation series and geoseries per mapped estuaries.

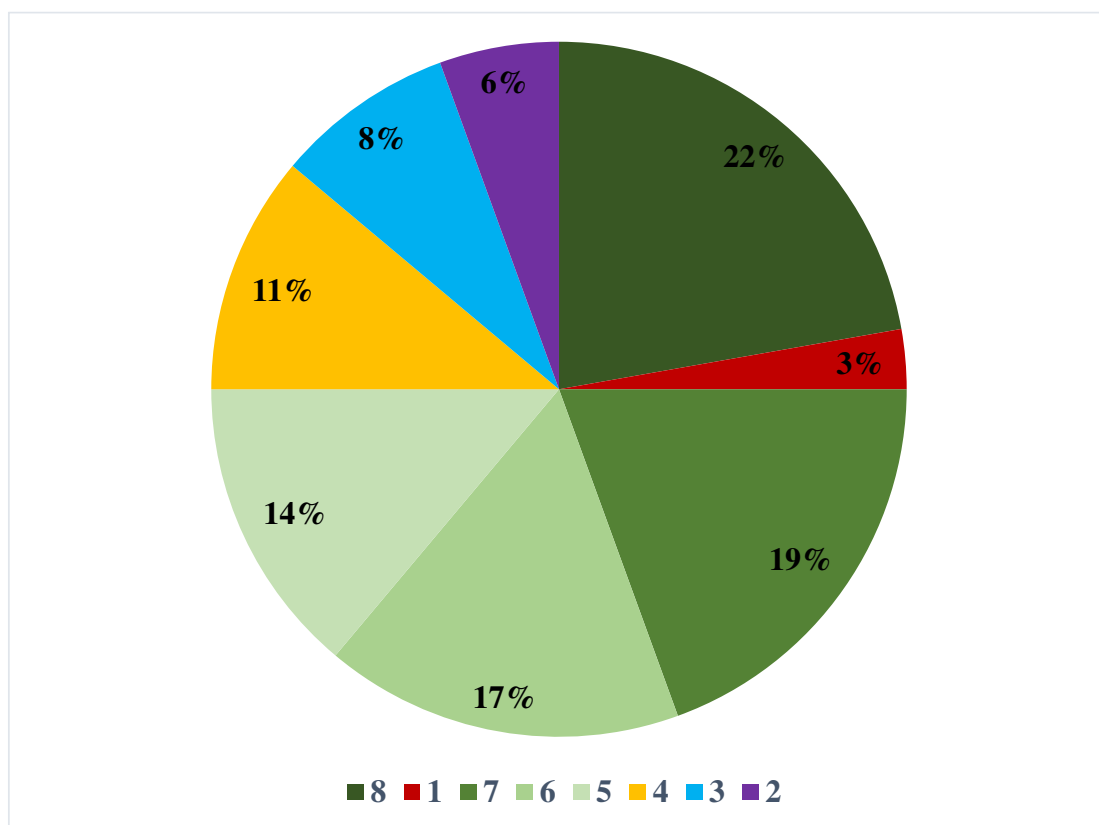


Figure 44 - Surfacic percent of vegetation series and geoseries in mapped estuaries. [1] Salty waters; [2] Brackish waters; [3] Freshwaters; [4] *Atriplici prostratae-Elymetum aterici* geopermaseries; [5] *Salicetum albae* holoseries; [6] *Salix atrocinerea* forests geoseries; [7] *Salicetum fragilis* holoseries; [8] *Fraxinus excelsior* forests geoseries.

5.6.1.1. Aulne estuary

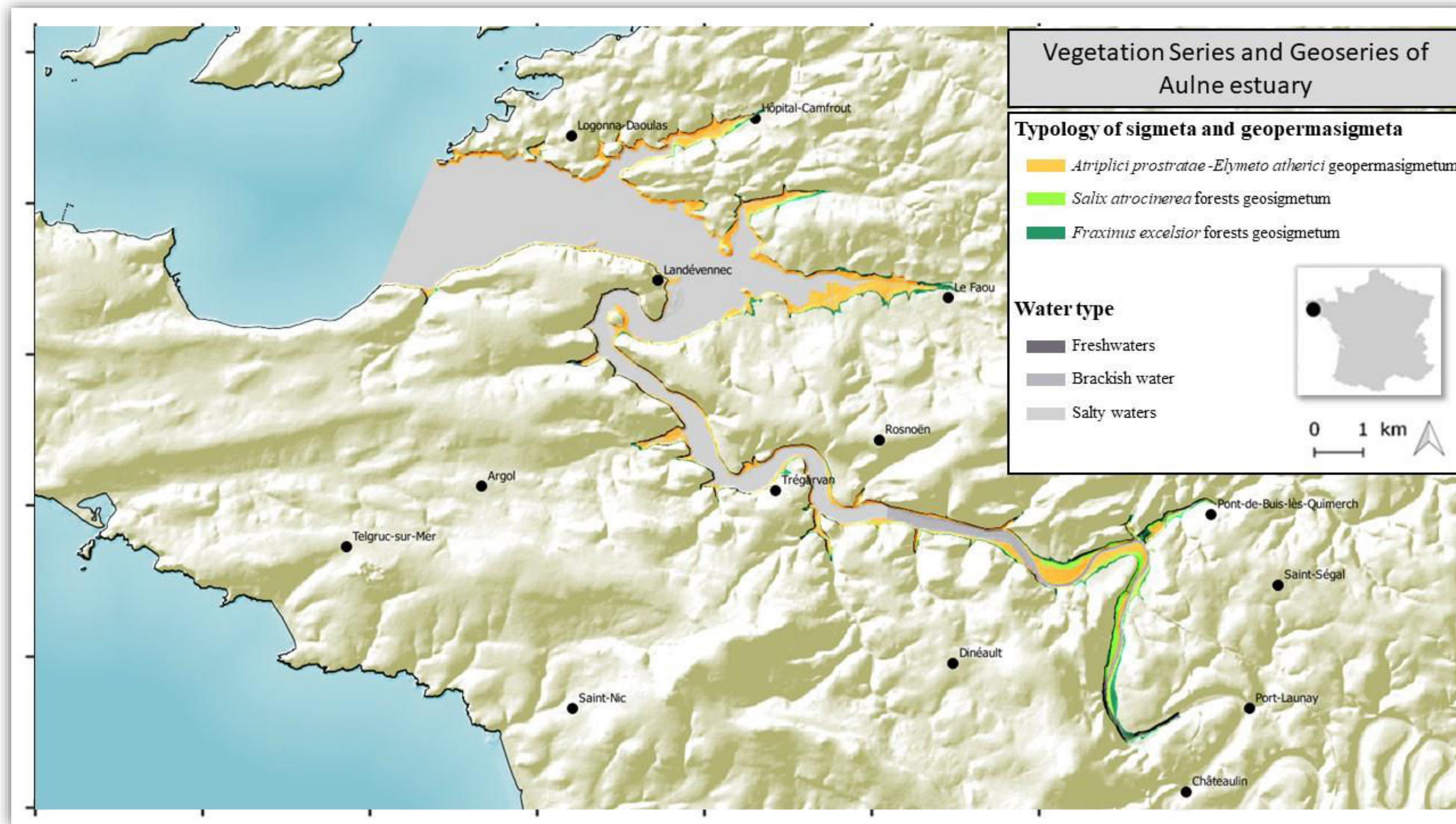


Figure 45 - Vegetation series of Aulne estuary, global view

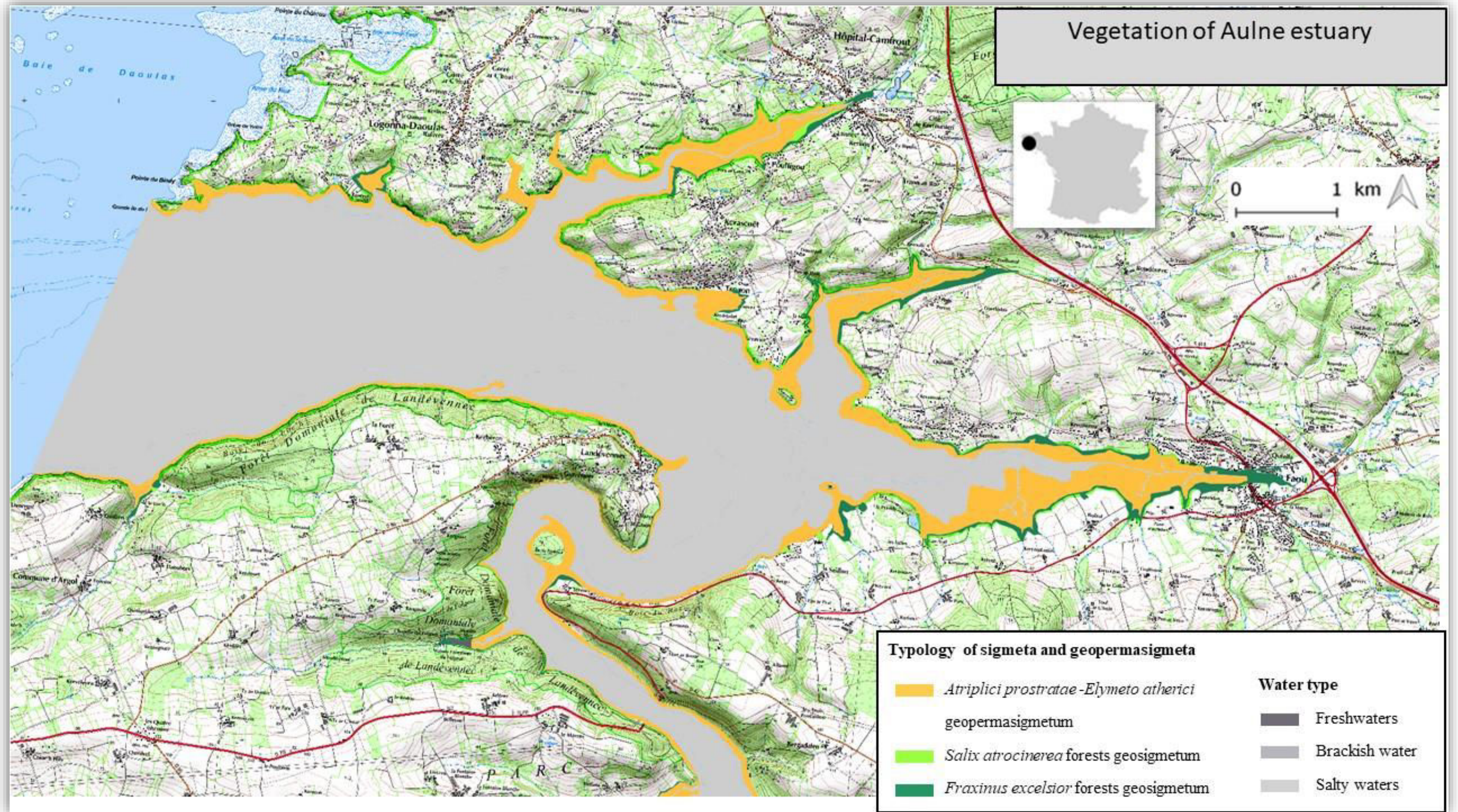


Figure 46 - Vegetation series of Aulne estuary - a zoom to the salty portion organization

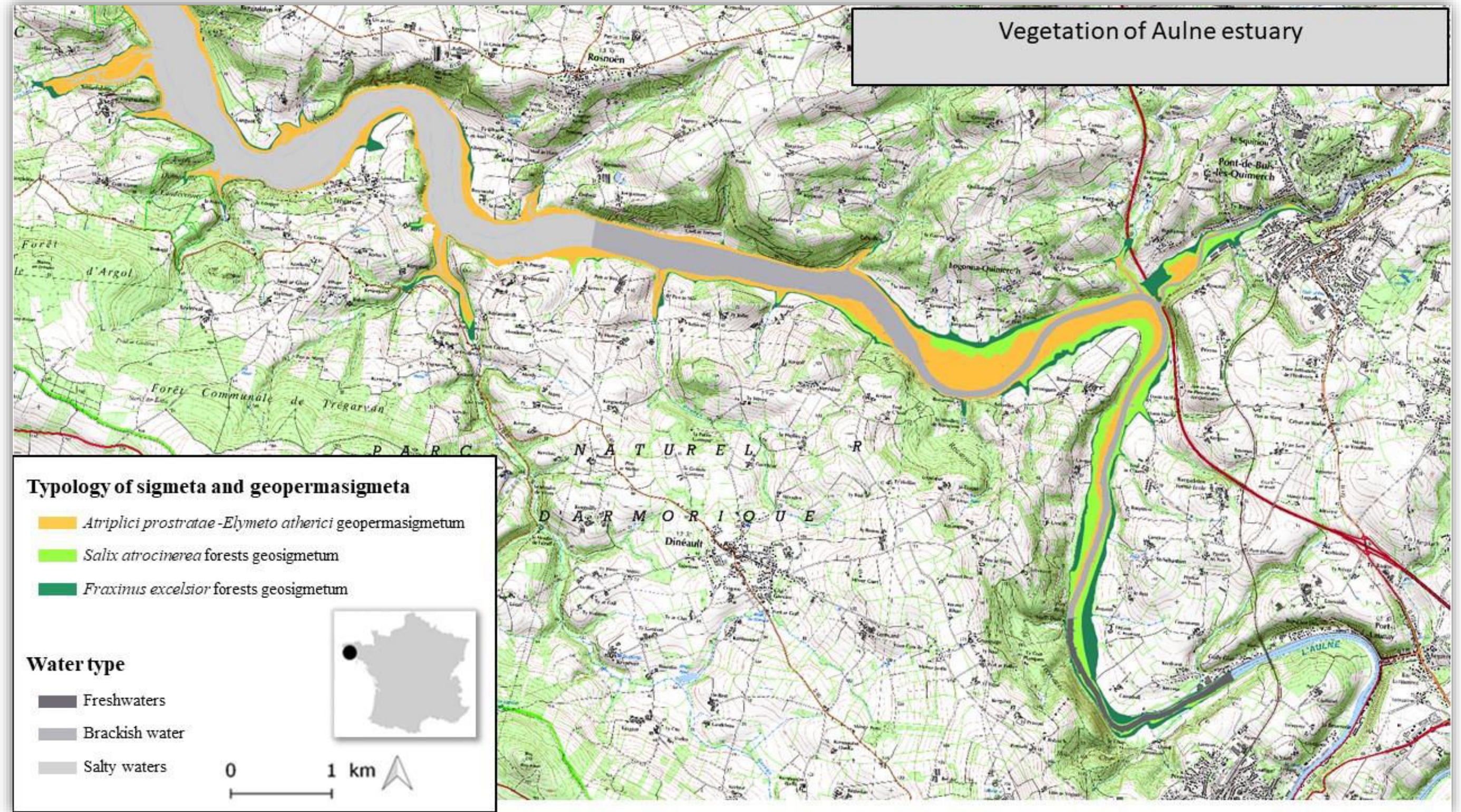


Figure 47 - Vegetation series of Aulne estuary - a zoom to the brackish water sector. The Oligohaline portion is stopped by a dam.

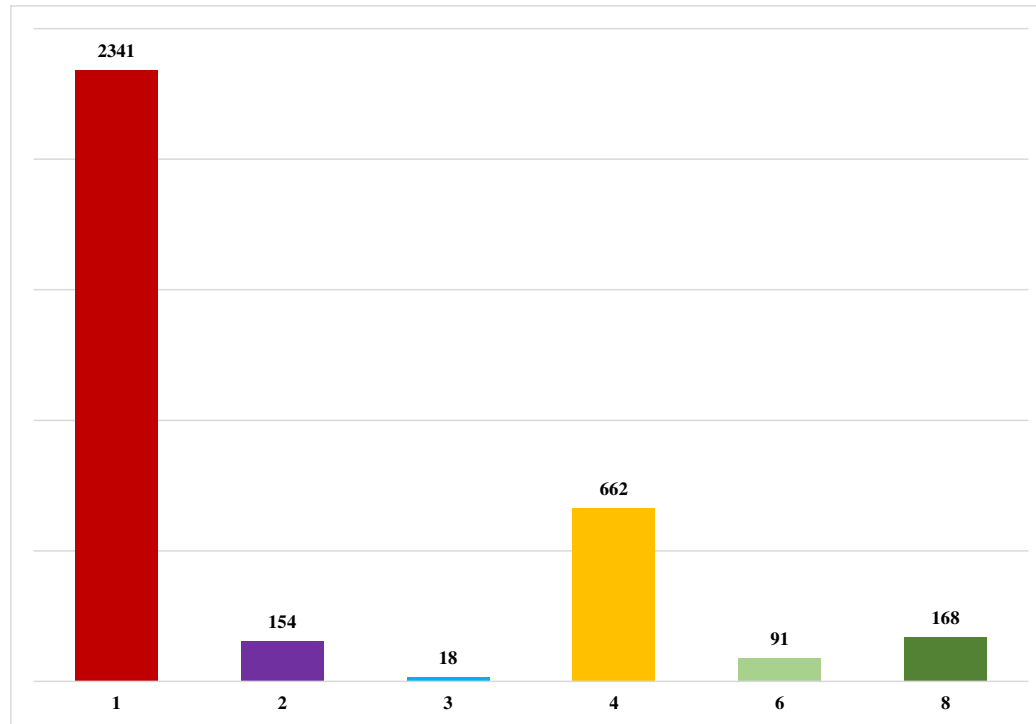


Figure 48 - Surface of vegetation series in Aulne Estuary [1] Salty waters; [2] Brackish waters; [3] Freshwaters; [4] *Atriplici prostratae-Elymetum aterici* geopermaseries; [6] *Salix atrocinerea* forests geoseries; [8] *Fraxinus excelsior* forest geoseries.

5.6.1.2. Laïta estuary

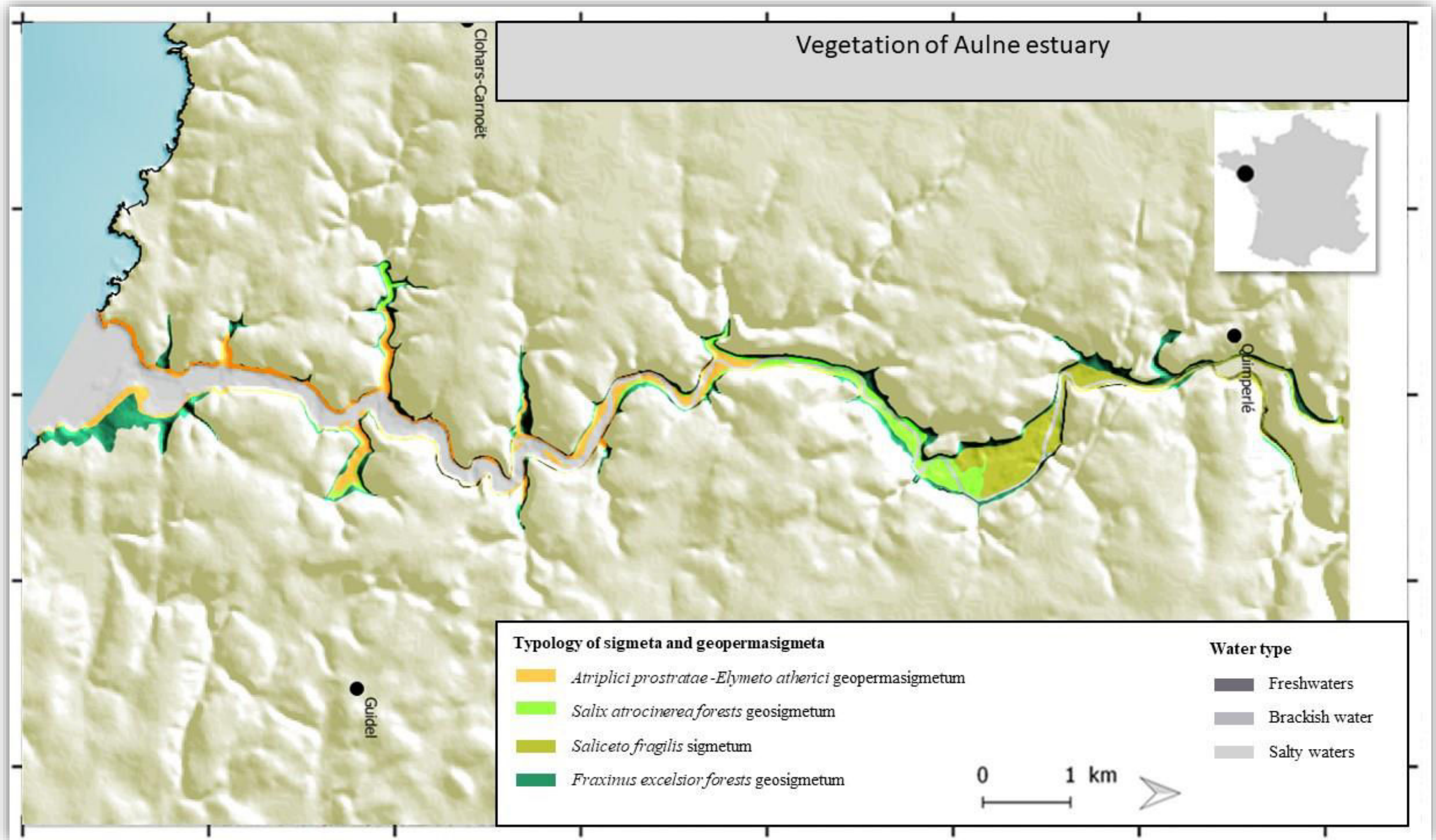


Figure 49 - Vegetation series of Laïta estuary

Vegetation of Aulne estuary

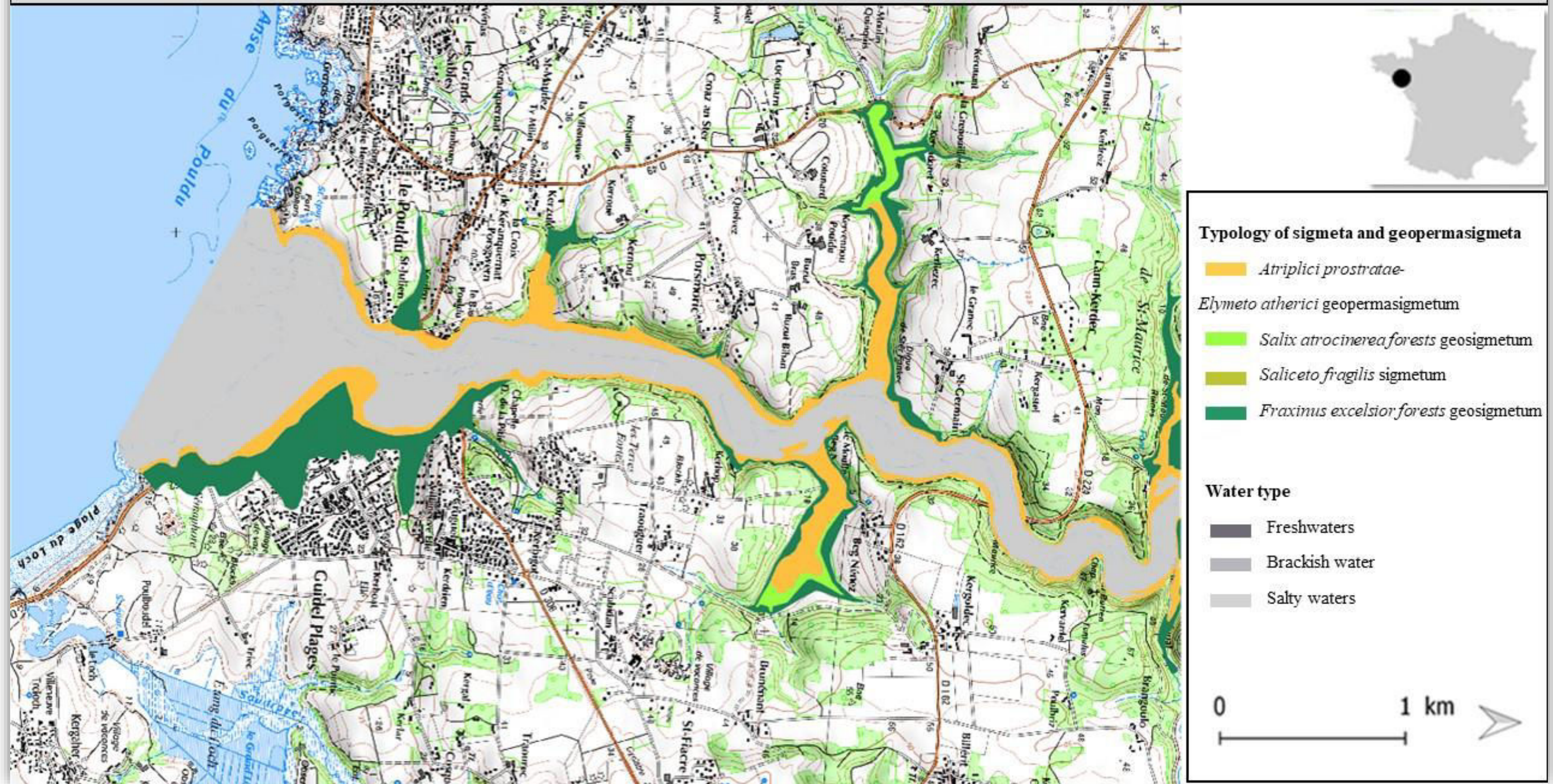


Figure 50 - Vegetation series of Laita estuary - a zoom on the salty portion

Vegetation of Aulne estuary

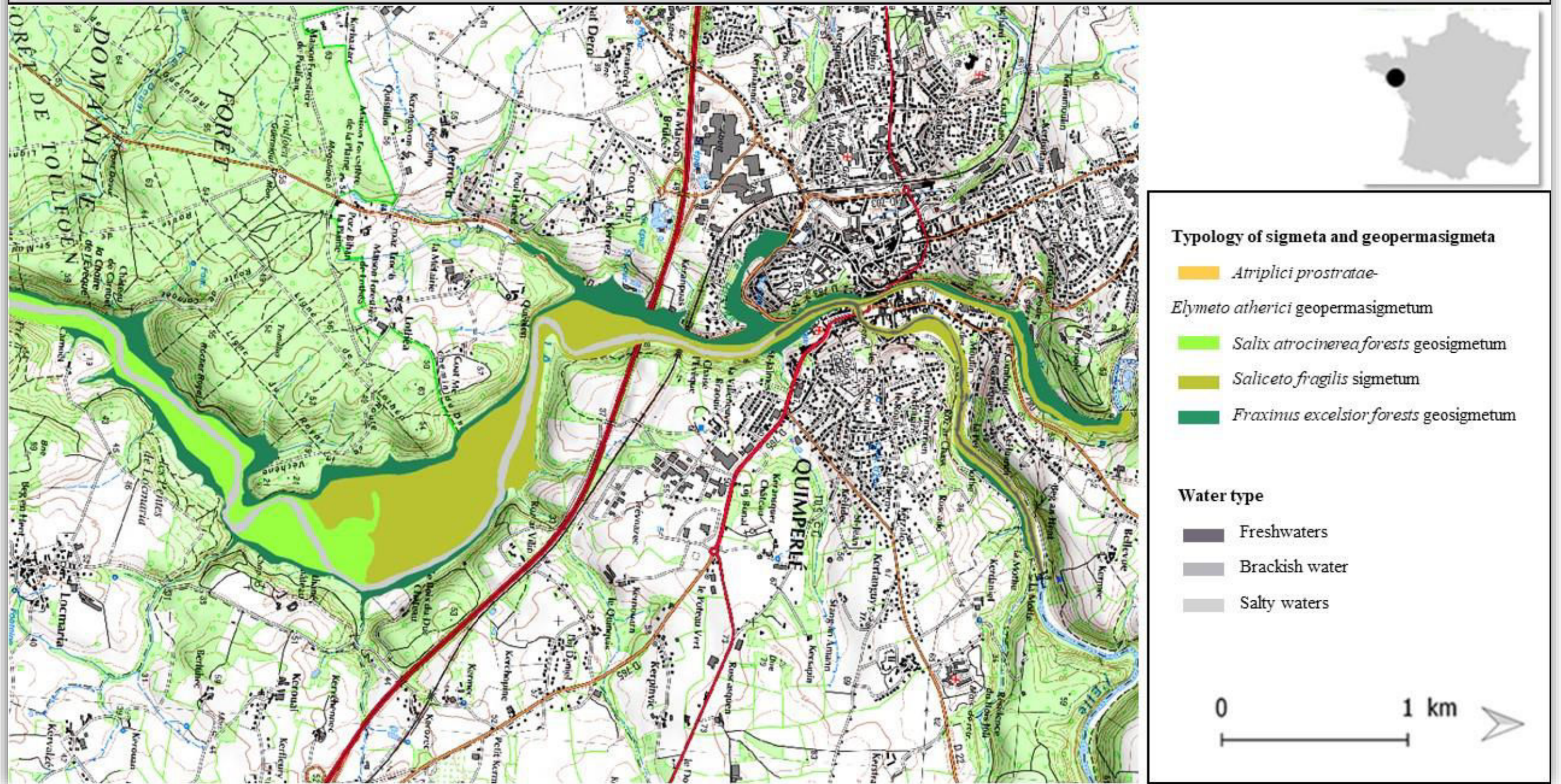


Figure 51 - Vegetation series of Laïta estuary –a zoom on the brackish portion

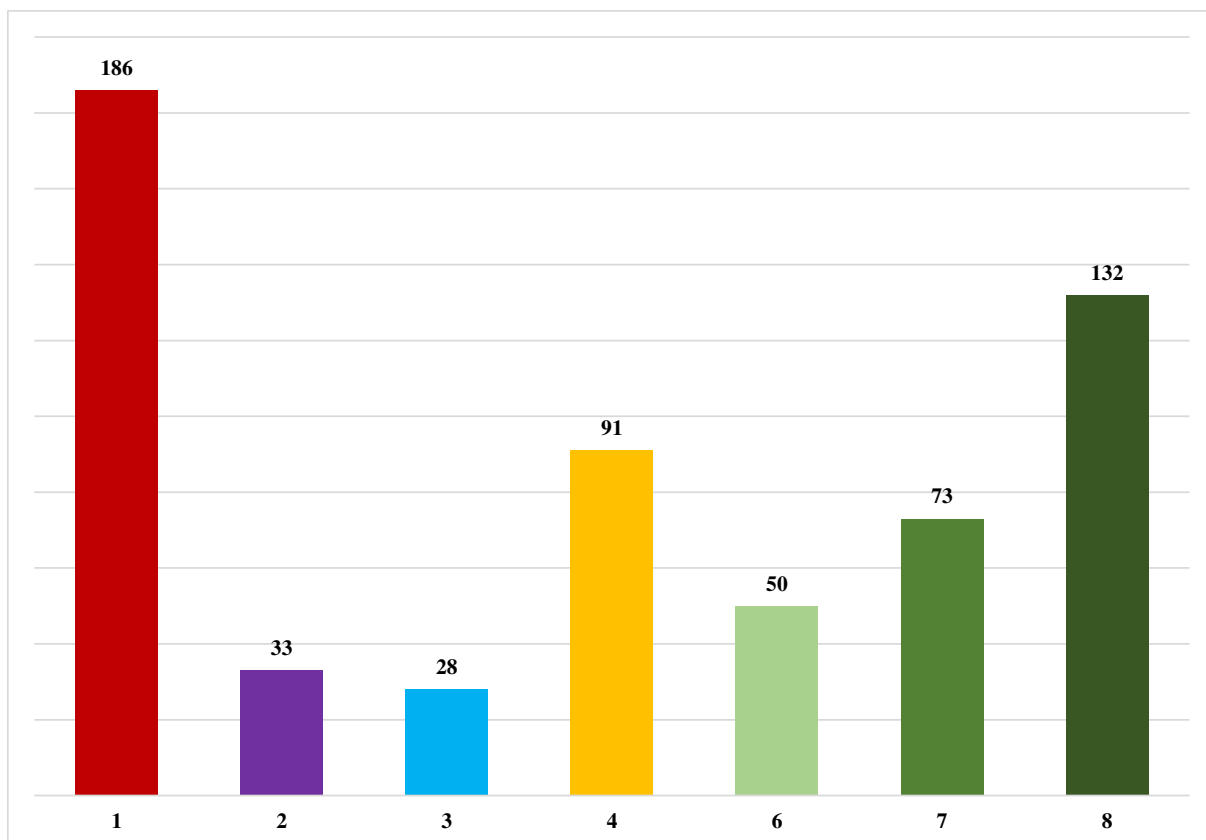


Figure 52 - Surface of vegetation series in Laïta Estuary. [1] Salty waters; [2] Brackish waters; [3] Freshwaters; [4] *Atriplici prostratae-Elymetum aterici* geopermaseries; [5] *Salicetum albae* holoserries; [6] *Salix atrocinerea* forests geoserries; [7] *Salicetum fragilis* holoserries; [8] *Fraxinus excelsior* forests geoserries.

5.6.1.3. Loire estuary

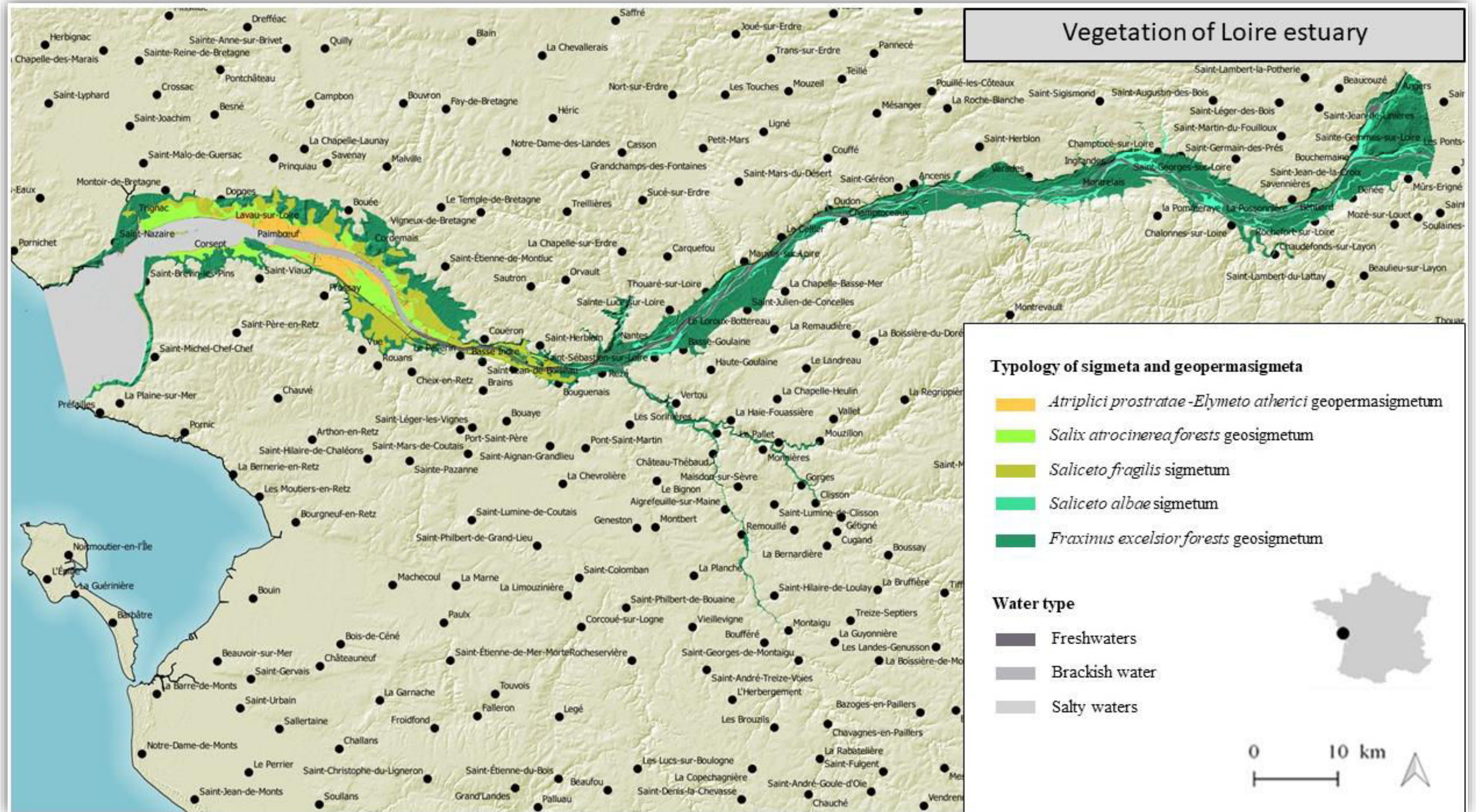


Figure 53. - Global series organization in Loire estuary

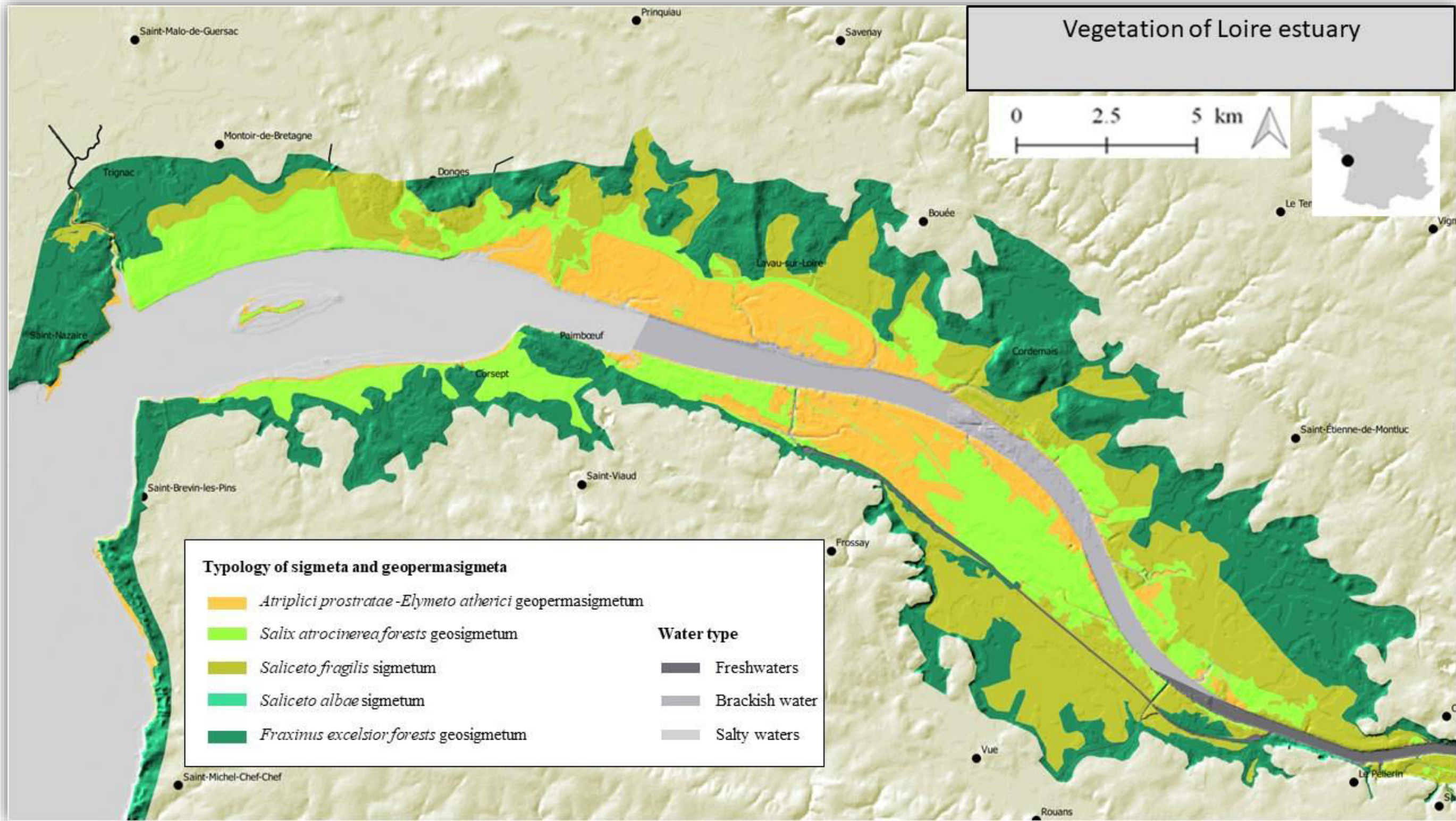


Figure 54 - Vegetation series of Loire estuary –a zoom on the salty portion

Vegetation of Loire estuary

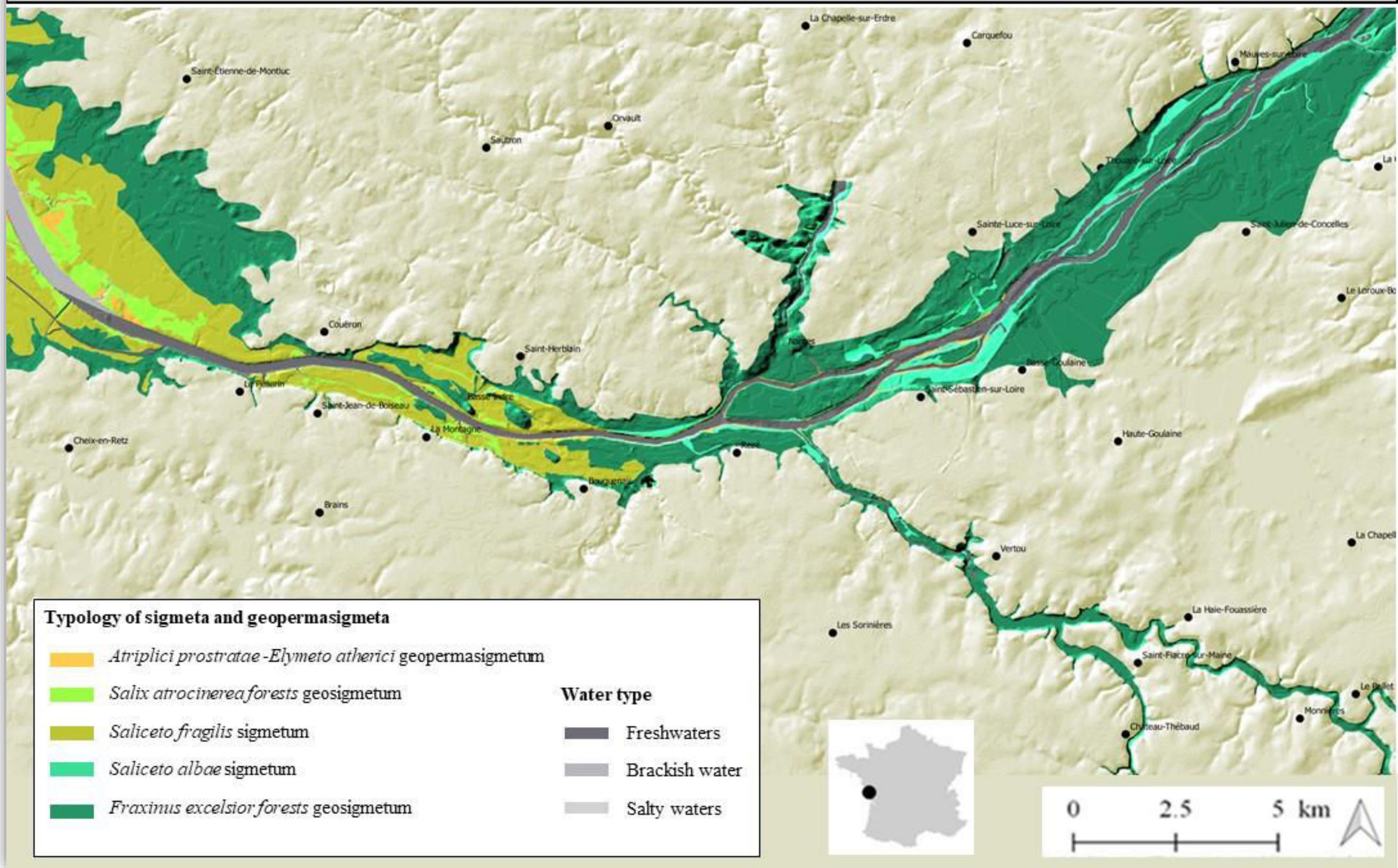


Figure 55 - Vegetation series of Loire estuary –a zoom on the brackish – oligohaline portion

Vegetation of Loire estuary

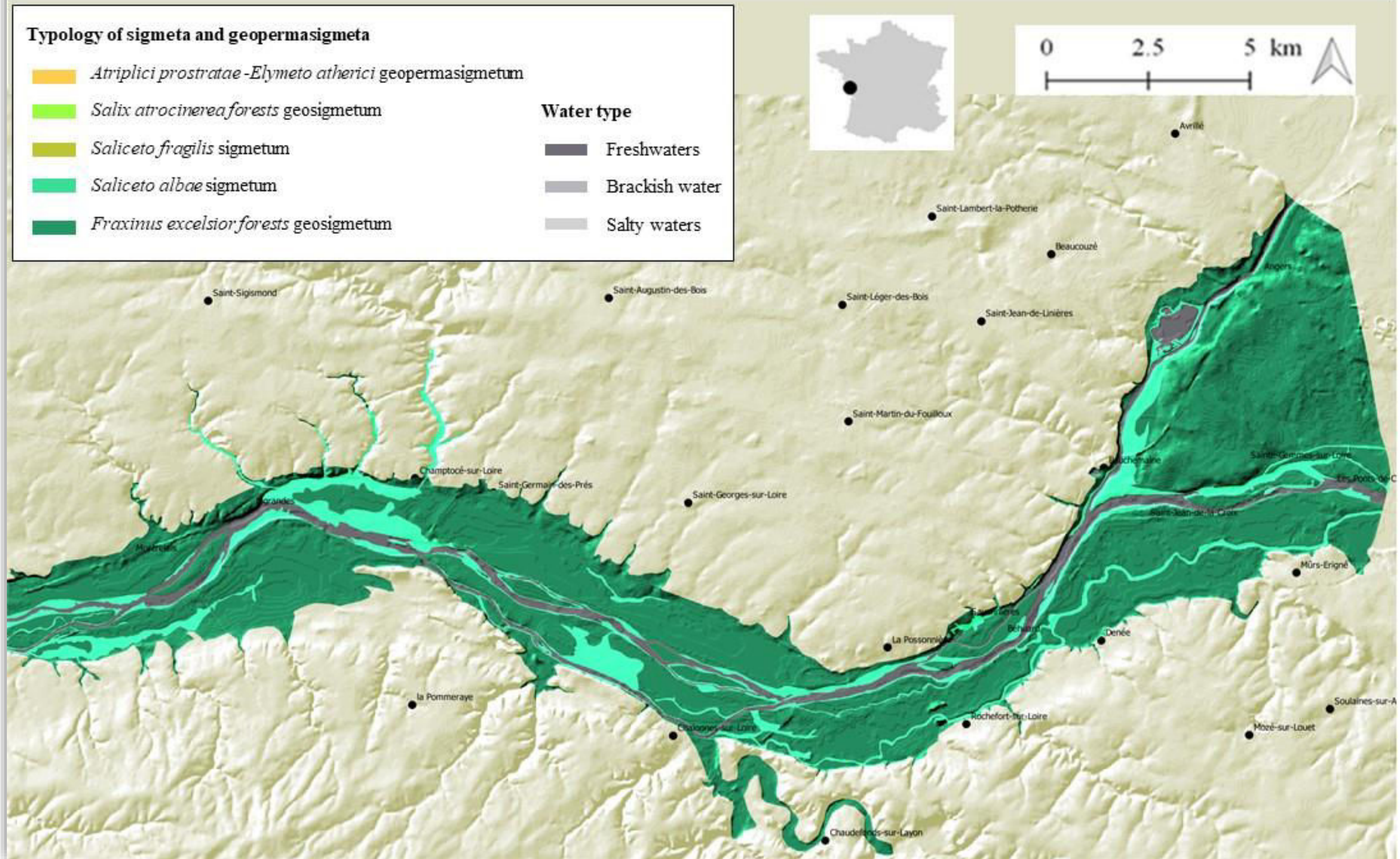


Figure 56 - Vegetation series of Loire estuary –a zoom on the freshwater portion

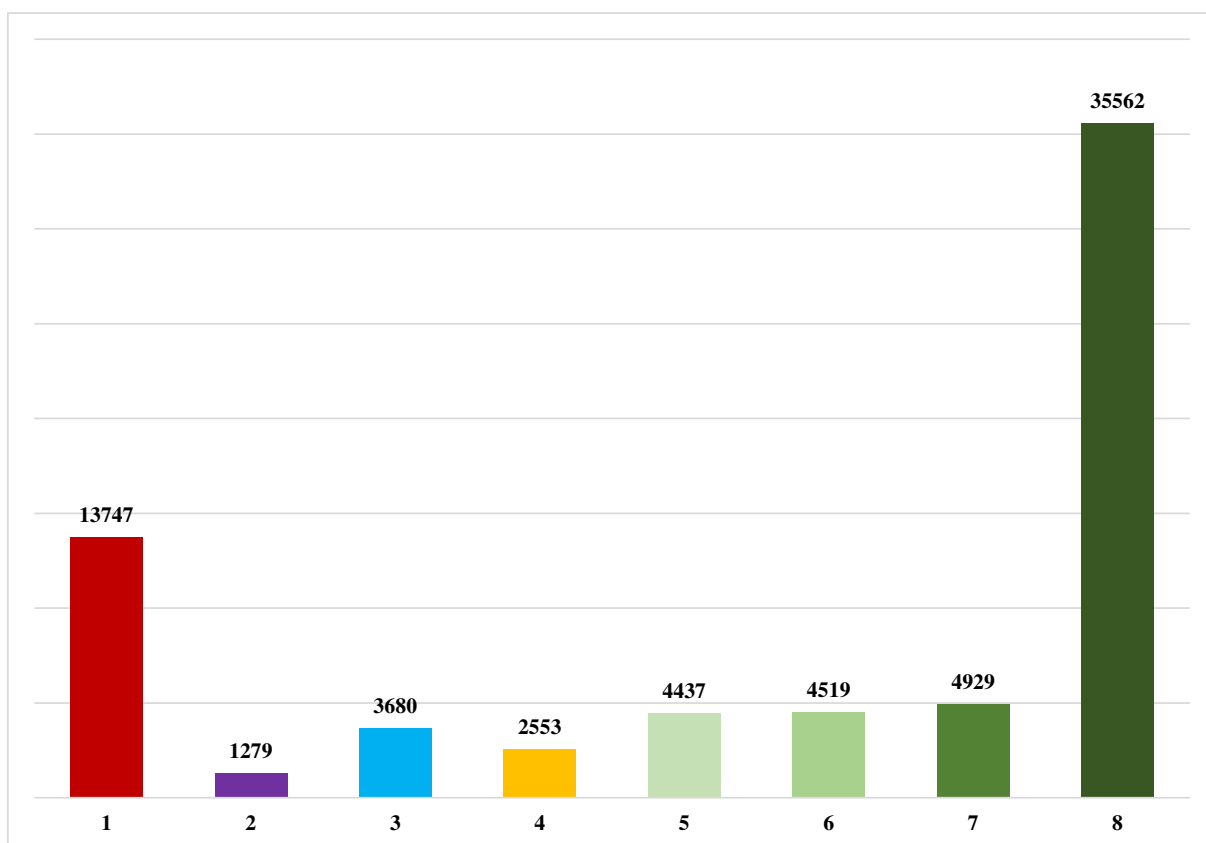


Figure 57 - Surface of vegetation series in Loire Estuary. [1] Salty waters; [2] Brackish waters; [3] Freshwaters; [4] *Atriplici prostratae-Elymetum aterici* geopermaseries; [5] *Salicetum albae* holoseries; [6] *Salix atrocinerea* forests geoseries; [7] *Salicetum fragilis* holoseries; [8] *Fraxinus excelsior* forests geoseries.

5.6.2. Transects from minor to major River bed

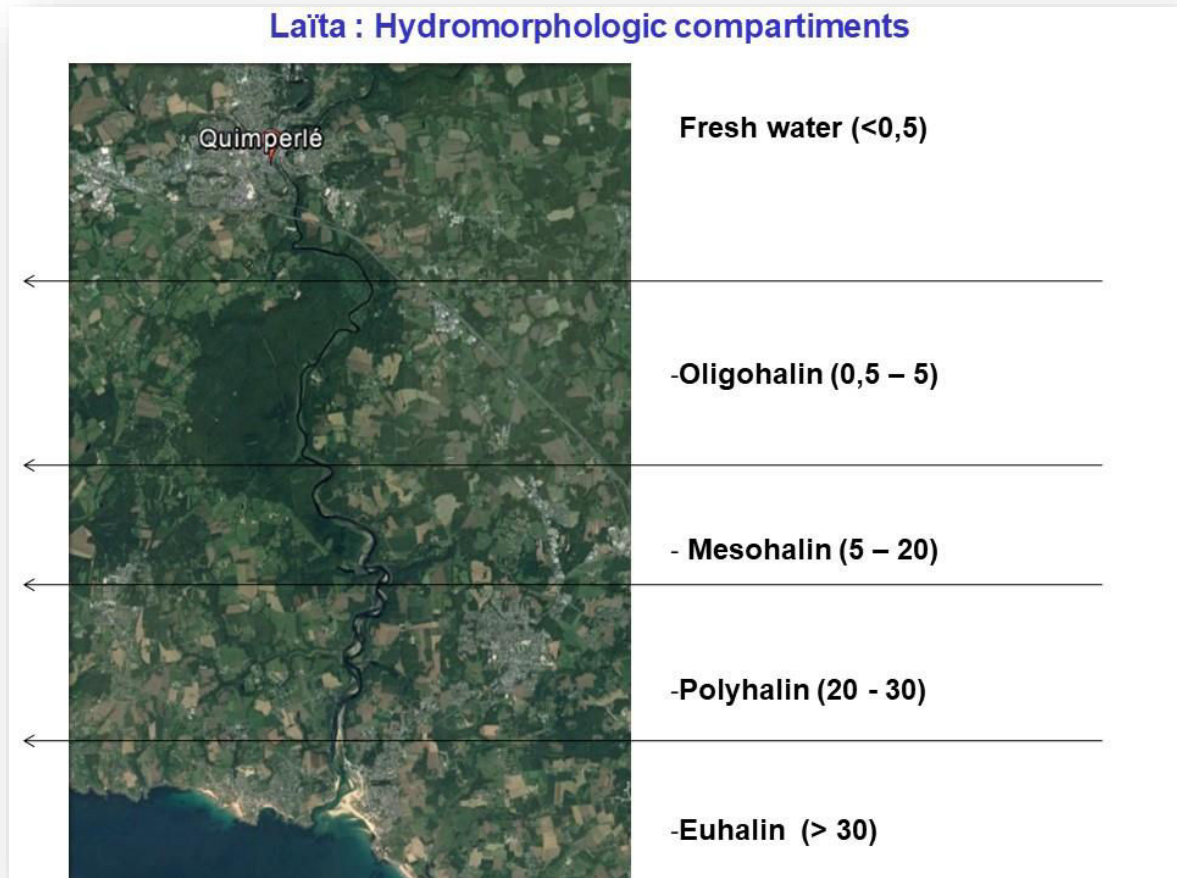
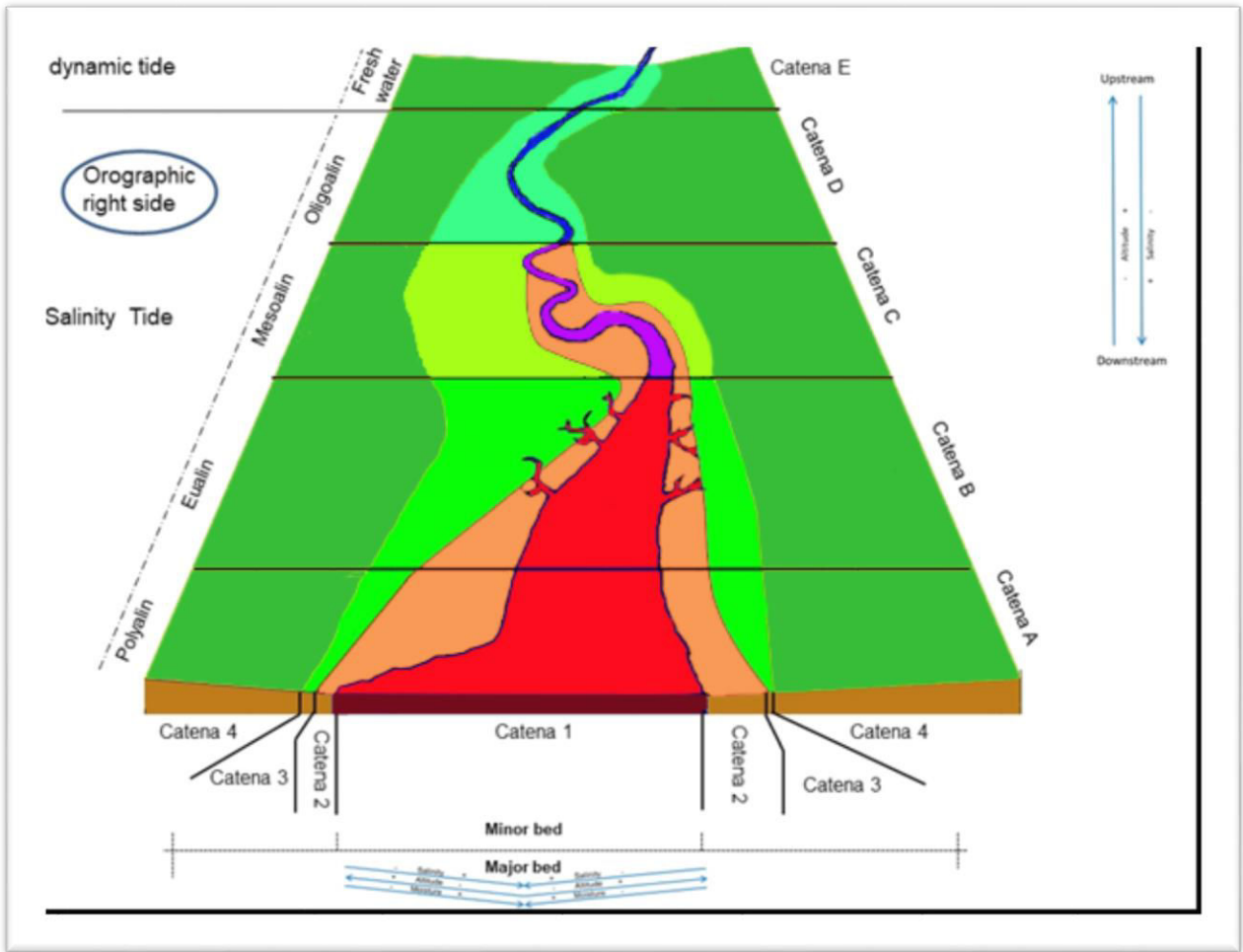


Figure 58 - Example of Salt compartments in Laïta estuary, from aerial photo.

5.7. Theoretical Series/Catenas scheme of an estuary

The vegetation geosystem is a catenal conceptual unit grouping plant communities that can be found in different Tessellas within a homogeneous geomorphological and bioclimatic entity. Plant communities here generally may belong to more series, usually organized along ecological or topographic gradients. The number of geosystems or geosigmata identified at a given biogeographic hierarchical level depends on altitude, geomorphology, soil, bioclimate. The catena is the geomorphological homogeneous spatial framework composed by several vegetation series, distinguishing the longitudinal catenas (A, B, C, D, E); and transversal catenas



Sigmata and Geosigmata	Physiognomic type	Wood type
<i>Atriplici prostratae</i> - <i>Elymeto atherici</i> geopermasigmatum	Salt marshes and meadows belt	Softwood forests community
<i>Salix atrocinerea</i> forests geosigmatum		
<i>Saliceto fragilis</i> sigmetum	Willows forests belt	
<i>Saliceto albae</i> sigmetum		
<i>Fraxinus excelsior</i> forests geosigmatum	Ash forests belt		Hardwood forests community
Salt compartments		
<i>Freshwaters</i>	Aquatic vegetation belt	
<i>Brackish water</i>		
<i>Salty waters</i>		
		<i>Lemneto minoris</i> geopermasigmatum

Figure 59. - Theoretical Series/Catenas scheme of an estuary after our synphytosociological elaboration

This scheme (Fig. 60 and 61) represent the last transect models derived by fieldworks, synphytosociology, bioclimatic and plant mapping elaborations.

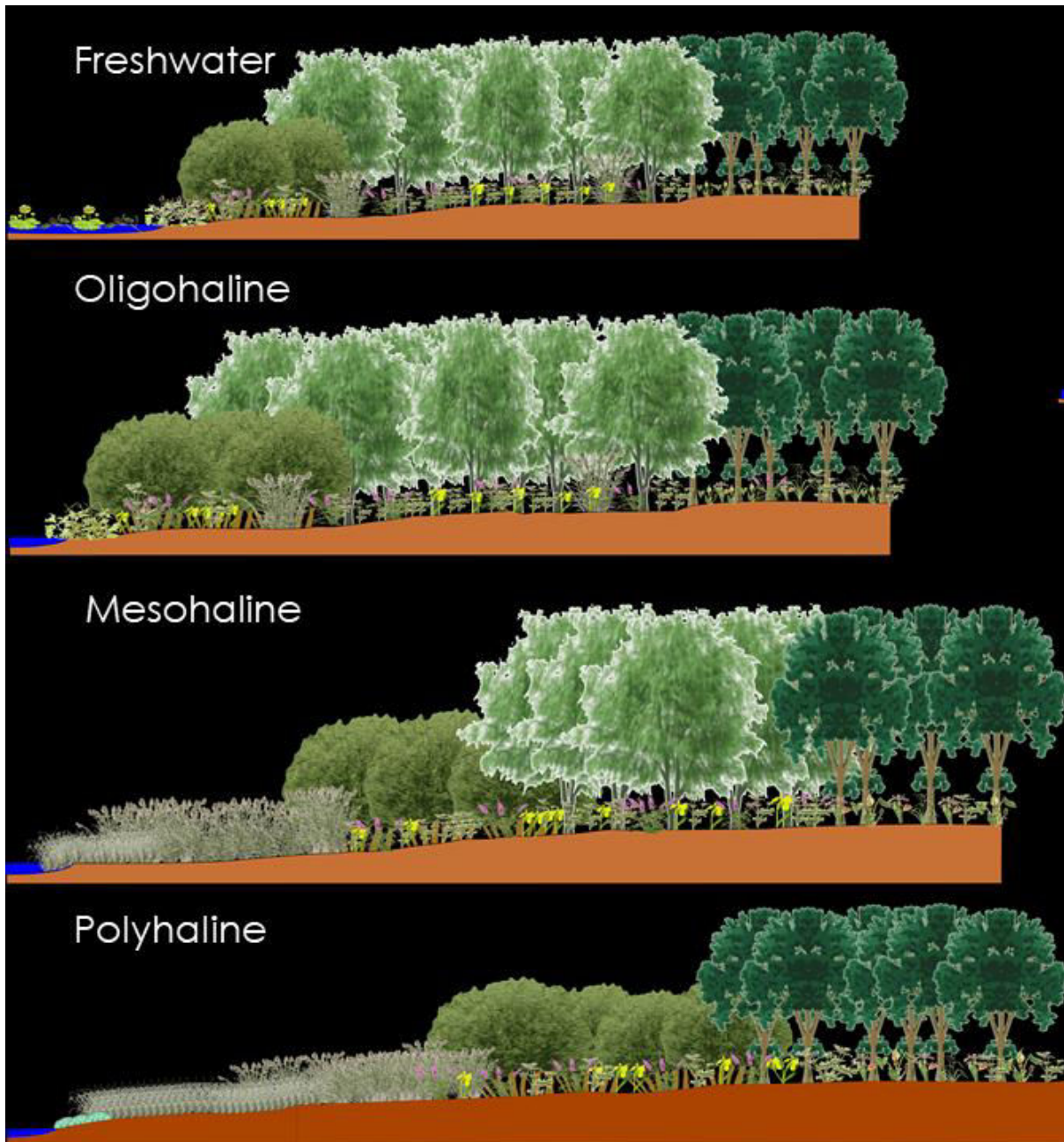


Figure 60. - Transect models, following the general vegetation series distribution, undelining the fisiognomic variations per salty sector

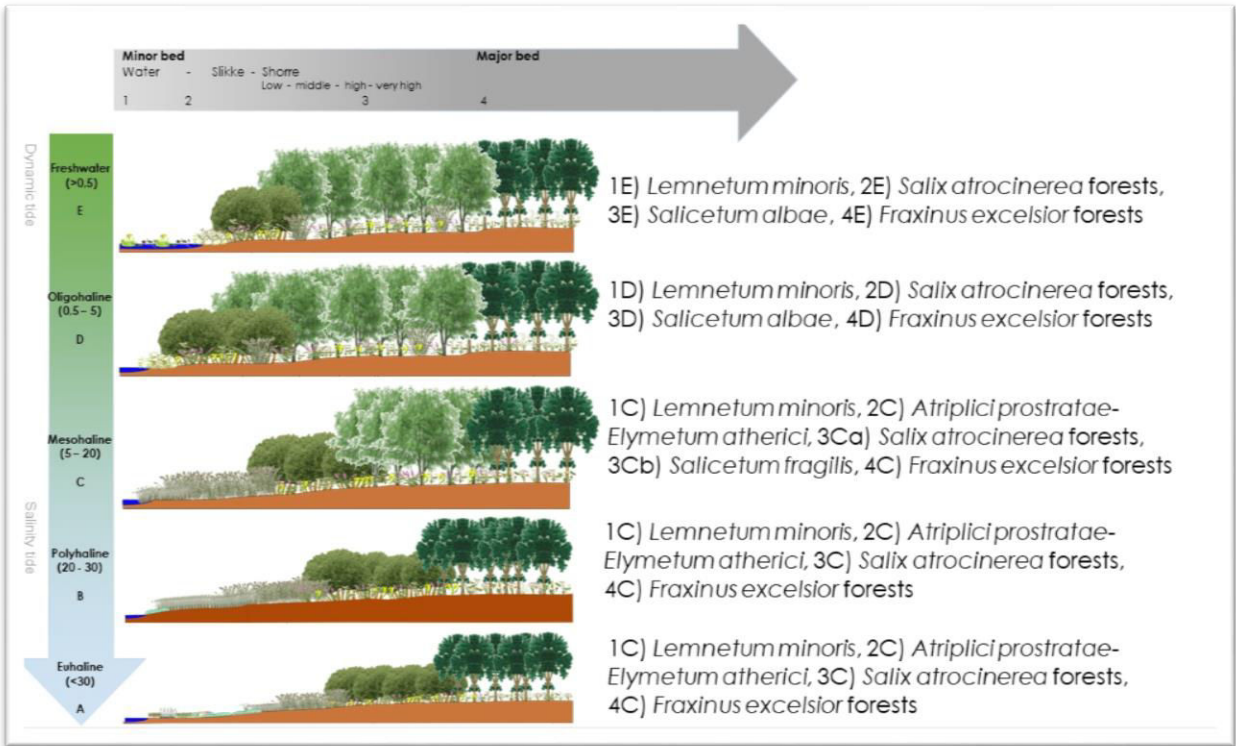


Figure 61. - Plant association general transect model per Up-Down and Left-right ecological compartments. For the same community

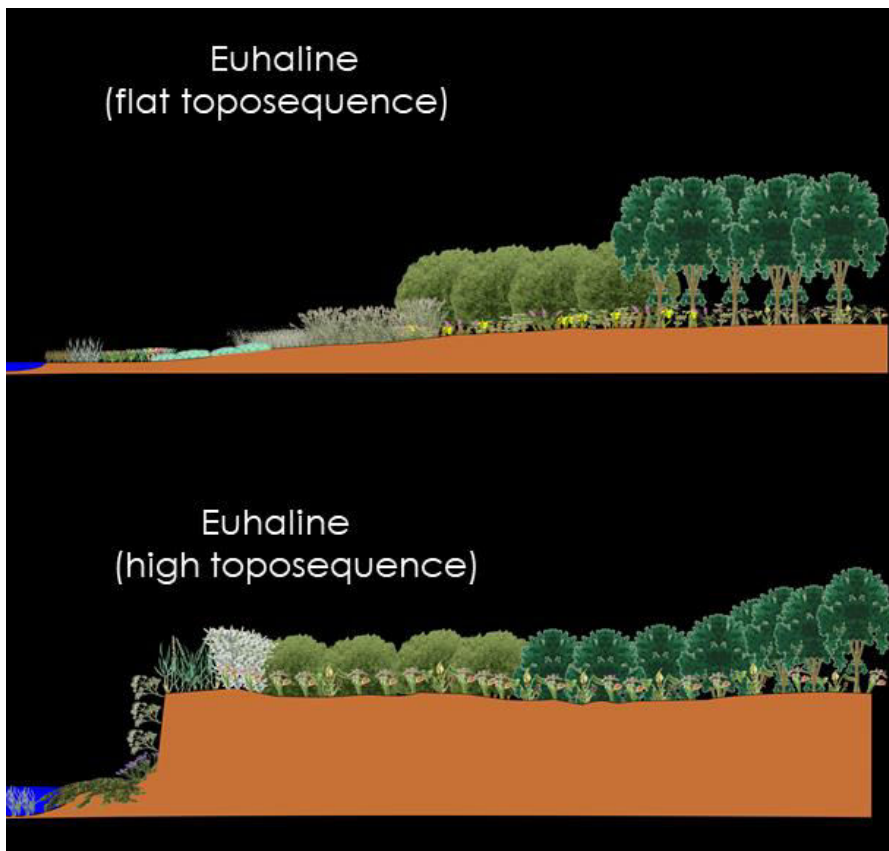


Figure 62. - Vegetation transect model difference between non confined and confined conditions in the same salt sector

We grouped the euhaline and polyhaline portions for the generic synphytosociological affinities. In this way, brackish waters shows intermediate vegetation characteristic between salty and freshwater communities, but they are more attributable to salty ecosystems while the oligohaline waters are more attributable to the freshwater portion.

As example, the aquatic vegetation is describable within a unique geopermasimetum but it could be subdivided into salty, brackish and freshwaters portions. The most salty portions have a remarkable presence of maerl and tidal marcoalgal community, together as aquatic sub-salty phanerophytes (more rarely). The brackish water is mostly represented by a microalgal community, often encrusted in the mud, rocks...

The oligohaline portion and freshwater aquatic vegetation is characterized by the typical fluvial and lacustrine water vegetation, especially in meanders, pools, bay and other slow flow portions.

Longitudinally, the salt mud and meadows community is replaced by freshwater mud and meadows; on very thin linear surfaces, often under the forests canopy cover.

About *Salix* sp. series, they consists in a sequence making a willow belt. Down-to-upstream the *Salix atrocinerea* forests are consequently replaced along the belt by the *Salicetum fragilis* and then by *Salicetum albae*. By ecological microvariation and by human impact the series could be mixed or interposed, so we can describe only a distribution trends as observed during fieldworks. Downstream, in the most coastal portions, the *Salix* species belt is represented mainly by the *Salix atrocinerea* marshy forests, making some coenosis. As example, in more marshy conditions *Salix atrocinerea* is associated with *Limnirs pseudacorus* and *Apium nodiflorum*. In more draining conditions it is associated with *Oenanthe crocata* and others megaphorb species. In sandy draining surfaces, *S. atrocinerea* is linked to *Hydrocotyle vulgaris*, *Schoenus nigricans*, *Oenanthe lachenalii* and others dunes slacks species, as was observed in Ria d'Étel, Baie des Trépassés and in only one case in Aulne estuary. In the last case, in the community we found also *Myrica gale*, showing a decalcified condition. In this case, the contact vegetation consist in *Erica* species moor and moor-forest (*Erica* species under *Quercus robur* canopy). In marshy and oligohaline conditions, we can find as associated species: *Schoenoplectus tabernaemontani*, *Schoenoplectus triqueter*, *Bolboschoenus maritimus* and *Eleocharis bonariensis*. In Étel estuary, we rarely found also *Hypericum elodes*.

Going upsteam, we see that the forests are increasingly approaching to the minor riverbed showing a substrate salt buffer capacity. Going up, the salt marshes and meadows belt is increasingly linear and then replaced by less salty vegetation until to represent freshwater species. We can cite *Apium nodiflorum* communities in wettest condition, then *Persicaria* and *Bidens* species and *Carex* species, *Phragmites australis*, and *Phalaris arundinacea*. We observed the tendency of *Persicaria hydropiper* that could be dominant in the oligohaline sectors; while in more freshwaters conditions, others *Persicaria* species tends to replace it (mainly *P. amphibia* f. *emersa* and *P. maculosa*). *P. lapathifolia* tends to install in freshwater portions, in more eutrophic conditions. From the upper brackish-oligoaline sectors, this vegetation is generally linked to a forest canopy cover potential.

The *Fraxinus* forest geopermasigmentum represent itself another up to down belt of vegetation. In these forests we observed the common presence of *Fraxinus excelsior*, occasionally we observed *F. angustifolia* scattered specimens elsewhere, but with a tendency to decrease inland. In drier position, *Quercus robur* can be dominant to *Fraxinus* species in canopy. In more coastal condition, *Fraxinus* forest could be replaced by mesic *Salix atrocinerea* forests or others pre-forests like elm formations (in woodland or shrub conditions following the

conservation status). They are characterized by ferns (mainly *Phyllitis scolopendrium*), and *Chamaeiris foetida*. This due to ecological constraints that favor the others species facing sea winds influence (till to find *Salix atrocinerea* dwarf forest facies). Another coastal exception found in Loire is linked by xerothermic conditions due to climate and soli types (the climate is more similar to the Mediterranean one, and the soil is very sandy) that let to *Pinus pinaster*, *Quercus ilex* and *Rhamnus alaternus* to take place within the *Fraxinus* forests. Marshy soil conditions in the major estuary bed represent another exception that allow to develop marshy *Salix atrocinerea* forest as infrabelt vegetation. Similar infrabelt phenomena appear upstream by *Alnus glutinosa* or others *Salix* species formations). Other possible exception are due to the confinement that reduce the vegetation series expression, inducing a vegetation of outcrops linked to a coastal or to an inner position.

6. DISCUSSION

This work intent to develop tools (different type of models) that can help to understand to what extent dynamic-catenal phytosociology can contribute to the habitats knowledge , bio-assessment and heritage value studies by vegetation (characterizing the quality of the plant landscape, the naturalness, the anthropization and the biodiversity). The choice to undertake a plant cartography integrated with synrelevés and phytosociology, provided a representative data on habitats, α and β plant Biodiversity framed in the related plant series (landscape). Our plant associations and plant landscape inventory and related mapping methodologies for vegetation series and geoseries aims to contribute to the elaboration of a catalog of series and geoseries of vegetation in the French Atlantic estuaries. Beyond a contribution of knowledge (functioning, distribution, assessment...) this work can be useful to the land managers, within the framework of the definition of the objectives of conservation, production and others management issues. The structuring of this tool could follow that of the Natura 2000 habitat improved by vegetation series, presenting habitats by the different serial and geoserial units from the coast to the inner portions of the estuaries (BIONDI, 2011; BIONDI *et al.*, 2011; BLASI *et al.*, 2000, 2004, 2014, 2005).

6.1. Bioclimatology

The climatic and bioclimatic study on French Atlantic estuaries produced different calibrated maps, to get a look on bioclimate and climatic factors variations along estuaries. To underline any microclimatic evidence between coastline to inner estuaries portions we also analyzed climatic data from the closer climate stations along the estuaries. Results show a strong determinant influence of the sea winds, and a thermic gradient from north to south.

We noticed a climate and bioclimate slow-variation between north to south and between coastline to inner portions (only in biggest estuaries). These variations affect the expression of some plant associations and species, replacing them as vicariants. The generic function scheme is always valid and the vegetation is always well represented by our series and geoseries. The changes can only be reflected as local exceptions, driven by different local geographic

variations. This is also explicable by the fact that the studied vegetation is of azonal biogeographical type; consequently the only driving factors are water and salt levels, together with human pressure, according to WALTER (1976), WALTER & BOX (1976), RUTHERFORD *et al.* (2006), and PEDROTTI (2013). In more exposed to wind sector (i.e.: coastline), we can observe some exceptions like truncated series. Some of them are more developed if compared the perma and curta-series, but they appear truncated if compared to the equivalent inner vicariant conditions. The main example is the *Salix atrocinerea* (rich in *Chamaeiris foetida*) mesic forests that replace the inner *Fraxinus excelsior* forests; or the *Ulex europaeus* and *Prunus spinosa* (often accompanied by others shrubs) that replace the *Fraxinus* forest and hardwood forests in windy coastline conditions in dunes and in pebbles accumulations.

In sandy estuarine portions, we also observed, how on actual dry grassland and shrubs it corresponds a potentiality for *Salix alba* forests; showing in this case how these thermoxeric character is of secondary type, due to the deforestation and representing in some ways a sort of secondary vegetation as index of desertification.

About thermic vegetation issues, especially in the Loire, in the inner sandy positions the *Salicetum albae* is closer to the *Salici albae-Populetum nigrae*. Along this estuary, we found some *Quercus ilex* and even *Quercus coccifera* as escaped from cultivations on sandy soils. Especially in Charente, we found *Sambucetum ebuli*, and communities of *Silybum marianum*, *Smyrniolum olusatrum* and *Thypha domingensis* as more evident. *Silybum marianum* and *Thypha domingensis* were temporarily placed in the related plant associations even if they consists in atypical facies, sometimes impoverished of characteristic species and for that reason they requires more in-depth study.

6.2. Phytosociology

Following the available bibliography of the study area, the most coastline portion vegetation resulted more known and more studied than brackish and freshwater estuarine portions. In spite of the evolutions, the progress and the in-depth analysis carried out by various authors also within the framework of CarHAB and the France vegetation Prodromus, the syntaxonomy appeared us still far from the complete clearness about the studied syntaxa. This work, together the others CarHAB experiences is also bringing new concerns about this issues (BIORET *et al.*, 2014; 2015a,b, 2017), realizing a wider, more structured (not only in large surfaces, but also in long time) and participative study to bring more knowledge in this regard (CHALUMEAU *et al.*, 2016; CHALUMEAU, 2018; PERRIN *et al.*, 2018).

In eight estuaries complex, fieldworks were for a total of 98315 ha, highlighting two series and four geopermaseries corresponding to 131 plant associations, 60 alliances, 43 ordos and 28 classes.

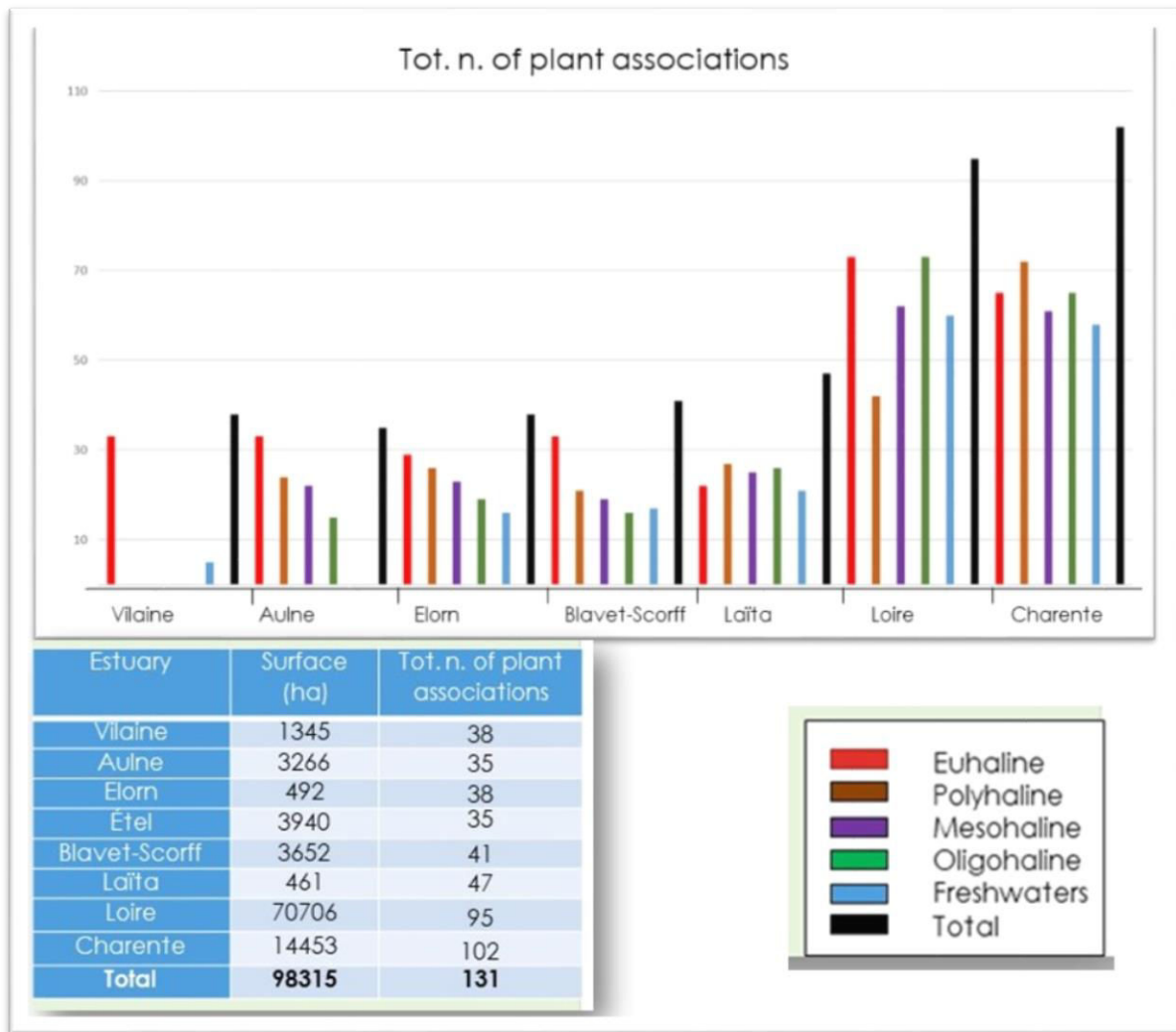


Figure 63 - Representation of plant association amounts per ecological compartments in studied estuaries..

Considering the presence of associations per salt compartment and comparing the amount of them per estuaries, as it is represented in the previous figure, we can see how we can distinguish large estuaries and smaller estuaries by vegetation. Charente and Loire between large estuaries, and Vilaine, Aulne, Elorn, Blavet-Scorff and Laïta between small estuaries.

In geography way, Charente estuary is considerable as small, if compared to Seine, Garonne and Loire estuaries surfaces. Analyzing the vegetation, largest estuaries are distinguishable by a bigger amount of plant associations and by larger surfaces of their expression. The riverbed of largest estuaries is basically less confined, larger and with a lesser incline slopes; conditions that favors the vegetation expression.

For that, Charente can be represented within the largest estuaries; representing the smallest of the largest estuaries group studied. Vilaine and Aulne estuaries do not express vegetation in each ecological compartment due to the barrages that stop or strongly limits the estuarine water dynamics, shifting out to the estuarine ecology. Therefore, it has been avoided to insert this vegetation in this elaboration in order to avoid to flatten or to blur the graphic tendencies. Similarly, we have omitted the data of Étél estuary because this one has a

predominantly ocean dynamic (therefore it can be considered more like a sea bight) avoiding a possible coastal vegetation over-representation risk.

Our phytosociological fieldwork does not claim to be a complete compendium of the plant associations of the study area, even if attention has been paid to the detection of primary and secondary associations, including the ruderal and Synanthropic ones. Between the axes to develop in future, we suggest to study and monitoring plant communities to clarify dynamics, associations and their syntaxonomy status.

Contextualizing the plant association distribution, following flood levels and salt compartments, we can group association by series, geoseries and geopermaseries as follows.

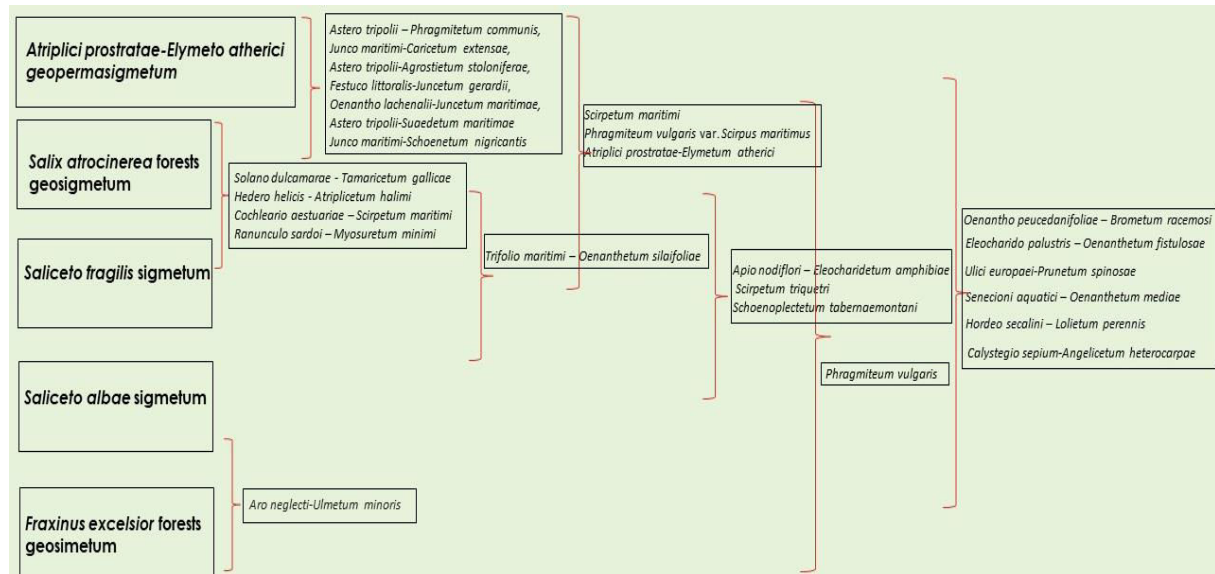


Figure 64 – Bioindication of plant associations in sigmeta, geosigmeta and permageosigmeta

About aquatic vegetation, we can group the whole community in a geopermasigmeta of aquatic vegetation naming it after the most frequent association (per estuary and per ecological compartment; and per frequency and surface presence). *Lemna minor* communities are unstable communities because their floating nature. *Lemna minor* communities in other hand are distributed up and down along the estuary, following the longitudinal and transversal directions, by water flows. They are considerable as relatively stable in upper (inner) estuarine conditions, or in predominantly freshwater pockets (i.e.: pools). These communities are less table in water pockets that vary cyclically, for example, they disappear in the summer, they are subjected to strong changes in salinity or they are subject of strongest water flows. For that reason, it is possible to find them until the river mouth, almost occasionally. In addition, for these reasons they can recover their pockets after the cyclical or occasional perturbations. In conclusion we can group all the aquatic vegetation in a geopermaseries named *Lemneto minoris* geopermasigmetum, dividing it in three sectors following the salt characteristics, as: freshwater, brackish and salt dominant portions. In the saltiest conditions the vegetation it differs from the amphibious tidal macro-algal community presence, and by the rare, punctual presence of sub-salty phanerophytes like *Ruppia* and *Zannichellia* species. The brackish portion could be identified by the presence of *Ranunculus baudotii*; and the freshwater portion (including the

upper oligohaline waters) by the strongest presence of *Elodea*, *Ceratophyllum*, *Potamogeton*, *Myriophyllum* species and *Nuphar lutea*.

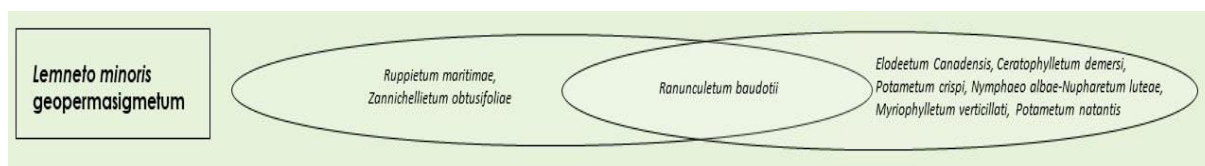


Figure 65 – Bioindication of plant associations of the aquatic vegetation permageosigmetum; and related subdivisions following the salt-water front.

In our relevés glasswort associations tends to be under-represented because our fieldwork period was not always according to the phenological optimum of these communities. The same problem could affect more or less others communities (mainly for non-visible species). For that, it could be useful to provide in future a longer time study dedicated to the same surfaces.

About willow belt communities, the phytosociological analysis allowed us to compare field surveys in order to see differences and similarities within these plant communities. We compared the willows plant association comparing the frequency after Tüxen, indicated by classes from: r, + to V, with Roman numerals (GEHU, 2006). These plant associations showed to be differentiated by only the dominant trees species in canopy, sharing the same understory composition, mainly characterized by megaforbs. The rarest *Viscum album* presence was remarked on *Salix atrocinerea* forests, only on Loire estuary. In largest estuaries we can see how largest and lesser is the slope and more we can underline how the lateral zonation is closer to the longitudinal one. We observe a *Salix fragilis* belt, often mixed with *Salix alba*, behind the *Salix atrocinerea*. *Salix alba* and *S. fragilis* are often mixed and with intermediate forms. We found also *Salix × rubens* forests, in Loire, between the mesohaline and oligohaline portions, with a potential between the three *Salix* series. This underline also how these willows communities could be identified in smaller scales and more generically within one geoseries of willows forest (Willows forests vegetation belt). Showing a possible trend as underlined in bigger scales, by our work.

About shrub communities, we can underline two types: young forest stages and a thicket. The *Irido foetidissimae* - *Prunetum spinosae*; *Rubio peregrinae* - *Prunetum spinosae*; *Rubio peregrinae* - *Ligustretum vulgaris*; showed a common ecological presence in each estuary, in any woody series. The *Ulici europaei*-*Prunetum spinosae* also showed a common presence in each woody series, but slightly distinguished for the mos draining substrate conditions, never found in marshy conditions. The *Hedero helicis* - *Rhamnetum alaterni* represent the vicariant community in Loire estuary, corresponding to the *Quercus ilex* and *Pinus pinaster* forest influence.

The *Hedero helicis* - *Atriplicetum halimi* represent the vicariant form of the previous associations as anthropogenic formation, especially in saltiest conditions, while in less salty condition, the *Solano dulcamarae* - *Tamaricetum gallicae* tends to take place. In the willow belt and in lowest *Fraxinus* geoseries, we can find *Salicetum triandro-viminalis*, *Salicetum purpureae* as shrub formations, especially in riparian conditions. Roselières community is

mainly characterized by graminoids coenoses. The most representative association of this community is the *Phragmitetum communis* bed. This plant association could be divided into different variation that following the actual syntaxonomy trend, tends to be revised and placed as synonyms in the same syntaxon. In riparian conditions we can find the *Calystegia sepium* variant (former *Calystegio sepium - Phragmitetum australis* Royer, Thévenin & Didier in Royer et al. 2006), often as mantle or under forests vegetation potentiality. Often ruderalized. In Laïta estuary, we found a particular form of this association rich in *Elytrigia atherica* and *E. repens*, and with *Calystegia sepium* var. *rosea* (up to St. Maurice). Up, near the city of Quimperle replaced by a larger presence of *Phalaris arundinacea* and *Calystegia sylvatica*. Another variant is rich in *Solanum dulcamara* [former *Solano dulcamarae - Phragmitetum australis* (Krausch 1965) Succow 1974)] placed in more marshy conditions from subsalty to freshwaters. Then a variant rich in *Bolboschoenus maritimus* (ex *Scirpus compactus*), previously known as *Scirpo compacti-Phragmitetum australis* Bueno & F. Prieto in Bueno 1997, typical for the mesohaline portions, from the upper salty to the lower oligohaline portion. It is even installed into lowest salty portion, with freshwater accessions (more than the *Astero tripolii - Phragmitetum communis*). This variant is often a head series, while in uppermost conditions belongs to forests vegetation series potential. *Astero tripolii - Phragmitetum communis* differentiate from the previous, by lesser development of red bed (less ligneous, less tall, thinner and with a more herbaceous facies), under sandiest (not muddiest) conditions.

Similar trends are for the secondary salty and sub-salty meadows community (i.e.: *Eleocharido palustris - Oenanthe fistulosae*; *Ranunculo ophioglossifolii - Oenanthe fistulosae*; *Junco gerardi - Oenanthe fistulosae*; *Trifolio maritimi - Oenanthe silaifoliae*; *Oenanthe peucedanifoliae - Brometum racemose*; *Senecioni aquatici - Oenanthe mediae*; *Hordeo secalini - Lolietum perennis*). These communities are very similar between them, often not respecting the same floristic composition as described, and very variable depending in geographic location, land uses and ecological micro-variations. These plant associations belongs as secondary associations, from the salt marshes and meadow sigmetum to the forests sigmeta. In wettest and freshwater conditions, we mainly found *Eleocharido palustris - Oenanthe fistulosae*; *Ranunculo ophioglossifolii - Oenanthe fistulosae*; *Senecioni aquatici - Oenanthe mediae*. In relatively saltiest conditions, we found *Junco gerardi - Oenanthe fistulosae*; *Trifolio maritimi - Oenanthe silaifoliae*. In relatively drier conditions, we found *Oenanthe peucedanifoliae - Brometum racemose*, and *Hordeo secalini - Lolietum perennis*. The most common association we found are the *Senecioni aquatici - Oenanthe mediae* for the wettest surfaces and the *Hordeo secalini - Lolietum perennis* for the relatively dryer conditions. These meadows represent surfaces from sub-salty to freshwaters. Simplifying following our field surveys we underline this trends to frame them:



Figure 66 – Sub-salty-freshwater meadows sigmafacies from the wettest (left) to driest (right) gradient

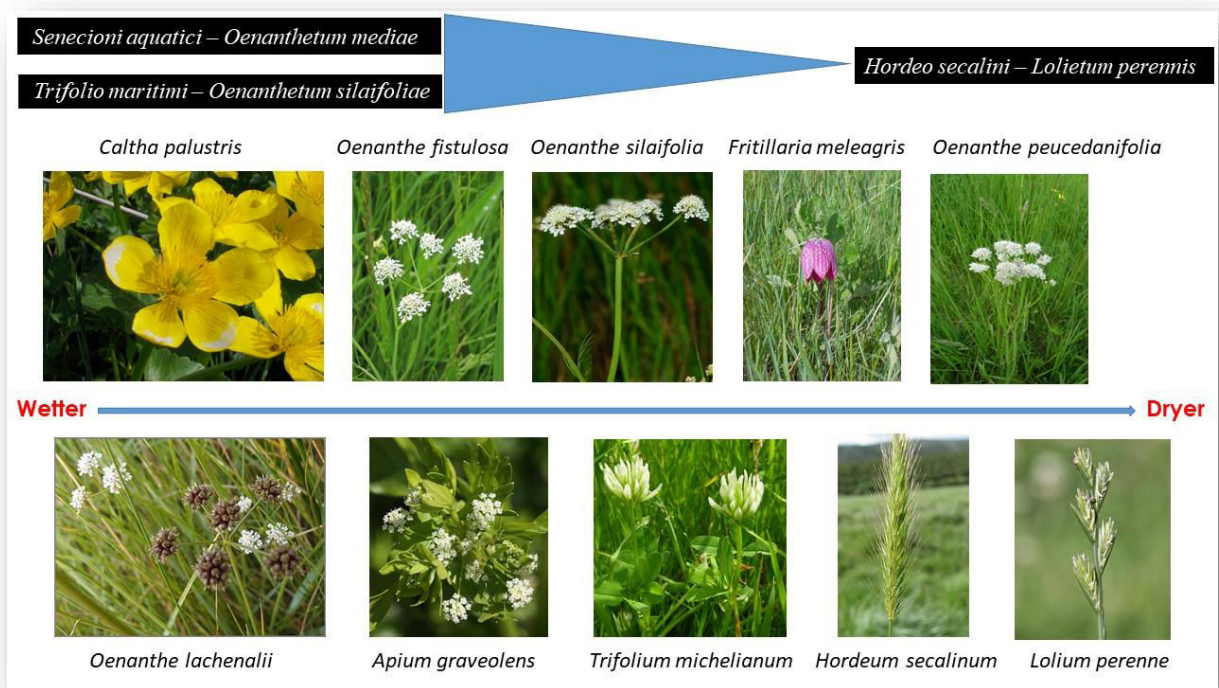


Figure 67 – Sub-salty-freshwater meadows. Upside the figure, following the triangle, going down we increase in salt influence; going right we decrease the soil moisture. Downside the figure, examples of bioindicator species along the related plant association's triangular gradient.

About meadows sigmafacies, under strongest land uses (grazing pressure) we have a substitution of plant association within the same habitat (and related vegetation series), as example: the *Pulicario dysentericae* – *Juncetum inflexi*; *Mentho longifoliae* – *Juncetum inflexi*; *Alopecuro pratensis* – *Cynosuretum cristati* Passarge; *Cirsio palustris* – *Juncetum*

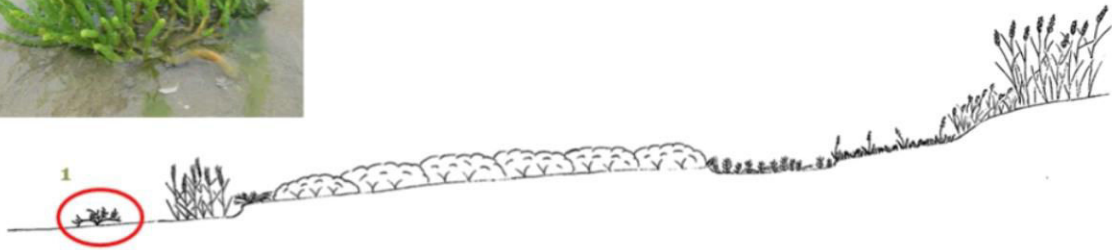
effusi Gallandat; *Junco acutiflori* – *Cynosuretum cristati*; *Lolio perennis* – *Potentilletum anserinae*; *Plantagini majoris* – *Trifolietum resupinati*; *Convolvulo arvensis* – *Elytrigietum repentis* and the *Alopecuretum pratensis*. In the previous figure, we can highlighting how these meadows are secondary and strongly depends to the land uses. The picture (b) underline the artificial limit between meadows and roselière, determined by soil use. In the picture (d) we can see a rare synanthropic meadow facies: the *Ranunculo sardoii* – *Myosuretum minimi*. The rarity of this plant association studied is linked to the very wide presence and cover of *Myosurus minimus* and the very large surface occupied by this association.



Figure 68 – Subsalty-freshwater meadows sigmafacies. Clockwise, we have a) grazed-mowed grasslands; b) more intensively grazed meadow; c) strongly grazed meadow, and d) a synanthropic meadow.

About salt marshes and meadows of the *Atriplici prostratae-Elymeto atherici* sigmetum, following the dynamico-catenal phytosociological analysis we can distinguish the following theoretical zonation, underlined by the related plant association sequence as representative example along the minor to major riverbed (Slikke to High Schorre):

Salicornietum dolychostachyae

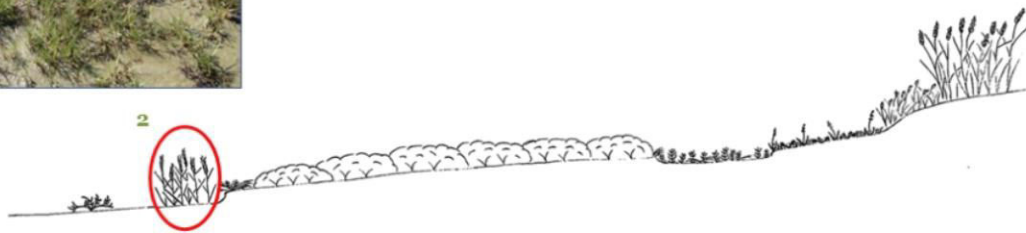


Slikke

Schorre

High schorre

Spartinetum maritimae



Slikke

Schorre

High schorre

Puccinellio maritima-*Salicornietum perennis*

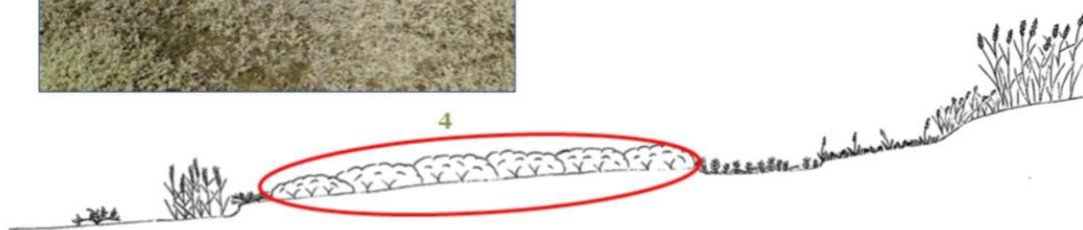
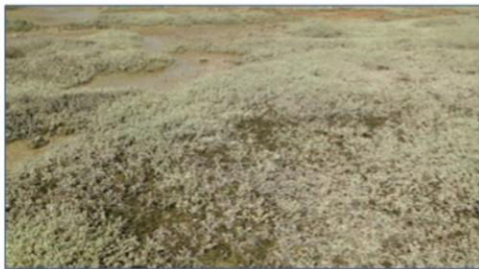


Slikke

Schorre

High schorre

Bostrychio scorpioidis-*Halimionetum portulacoidis*

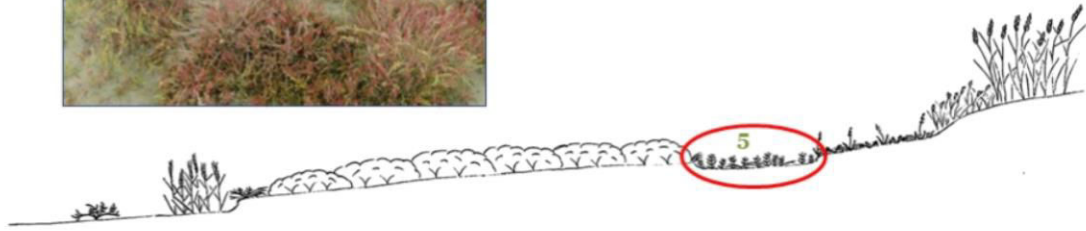


Slikke

Schorre

High schorre

Puccinellio maritima-*Salicornietum ramosissimae*



Slikke

Schorre

High schorre

Aster tripolii-*Suaedietum maritima*



Puccinellio maritima-
Salicornietum ramosissimae



Salicornietum pusillo-
ramosissimae



Triglochino maritimi-
Limnietum humilis



Plantagini maritima-
Limnietum vulgare



Slikke

Schorre

High Schorre

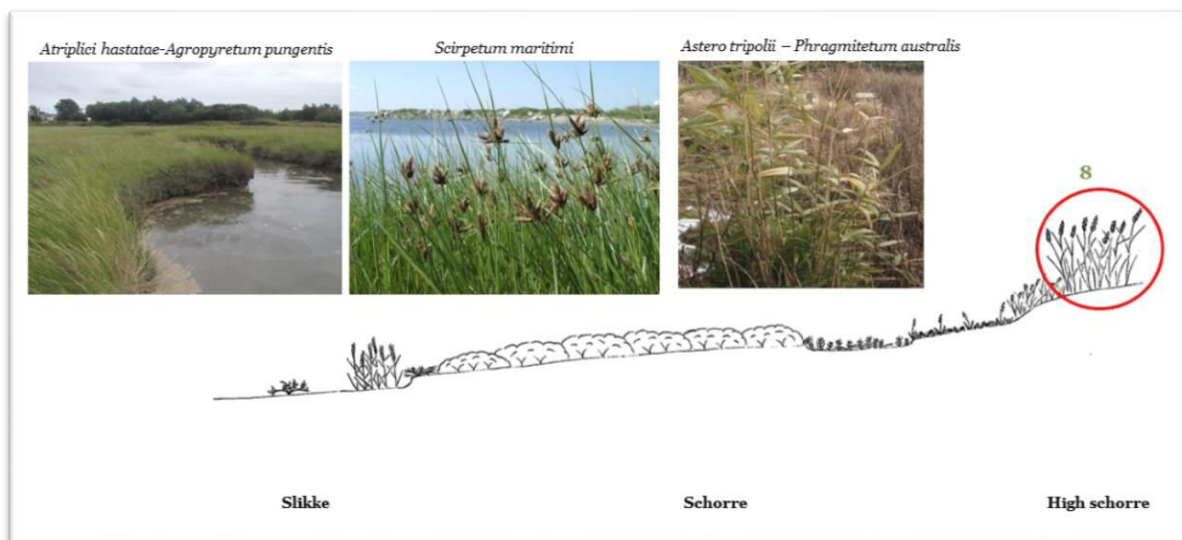
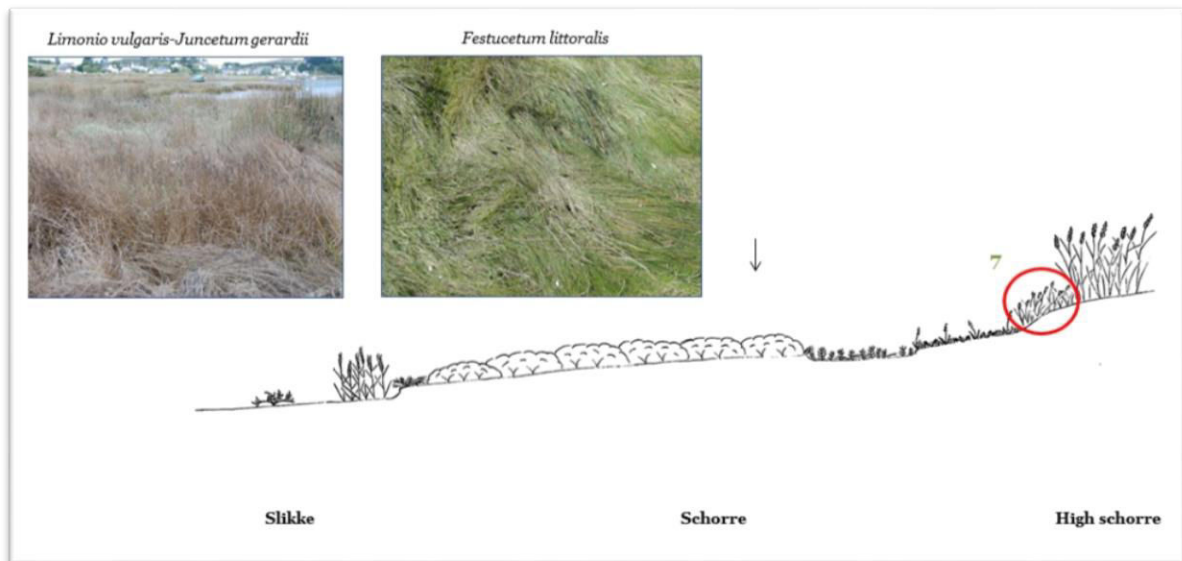


Figure 69 - Images sequence of the Salt marshes and meadows bio-indicator plant associations, from the minor to major estuarine bed.

About the Salt marshes and meadows community, it was observed that in saltiest conditions, this community is characterized at lower levels by *Spartina* and glassworts species (Slikke). In the middle position (Shorre) is characterized by *Halimione portulacoides*. In uppermost conditions by Tall Sedges or reed bed associations in moister conditions, while in driest or sandier drained condition this community is replaced by *Elymus athericus* meadows.

Going up to the upper and less salty conditions, the most salt tolerant species decreases till to disappear, as it is for glassworts; the *Halimione portulacoides* develops lesser and in thinner linear communities till the lower brackish level (rare and punctual in the upper), giving more place to tall Sedges and reed bed associations that develops in larger surfaces.



Figure 70 - The saltiest aspect of the salt marshes and meadows, developed in large surfaces. Sillon des Anglais, lowest Aulne estuary sector.

Generally, glassworts and *Halimione portulacaoides* are linked to salt and rich mud deposits, even if they appear between shells and pebbles deposits, as it is for the previous figure.



Figure 71 - Slope failure with *Halimione portulacoides* and “*Daucus carota* and *Dactylis glomerata*” meadows. The *Daucus carota* and *Dactylis glomerata* meadows generally here belongs from the *Fraxinus excelsior* and *Quercus robur* forest potential vegetation.

In sandier and rocky drained conditions, in the salt marshes and meadows we can find the driest aspects, never or only rarely flooded, but in any case determined by the estuarine dynamics. In sandier condition, we can observe the transgression of dunes and beaches species. In rocky condition, we observe other species, which sometimes lives also in sandier places like *Crithmum maritimum*, *Silene uniflora*, *Honckenya peploides*, *Armeria maritima*, *Daucus carota*, *Dactylis glomerata* and *Spergula maritima*, generally linked to the residual presence of *Festuca* sp pl., *Elymus athericus* and *E. repens*.

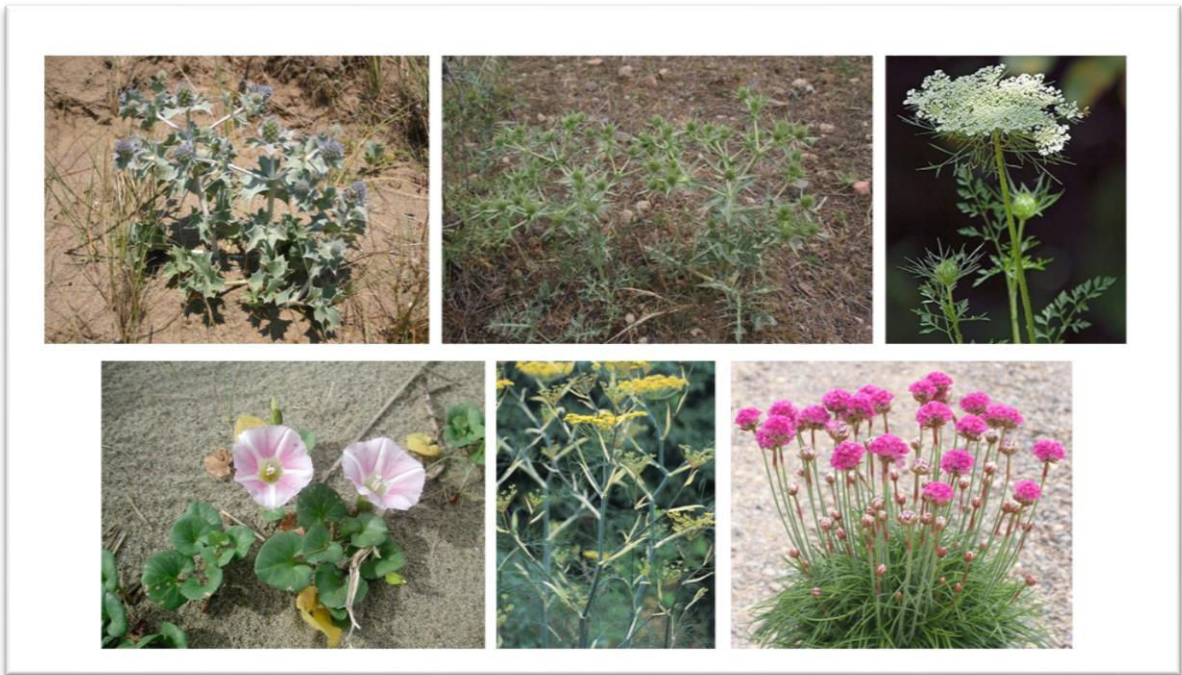


Figure 72 – Trasgressive species examples for sandier dry conditions: *Eryngium maritimum*, *E. campestre*, *Daucus carota*, *Calystegia soldanella*, *Phoeniculum vulgare* and *Armeria maritima*.



Figure 73 - Trasgressive species examples for sandy and rocky places: *Spergula maritima*, *Chritum maritimum*, *Limbarda crithmoides*, *Silene uniflora* and *Honckenya peploides*.



Figure 74 – The contact between *Quercus robur* forest and Salt meadows and marshes following the estuary bed confinement by a slope failure. Elorn estuary, in winter aspect.

In confined positions on the slopes, it is possible to find forest canopy lying on salt marshes and meadows. The branches protract, creating a “Siparium” front curtain on salt marshes and meadows community. The forest canopy is linearly sheared, at the same level that corresponds to the tides salt water level. In this condition, the salt marshes and meadows community is developing less biomass, because enriches of annual and shadow tolerant species, impoverishing in heliophilic species that are otherwise dominant. For that reason, this community can appear less dense or even without vegetation in conditions of stronger currents or in less indicated phenological periods, such as winter.



Figure 75 - The upper Scorff estuary portion in summer, with a slope vegetation differences following the banks inclination type.

About forest communities, in confined conditions, we can observe a vegetation differences between the two estuarine banks. In the picture, at the left side (orographic right) we can observe a zonal vegetation of *Fagus sylvatica* forests on a steep slope. In the other bank, we observe a *Salix* species and *Faxinus excelsior* mixed formation on the alluvial plain. In flatten condition we observe a normal series sequence and expression.



Figure 76 – A typical aspect of the *Salix atrocinerea* forests series. Mature head series sigmafacies, in fluctuation. Behind the primary tall roselière (Reed-bed facies, *Phragmitetum communis*). Aulne estuary.



Figure 77 – A grazed aspect of the *Salix fragilis* forest series. Mature head series sigmafacies. Behind the primary low roselière (*Apio nodiflori* – *Eleocharidetum amphibiae* and *Scirpetum triquetri*). Loire estuary.

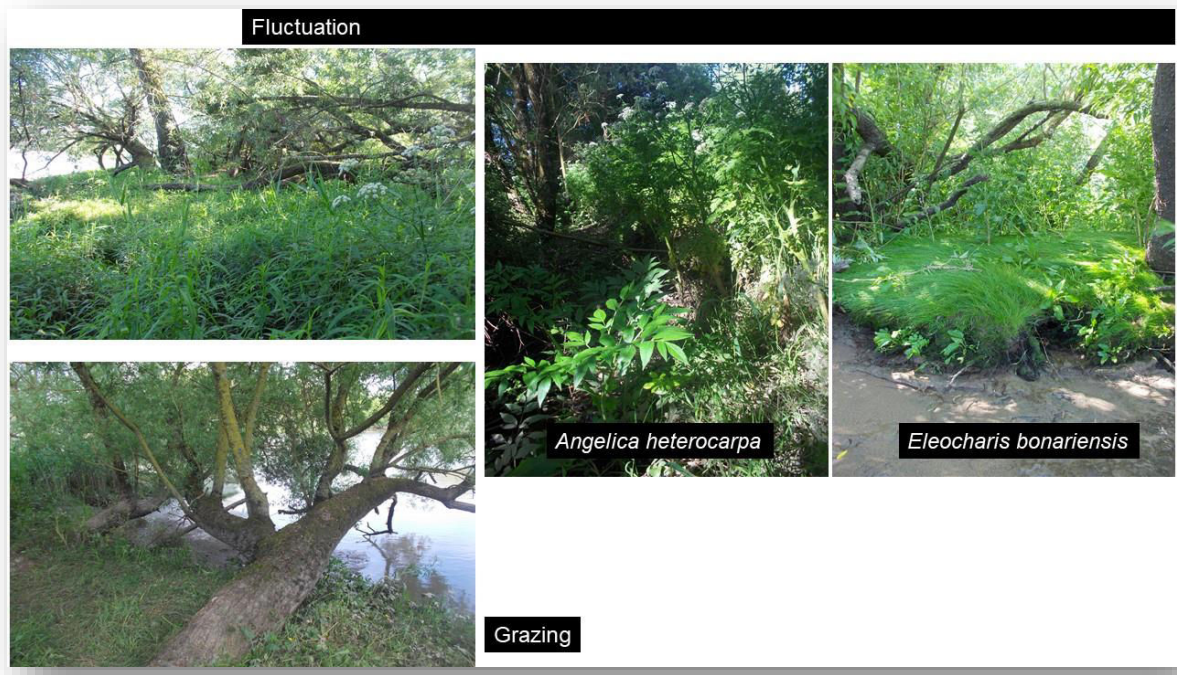


Figure 78 – *Saliceto albae* sigmetum head series variations. Clockwise we have four facies of mature forests. The first is in fluctuation; the second is characterized by the presence of *Angelica heterocarpa*; the third is moister and characterized by *Eleocharis bonariensis*, *Apium nodiflorum*, *Limniris pseudacorus* and *Jacobaea aquatica*. The fourth is a mature but grazed forest.

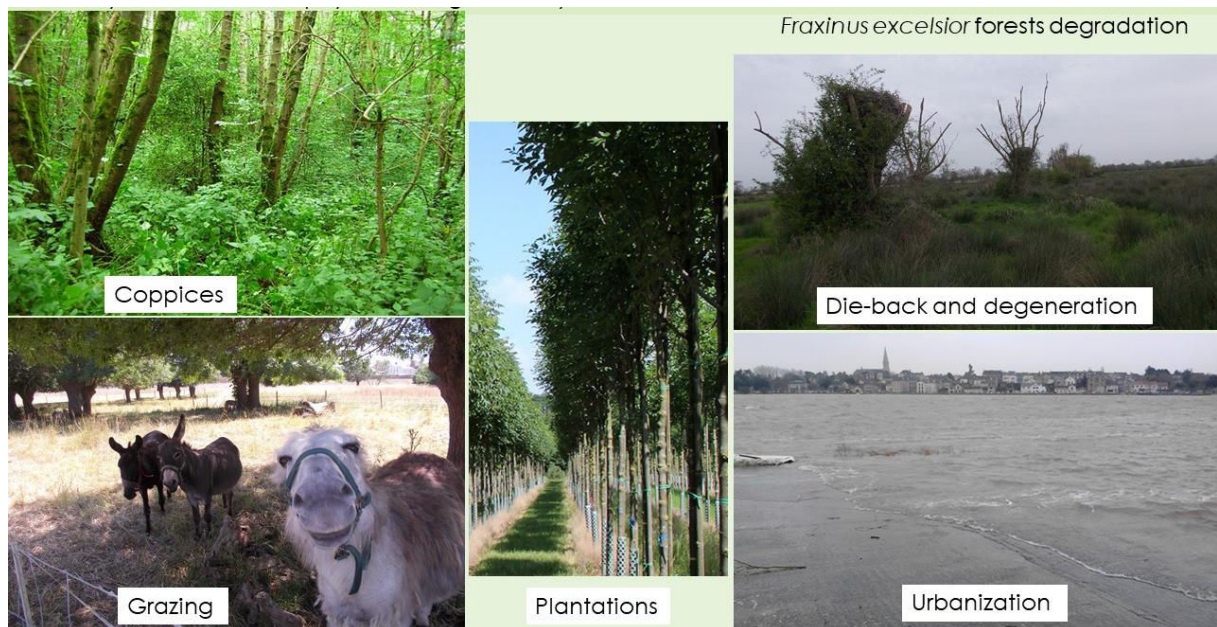


Figure 79 – *Fraxinus excelsior* forests sigmafacies variations. Clockwise we have a typical coppices facies; plantation facies; Die back and degeneration facies due to the salt front shift and flood changes; a typical grazed forest and the urbanized surfaces.

6.3. Typology and mapping plant landscape

6.3.1. Typology and map of vegetation series and geoseries

In total, we mapped by QGIS 3 representative estuaries for a total of 74433 ha of surfaces evidencing 2 series and 4 geopermaseries.

A difficult task of the fieldwork was linked to understand the vegetation potential in Tessellas (Series) under strong anthropization on large surfaces, mainly linked to two reasons: the land uses that deleted head series (changes in actual vegetation), and land forms changes that caused changes in potential vegetation expression.

Due to deforestation and soil uses, some large portion could have any concrete evidence on the head series vegetation, so we can only suppose it.

In geoserial sets, we considered the potential vegetation that has more or less the same surfacic distribution. Geoseries consists in some head series plant associations that shows wide distribution, selecting the most represented one to give the name. When one or more association are linked as exception to one head series association, and they are not so significant in surfaces occurrence (and they can occur linked to some series) we decided to link them to the main head series association. This, in order to simplify the system according to the generalization principle of cartography. As example, the marshy *Salix atrocinera* forests make their own series within the “*Salix atrocinerea* marshy forest sigmetum” patches; but they consists to a linked association in other *Salix* species forests series and *Fraxinus* forests geoseries, where they became sparse, punctual, less typical, and more rare as head series. The *Alnus glutinosa* forests are linked to the willows series or *Fraxinus* geoseries, depending on their case-specific occurrence.



Figure 80 – An example of spatialization of vegetation series in the *Saliceto albae* sigmetum, riparian freshwater facies in Loire estuary.



Figure 81 – An example of spatialization of vegetation series in the *Saliceto albae* sigmetum, sandy draining soil facies. In this conditions meadows and shrublands enriches in xerothermophilic species. Loire estuary.



Figure 82 – An example of spatialization of vegetation series in the *Saliceto albae* sigmetum, riparian oligohaline facies on sandy soil.



Figure 83 – An example of spatialization of vegetation series in the *Saliceto albae* sigmetum, sandy draining soil and grazed facies.



Figure 84 – An example of spatialization of Serial complexes in freshwater estuary portion of Loire.

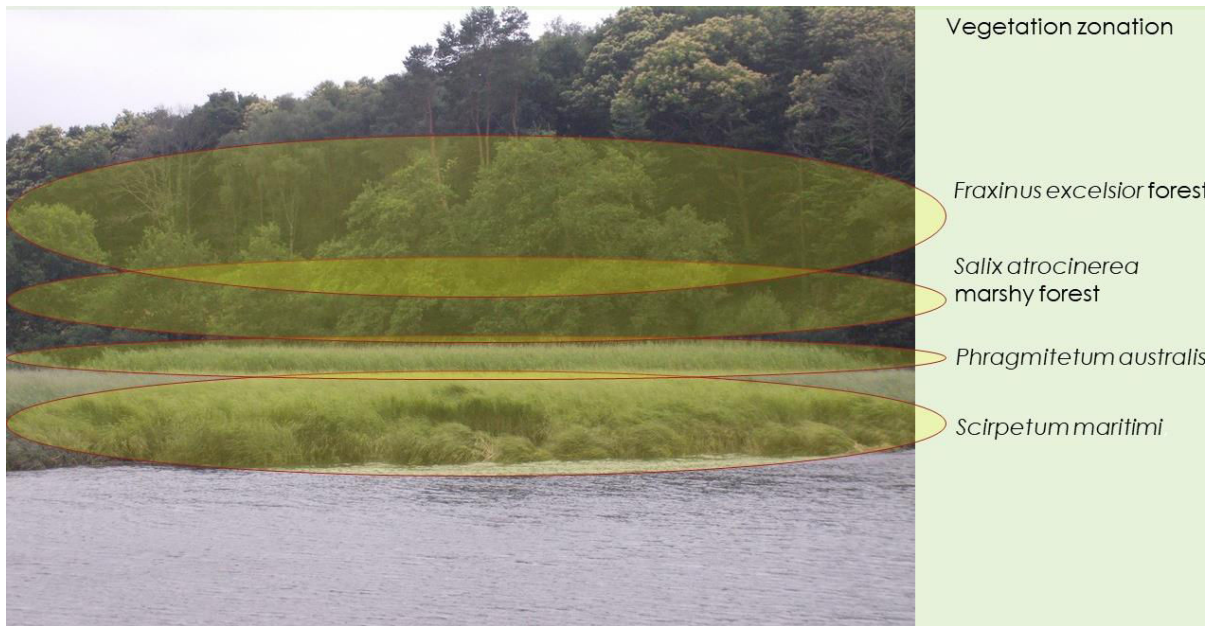


Figure 85 – An example of spatialization of Serial complexes in brackish water portion of Blavet-Scorff estuary.



Figure 86 – An example of spatialization of Serial complexes in salt water portion of Charente estuary. Up, behind the salt marshes and meadows vegetation, we can see *the Solano dulcamarae - Tamaricetum gallicae* and the estuarine forests.

6.3.2. Spatial and temporal scales

For the plant mapping typology and for the assessment of plant landscape units, the scale remains the fundamental parameter for the vegetations study, up to phytogeographic divisions. The scale of 1: 25 000 chosen in the CarHAB program implies an extremely fine degree of precision of all the parameters that must be taken into account in the vegetation series and geoseries studies. Data crossings between vegetation series and geoseries with ecological, abiotic and biotic data, generally are available on a smaller scale (1: 50 000 to 1: 250 000). This could easily limit the thematic maps superposition, and consequently the ecological and chorological analysis of vegetation series and geoseries. For that reason, we decided to define our series and geoseries to be easily and precisely adaptable for larger and smaller scale following the necessities, as an elastic skill. The adaptable scale (from big to small) resulted as appropriate for global applications; and for more detailed elaborations or representations.

The stability in time of the plant cartography representation depends on human impact on natural trends. The temporal scale used, resulted appropriate to our goals; resulting as advantage in sense of stability in time (expected on almost 100 years), potential vegetation identification, and series definition.

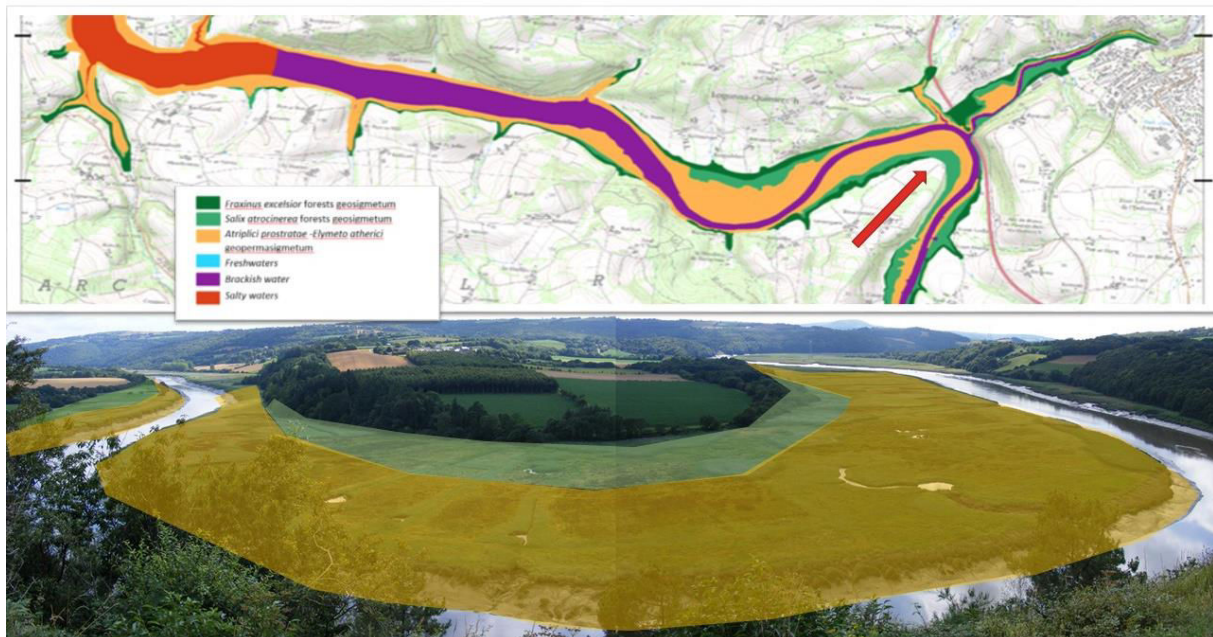


Figure 87 – An example of plant map spatialization of Serial complexes in brackish water portion of Aulne estuary. Down, in detail is represented the point indicated in the cartography with the red arrow: aquatic environments (riverbed and pools), Salt marshes and meadows (*Atriplici prostratae-Elymeto atherici geopermasigmetum*) brackish variant, *Salix atrocinerea sigmetum*, and *Fraxnius excelsior forests geosigmetum*.

6.3.4. Plant landscape representation at smaller scale

More the scale is smaller, less is possible to represent details in thematic maps, avoiding the detriment of maps quality by data overload and illegibility. This let us to promote a hierarchic system that can be organized and assembled according to the criteria of biogeography, and in particular the phytosociology of the landscape. For that purposes, we grouped the series

in catenas (or geoseries). As example, at smaller scale, the willows forest series are assembled in a Willow longitudinal geoseries. The aquatic vegetation was assembled in a longitudinal geopermaseries. Ash forests geoseries we can distinguish some scattered and interposed association that could be as head series, even if actually they are to residual and fragmentary to understand their relate vegetation limits.

In azonal estuarine series, each Tessella is similar to the closest ones, varying following some clines (salinity; soil humidity, and topographic level) in various direction (longitudinal and transversal), representing an azonal surface (a terroir). In this way, an essay was recently carried out in different conditions by (PEDROTTI & GAFTA, 2003; CATTEAU *et al.*, 2010). Depending on the scale factor and the level of generalization of the estuarine representation we could represent the series spatialization (organization of the Tessellas) according to the geographic (abiotic) using the Latin accretion adjectives¹⁵:

hypocatenas (as commonly do by geoseries, geopermaseries...) - following small variations;

catenas in the strict sense – following meso-variations (grouping close series and geoseries);

megacatenas – following macro variations (grouping catenas in one direction: longitudinal, transversal...);

hypercatenas – following hyper-variations (grouping catenas in almost two directions: longitudinal and transversal).

Following this increasing “in accretion”, we gain in simplification (generalization) but we lose in details (resolution) that is an advantage in smaller cartographic scales but a disadvantage in bigger scales. At the high generalization (by accretion) level all the estuarine surfaces could be grouped in one only patch (hypercatena) of azonal estuarine vegetation that correspond to the estuaries terroir.

In lower level, we could distinguish by megacatenas (i.e. the catena of water vegetation, the catena of riparian vegetation, and the catena of mesic vegetation).

In lower level by catenas we could represent longitudinally the belts described by the dominant vegetation (the belt of hygrophytes, the belt of *Salix* species forests, and the belt of *Fraxinus* species forests...), while transversally the steps of the salty front portions.

These vegetation belts represent band of vegetation in large sense, described with some nuances by different authors as Vegetation belt; Plant parcels; Cingolo, Ceinture, Guertel of vegetation. They consist of vegetation structured in (more or less) parallel or concentric stripes composed of plant communities along an ecological gradient, mainly of edaphic type. The vegetation belts correspond to the observable zonations at the edge of lakes, rivers and others waterbodies (FAMIGLIETTI & SCHMIDT, 1969; BEGUIN 2003, 2009; GÉHU, 2006a; PEDROTTI, 2013). In lowest level, we could represent the hypo-catenas corresponding to geoseries in their large sense (geoholoserries, geopermaseries, geocurtaseries...). Following these issues, our study model and plant mapping provides an elastic tool to be adapted in spatial rearranging, following the scale and resolution problems.

¹⁵ http://www.treccani.it/enciclopedia/accrescitivo_%28Enciclopedia-dell%27Italiano%29/

6.3.5. Vegetation variation per geomorphological features in estuaries

In studies estuaries, from estuarine mouth to the freshwater portion, in each ecological compartment we can distinguish some common variations, and exceptions linked to the local particular geomorphologic characteristics.

The main variation follows the confinement of the estuaries riverbed, and the related continuity (lateral, longitudinal and vertical ones). In fact, more the estuaries are confined and less the vegetation series gradient is developed (series tends to be thinner, linear and fragmentary), till to jump one or more series, influencing also the community richness and the transgression phenomena.

These confinement and continuity issues importance reflect also on human influence, following artificial river-banks, barrages, dams... that stop or influence in some ways the hydrodynamics and the geomorphology issues. As example, in all the barred salt or brackish bright, bays, marshes and rivulets we found a freshwater vegetation. In this way we can found for example *Alnus glutionsa* forests instead *Salix atrocinerea* forests (in marshier conditions) or even replacing the *Fraxinus excelsior* forests (in less marshy conditions). Or as it is for the strong *Alnus glutionsa* presence in the lowest Erdre river, instead that a rare punctual presence. The same was observed for the *Alnus glutinosa* forest presence close to the “Chapelle du Folgoat” (Landévennec), near an old tidal mill – in the Aulne estuary.

As it is for some freshwater portions from the Étel and Laïta estuaries in their salty portons, behind lateral barrages. Or as it is the case of the Vilaine lowest estuarine riverbed that up to the Arzal barrage manifest a freshwater aquatic vegetation in a former salty sector, and consequently shows a vegetation freshwater shift (i.e.: salt-muds in freshwater marshes, salt meadows in meadows, reed bed and even forests) just behind the estuary barrage.

The Guily Glaz dam, built in the Aulne estuary to limit the impact of floods on the watershed. This barrage occurs in the oligohaline sector, influencing the tidal dynamics, mostly reducing the surfaces and the expression of the vegetation linked to dynamic tides,

Reclamation and artificial burial caused a lot of changes and related vegetation exceptions in estuaries riverbed: causing in most cases a potential vegetation changes. The biggest examples are from Loire estuary where along both the banks, some series transversal shift occurred as consequence of the artificial accumulation of sediments, followed by the channel deepening for navigation purposes. In this condition, the willows series (*Salix atrocinerea* and *Salix fragilis*) shifted, and they could be find even instead of “salt marshes and meadows community”. This is more common and easy to understand if looking to the Saint Nazaire – Donges (orographic right) riverbank filled for portual-industrial purposes; looking the East Donges artificial accumulation of estuarine bed debris, till to Le Pellerin and Nantes.

Another example of changes linked to the continuity artificialization is done by the channeling activities carried out for navigation purposes and by barrages that created new marshy areas and let the salty portion up-shift where salty muds and meadows goes up, taking the place of freshwater marshes, meadows and even forests. In the Loire estuary, *Angelica heterocarpa* and *Scirpus triqueter* populations monitoring programs showed the up shifting of their distribution, following the changes in salinity front and the sedimentation regime (Mignot and Le Hir, 1997; Magnanon *et al.* 1998; Dupont 2001; Le Bail and Lacroix 2005; Geffray and Kaupe 2012). This demonstrates how these species are dependent on their environment and its evolution. In Charente estuary, Terrisse and Champion (2008) reported the regression and degeneration of

A. heterocarpa, following the same trends of the Thermo-Atlantic sub-salty meadows habitat, linked to the disappearance of a regular brackish water submersion period. The disappearance of these two typical estuarine components, replaced by freshwater vicariant elements, are ascribable to works and barrages for navigation, water regulation, water uses and agricultural purposes (i.e.: dams; canalization, reclamation and deforestation). The drainage affects the potential vegetation expression allowing a shift from wet series to drier ones. This is especially affecting vegetation limits and intermediate series levels, wide-spreading the transgressive phenomena and originating some mixt species communities, making hard to place them (i.e.: *Salix* sp. pl; and *Fraxinus* sp. pl mixed forest, or bottom valley *Fraxinus* forest with an understory typical from *Salix* forests and vice-versa), as generally observed in each estuary. The vertical continuity is influencing a lot the vegetation creation a special vegetation types. As example of this, we can cite the influences of the freshwater accessions in salty environments; or the possibility of marshy vegetation spots in the major riverbed or “salants” (summer-salty) meadows, that are dry and with salty outcrop in the dry season. The canalization tends to delete this variation, negatively affecting this vegetation expression.

In the salty portion, the geomorphology and the hydrodynamic influence the vegetation expression according to the substrate type and the estuary mouth type.

The substrate influence on vegetation depends on its granulometric size: when thinner (mud) on large surface and low slope, it allow the greatest expression of salt marshes and meadows; if the deposition-erosion swing is not so strong to reshape continuously the surface. Increasing in granulometry it was observed a decreasing of salt marshes and meadows expression, till in rocks (armor, cascades and rocky outcrops) where the vegetation tends to develop lesser, scattered, or driven by local (more or less temporal) thinnest sediment accumulation patches. This is for example from the lowest Loire, Aulne, Charente, Blavet-Scorf, Elorn and Laïta portions. In this case, more the soil in sandy and more the vegetation contact influence (transgression) is from dunes (in drier level), dune-slacks (moister level), or rocky type.

The mud deposits between sand, pebbles and pebble-shell bars allows a huge development of salt mud and meadows vegetation. Sandy banks or dune influence in estuaries let to have some influences (transgression and contacts) from the dune-foot and riverbed/shore vegetation creating some particular and typical phytoassociations variant.

If muds or sand are moving, in both cases we can found an almost total absence of vegetation; as is for rocky places, showing only occasional scattered or less developed specimens or vegetation fragments influenced by more stable or thinner deposits (or freshwaters accessions), as is for example from the lowest Loire, Étel, Laïta, Blavet-Scorf and Vilaine.

If the river mouth more influenced by the ocean, the tidal flux is dominant (it is more influential) than the river flux, the estuary increase or completely shows a sea bay characteristic, as it is the case of Étel. This characteristic consists also in a more sea vegetation expression in the channel. Here, the brackish (mesohaline-oligohaline) vegetation evidence consist only in a very thin and small *Scirpus tabernaemontani* spot presence; upstream the river-torrent geomorphology and vegetation is quickly marked. In opposite case, when the river mouth is less exposed or less open to the sea, we find very mud estuaries, as is often the case for the estuaries of the Brest roadstead.

When the tidal flux is limited for natural or artificial conditions we can see how the freshwater influence could become dominant also if the freshwater flow is negligible, as is the case for interior estuarine bays, or in smaller (very small) estuaries as observed in the half upper Penfeld portion, in “Caro” and “Baie des Trépassés” torrents estuaries (their estuarine portion

consist actually in a lagoon type, tilting from freshwater or oligohaline - to semi-salty, occasionally).

7. CONCLUSION AND OUTLOOKS

Our work was subdivided mainly in three steps:

- In the first step we studied topographic and environmental thematic maps, aerial photo, available databases, and bibliography, in order to make a review of the state of knowledge on French Atlantic estuaries and to understand more as possible their characteristics, human impact and plant association described. This let us to compare our study area with the international literature and to define 8 selected estuaries where to make indept studies (fieldwork).
- In the second step, we carried out geography, botany and ecology observations, together with plant mapping, phytodynamic, phytosociological and synphytosociological relevées. We make relevées mainly in estuary surfaces, but also in surrounding areas looking for representative areas as test points, considering them as reference for non-estuarine surfaces to makes comparisons and to have control surfaces.
- In a third step we elaborate climate and fieldwork data by bioclimatic indices and by QGIS software, crossing the obtained data.

In total, in 8 estuaries complex, we made fieldworks for a total of 98315 ha, highlighting 2 series and 4 geopermaseries corresponding to 131 plant associations, 60 alliances, 43 ordos and 28 classes. Then we mapped by QGIS 3 representative estuaries for a total of 74433 ha of surfaces.

About our main research question and hypotheses, our research underlined how the French Atlantic estuaries systems could respond to recurring and homogeneous main environmental characteristics (topography, geomorphology, hydrodynamics, human impact, salty levels, and biogeography). Our work results in modelisation by plant mapping, ecology compartments, transect schemes, phytosociology and synphytosociology tables. We elaborate estuarine model of vegetation distribution and potential, but also a common generic theoretical scheme of an estuary; testing it also with very small estuaries like Penfeld, Ruisseau du Caro and Ruisseau de la Baie des Trépasée, looking for how difference are linked to homogeneous main environmental characteristics studied.

We defined in that way also how environmental characteristics, and related ecological gradients affecting the estuarine systems and the plant landscape.

The principal characteristics driving the common base in estuaries system resulted in topography, salty and water levels; while geomorphology exceptions, sea winds, substrate, bioclimate, and human impact resulted as influential factors.

We noticed a climate and bioclimate slow variation between north to south and between coastline to inner portions (only in biggest estuaries). These variations affect the expression of some plant associations and species; replacing them as vicariants. The generic function scheme is always valid and the vegetation is always well represented in our series and geoseries by dominant species and associations. The changes can only be reflected on the possible

description of different geographic variations. This is also explicable by the fact that we are on azonal vegetation, consequently the only driving factors are water and salt levels, together with the human pressure. In more exposed to wind coastline we can observe some exceptions like truncated series. Some of them are more developed to the perma and curtaseries but they are not enough developed if compared to the equivalent inner vicariant conditions. The main example is the *Salix atrocinerea* mesic forests (rich in *Chamaeiris foetida*) that replace the inner *Fraxinus excelsior* forests; or the *Ulex europaeus* and *Prunus spinosa* (often accompanied by other shrubs) that replace the *Fraxinus* forest and hardwood forests in driest and windy coastline conditions, and also in dunes and in pebbles accumulations.

In sandy estuaries portions we observed also how on actual dry grassland and shrubs could correspond a potential for *Salix alba* and other species. In biggest estuaries, we observed how the Mediterranean characteristic became more evident. In Loire, in the inner sandy positions the *Salicetum albae* is more close to the *Salici albae-Populetum nigrae*, and we found some *Quercus ilex* and even *Quercus coccifera* as escaped to cultivations. Especially in Charente, the *Sambucetum ebuli*, and communities of *Silbium marianum*, *Smiranium olusatrum* and *Thypha domingensis* are more evident.

We can observe also how after land filling, barrages and reclamation we have some plant potential exceptions.

Vegetation traits, distribution and models resulted a helpful tool to classify estuary types. Phytosociology and synphytosociological methods and concept resulted useful to obtain this models and classification but it could be necessary a more accurate and in-depth study focused on more long time monitoring. We noted that often plant associations need a better ecological characterization and a syntaxonomical review in order to obtain more precise results. In fact, the plant communities not always fits with the already described associations, or they are not easily and precisely attributable to the described associations, mainly for two reasons: the first was the discovery of new communities that should be studied in more detail to describe new associations. The second reason is that some associations especially between pastures and meadows are often different from the ones described in bibliography, showing how these communities are variable in their facies and time, how they are instable in their environments following the land uses fluctuations and global changes. Land uses fluctuations depends also to the traditional uses of these meadows, under posed to a mixed uses of these surfaces (pastures and mowed grasslands, and used under a variable intensity). Endemic variations that are made more complex by the influence of global changes.

We found some new communities that need to be in-depth, especially concerning forests of *Salix atrocinera* communities and *Fraxinus excelsior* communities. Some meadows also need more in-depth studies like the *Daucus carota* and *Dactylis glomerata*. However, even reed bed communities need more clarifications to be used more precisely. Forest are still too young, disturbed or fragmented to have always a precise and incontrovertible ideas on them, giving further difficulties to use them as referential status. Often large surface has any forest cover also if there is some potential for their development.

This research work focused on the typological characterization and plant mapping issues of series and geoseries of vegetation, proposing a methodology that follow the principles of the landscape phytosociology, looking on what is the role of biotic and abiotic factors involved in the distribution and dynamics of vegetation, and the structural and spatial organization of the series and geoseries resulting on the modelization of the environmental gradients. The first part of our work was set up in a strict conceptual framework to provide a first methodological characterization of series and geoseries, related plant mapping, and applications to the

landscape phytosociology. The description of the general features influencing the of coastal, river and estuary dynamics vegetation showed the specificities inherent to these environments, mainly related to the exposure of plants to ecological conditions such as wind, salinity, topography, substrate...

Development of morphological and physiological adaptations in plants is one of the direct consequences of these ecological constraints. Beyond the gradient linked to this situation of interface between land and sea, this study has retained the importance geomorphology, ecology, hydrodynamics, landscape and geographic issues for the distribution of the estuarine vegetation and organization along gradients studied. This, taking into account current and past human activities in the definition of series and geoseries: integrating the actual and potential vegetation within series and synrelvés. Our study objective was to transpose the general methodology and principles of the landscape phytosociology, applied to estuaries, to characterize the series and geoseries of vegetation and mapping them trying to find also a possible model of estuaries functioning and vegetation distribution. We focused on the analysis of the data collected during the research work. Due to the spatial extent of our study site, climate plays an important role in the differentiation and replacement of vegetation from north to south – following the microclimatic and biogeographic variations. Our model takes into account this and it applicable to the estuaries of the French Atlantic estuaries.

The results will be integrated into the future France vegetation maps, and into the future catalogue of French vegetation series and geoseries; both expected in future as fruits of the CarHAB program.

A research perspective, already started under the CarHAB program, with the participation of our data, concerns the use of white backgrounds to facilitate tessellary divisions. Recently, a test was started by the ISTHME laboratory of the University of Saint-Etienne to identify the most relevant indicators to model in the context of the spatial delineation of our studied vegetation and others researches within the CarHAB project. This, to identify ecological markers that could allow us to define more clearly the vegetation limits.

Another outlook to be developed consist on the implementation of the ecological analysis and elaboration of data by precise sampling of all the ecological variation along gradients, and making statistical elaborations looking for any type of correlation with the vegetation variations and micro variations, even exceptions. The issues liked to refine plant mapping and synphytosociology fieldwork to mathematic and digital skills like statistic, imaging and remote sensing tool that could represent an interesting field to be developed in order to give a more qualitative and quantitative data to refute our analysis and to develop all the possible applications.

Our works focus *a priori* in habitats or environments of national and international importance (“Natura2000” habitats), Water Framework Directive (2000/60 / EC), and Ramsar convention on wetlands.

For that a more in-depth knowledge and description of habitats and vegetation is necessary. For that reason, a more in depth phytosociological and synphytosociological monitoring could be a very good and fine skill to understand the evolution and to assess heritage and bioevolutions of habitat in a finer and precise way based not only in species presence but also in plant associations and series presence and status. This also because the same habitat could be represented by different plant association of different ecological value, artificialization degree and rarity.

The ecological limits can be roughly defined by longtime analyzes. In water ecosystems, they can be defined following the moving aquatic masses, taking the main channel as a

reference point. In any case, the ecological limits can be described by vegetation monitoring, since plants (and related communities) are important bioindicators. Plants and vegetation represent effective bioindicators, known in the aquatic field as Macrophytes. The study of macrophytes is a monitoring methodology used and officially recognized by the European community, which has been developed since the beginning of the 2000s as evaluation tools, as part of the implementation of the Water Framework Directive. Indeed, the study of vegetations allows monitoring of global changes, in the long and short term, because plants are strictly linked to the expression of biodiversity and therefore to environmental conditions, functioning as bio-indicators. . The monitoring of macrophytes is widely used for the assessment of wet systems (aquatic in the broad sense) by integrating environmental changes, community structure (species and communities presence / absence and frequency), phenology, development (traits in large sense), vegetation series and plant dynamic trends. Our study wants to be a contribution in this way. It could be necessary to improve plant association and higher and lower levels making further surveys, distributing relevés in a denser, and wider geographic area, fitting the most appropriate seasons and the best plant phenological times per plant association, making repeatable fieldworks protracted over the years.

It would be crucial on management and conservation measures to let the possibility for each series to have a free development of the natural dynamic to better understand the potentiality and to better study the plant landscape. Event though the development on the application to the management and human impact and ecological assessment following the definitions of naturalness, hemerobia and resilience and following the evolution of the various criteria, in order to these thematic (GÉHU, 2006; SENDER *et al.*, 2017; CHALUMEAU, 2018).

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ANNEXES

Others PhD study experiences

The main activity during the PhD study, was carried out in France, within the CarHAB research project and additional or preparatory observations and activities were carried abroad, in Italy and Poland within other research projects aimed to study and model plant communities at different scale. The foreseen levels of study, encompassing ecology, vegetation communities and dynamics, gradients, biodiversity and related issues, have been also addressed to possible suggestions or indications for land management and biodiversity conservation policies.

The core investigation was then much focused on inland-sea interface as a transition from intertidal-shoreline (and somehow brackish water), to mesophilous ecosystems, following ecological, geomorphological and geographical gradients (coenoclines). Plant communities were studied at smallest (series *s.l.*) to the landscape levels (geoserries, altitudinal belts, mega-geoserries...) focusing on French Atlantic Estuarine communities.

Among the tools used to refine and improve the research activities, an introductory experiences concerned the active participation in the SIGNAL research project¹⁶, studying plant community structure on secondary grassland in Europe, their resilience and variations following predicted global changes stresses (according to the Intergovernmental Panel on Climate Change - IPCC¹⁷).

SIGNAL Project experience



SIGNAL¹⁸ is an international research project, funded by the BiodivERsA¹⁹ call of the ERA-Net²⁰, in partnership with additional national funding agencies, among which the University of Camerino (UNICAM) and State Natural Reserve of “Montagna di Torricchio”, Italy²¹. This Project investigates the effects of climate changes on secondary grassland; the role of selected alien species, mowing treatment, biodiversity, productivity, plant functional traits and functional types. A geographic-based pan-Europaeen gradient was used, by the use of experimental areas belonging to the partners (Belgium, Bulgaria, France, Germany, Hungary, Italy, Switzerland, Turkey, Israel, Austria)²². Following a climatic gradient between less to more dry countries we have: France and Germany (mean annual precipitation/MAP: 750–1200 mm; mean annual temperature/MAT: 8° C to 7° C, respectively); Italy and Bulgaria (MAP: 880–560 mm; MAT: 12.1° C to 10.2° C, respectively), to xeric ones in Turkey and Hungary (MAP: 715–550 mm; MAT: 16.7° C to 10.5° C. Study sites can differ in management, history, geology and edaphic factors, but they represent in any case a common type of meadows for the respective study country (WELLSTEIN *et al.*, 2014b).

The general purpose focuses on studying the effects of extreme weather events on secondary grasslands, to reveal eventual resilience mechanisms, thresholds and tipping points. Installations provided a statistically sound system of replicated experimental manipulations of climate extremes. Results have

¹⁶ https://www.bayceer.uni-bayreuth.de/signal/en/mitarbeiter/mit/mitarbeiter_detail.php?id_obj=11472

¹⁷ <http://www.ipcc.ch>

¹⁸ Info shared and developed within the official program members net: http://www.bayceer.uni-bayreuth.de/signal/en/mitarbeiter/mit/mit_ag.php

¹⁹ <http://www.biodiversa.org/>

²⁰ http://ec.europa.eu/research/era/era-net-in-horizon-2020_en.html

²¹ https://www.bayceer.uni-bayreuth.de/signal/en/links10/gru/html.php?id_obj=113240

been addressed to provide evidences which may serve to regulate ecosystem services in the face of climate extremes and foster the identification of early warning signals of thresholds of regime shift. European grasslands provide many ecosystem services and have a crucial influence on the landscape and the quality of life, thus spatially and economically preminent across Europe. Extreme weather events (eg.: extreme drought), changes in the land use, and the presence of invasive alien species, can threaten biodiversity, resilience and the services provided by these systems (LEADLEY *et al.*, 2010). On the other hand, the complexity of the landscape mosaic and the biodiversity of these phytocoenoses can act as a buffer to such pressures, like a “Shock absorber” (*sensu* MAYNARD-SMITH, 1974; DE SANTO, 1978). The resilience and potential mechanisms of stabilization are represented by some factors, like species richness (insurance hypothesis, YACHI and LOREAU, 1999), presence of key species (SPEHN *et al.*, 2002) and intraspecific diversity. Studies including both species richness and traits have been claimed as a promising way of addressing ecosystem processes (DIAZ and CABIDO, 2011). To understand how mowing techniques can positively or negatively affect the resilience, productivity and endurance of that meadow community, we have analyzed the stressed areas with different types of scattering (at different height from the ground: 0, 5 10 zero), comparing them squares subjected to the same scales but without climatic stresses.

SIGNAL hypotheses and related experimental design

A long, accurate and pluriannual field work was necessary to carry out the experiments following a common experimental design across all sites. Extreme weather events and the presence of invasive species have been identified as two of the currently most pressures threatening biodiversity, resilience and ecosystem services of semi-natural grasslands and can suddenly drive them beyond thresholds of system integrity. SIGNAL had the aim to and quantify the role of "species diversity", of "within species diversity" and of "key species such as legumes" acting against those two pressures and enhancing resilience of grasslands, which are. Response parameters have been chosen to relate biodiversity to ecosystem services.

Five hypotheses were set to be investigated:

H 1) Droughts suddenly shift European grasslands across thresholds of functional resilience and reduce ecosystem service provision. Resilience varies across the pan-European precipitation and continentality gradient.

Method: Drought field experiment (common)

H 2) Non-native invasive species are additional pressures for grassland biodiversity and functioning, accelerating major system shifts in the face of extreme weather events. In turn, extreme weather events increase invasibility.

Method: Drought field experiment (common) + Mesocosm experiment (optional)

H 3) Biodiversity increases functional resilience in the face of extreme weather events (drought). Key functional traits (i.e. legume) modify community response.

Method: Mesocosm experiment (optional)

H 4) Within-species-diversity increases functional resilience in the face of extreme weather events.

Method: Mesocosm experiment (optional)

H 5) Mowing technique enhances diversity and consequently resilience against climate extremes.

Method: Drought field experiment (common)

The Italian site relèves experience was especially focused on H1, H2, and H5 (Drought field experiment; Fig. 88).

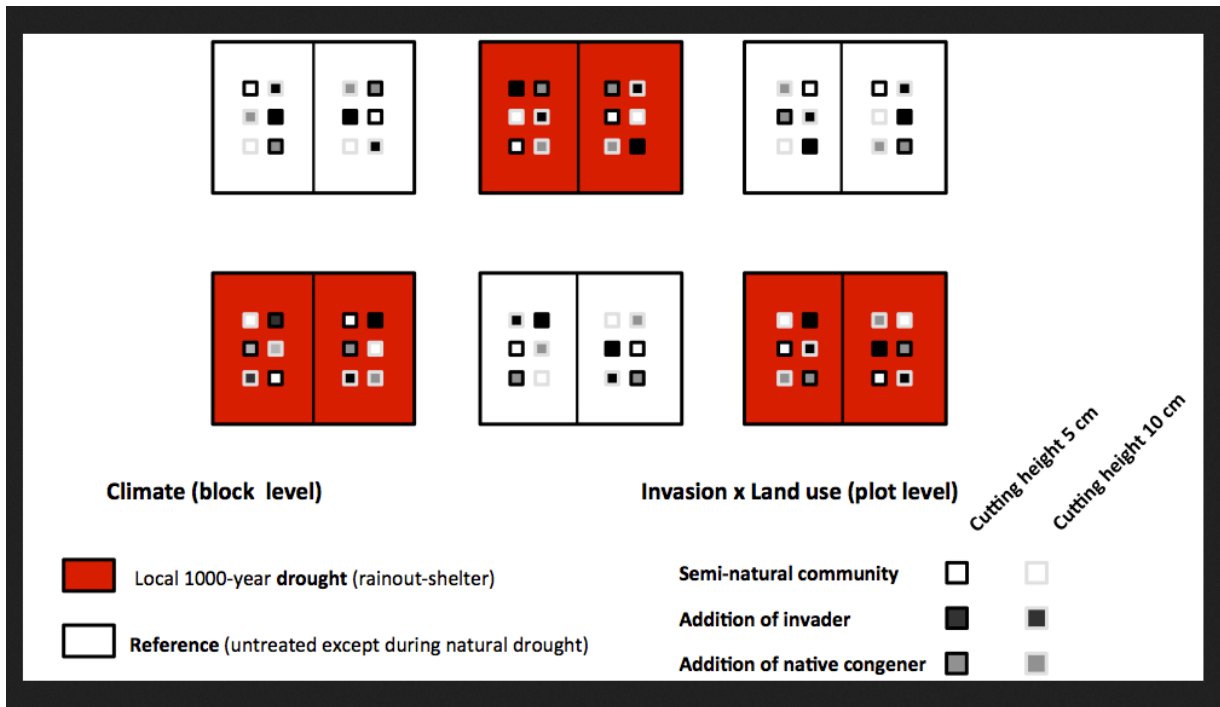


Figure 88 - Drought field experiment scheme of the experimental design, from: <http://www.bayceer.uni-bayreuth.de/signal>.

SIGNAL - Italy

SIGNAL-Italy study site is a 700 m² (35x20m) stable meadow in a flat area. Study site meadow is located in the “*Arboretum apenninicum*” (43°10’11,70’’ N, 13°04’54,83’’ E) established in 1990 by the Camerino University, in an area of 10 hectares near Camerino, Marche region (Central Italy), between 495 and 582 m a.s.l. (PEDROTTI, 1992).

Climate belongs to sub-mediterranean (meso temperate) sub-humid continental model, typical from the sub-Apennine (PETRARCA *et al.*, 1999; HIJMANS *et al.* 2005; RIVAS-MARTÍNEZ, 2005; 2008). Based on the 1950-2000 data from thermopluviometric station in Camerino (AMICI & SPINA, 2002; SPINA *et al.*, 2006), average annual precipitation is 880 mm, with a relative minimum in summer and peaks in autumn and spring. Winter snowfall is frequent and often very abundant. Mean annual values of temperature is 11.87°C, the average temperature of the coldest month (January) is around 2 °C, while that of the hottest months (July and August) is around 22°C.

A within-site climate and soil station was installed during 2013-2015, to detect the characteristics variations of the study area: the Site MAT reports 12,1°C, and a MAP of 880,2 mm.



Figure 89 - Meadow from the Italian site of the SIGNAL experiments, and its surroundings: in spring habitus. In the background *Quercus robur*, *Fraxinus excelsior* and *F. angustifolia* trees.

The geologic substrate is the Flysch from the Marche hills, with alternating layers of sandstone, clay or marl; the soil is deep, with a silty-clay or clay texture. The substrate consists in a Pelitic-sandstone, while the soil in a Haplic Calcisol. The site was alternatively cultivated or mowed, as typical local soil use. In 1990 the study area was already not cultivated since several years (PEDROTTI, 1992), and the land use defined as stable meadow, mowed at least once per year. It corresponds to a typical formation of secondary meadows, from low-altitude, in the hilly belt (*Quercus pubescens* zone). Some ecological condition showing a potential for *Quercus robur* forest persist in the study site, as witnessed by the presence of “dump” species in the site, like *Populus nigra* L., *P. × canadensis* Moench., *Quercus robur* L., *Acer campestre* L. *Ajuga reptans* L. *Oenanthe pimpinelloides* L., *Hypericum tetrapterum* Fr., *Epilobium tetragonum* L. (s.l.), *Fraxinus excelsior* L., *F. angustifolia* Vahl., *Tilia × europaea* L., *Ulmus minor* Mill., *Prunus avium* (L.) L. Ancient forests of *Quercus robur* were destroyed in the zone to make cultivation fields (CIANFAGLIONE, 2014). These types of meadow are often characterized by different plant communities and plant assemblages. In particular, our meadow consists of some small patches characterized by more or less nitrophilic, humid, ruderal, disturbed, or trampled conditions. Dry local conditions are related to disturbance and ruderality. Following the species richness survey, the studied meadow is possibly close to a community belonging to the *Agropyro repentis-Dactyletum glomeratae* Ubaldi 1976 em. Ubaldi, Puppi & Speranza 1983 Association, even if the on-site *facies* includes some different ecological aspects. The association is considered as characteristic of “Calanchi” (i.e.: BIONDI and PESARESI, 2004): a typical hilly “Badlands” formations from Central Italy (PHILLIPS, 1998) characterized by argillaceous substrate riche in evaporites. (DEL PRETE *et al.*, 1994, DE SANTIS *et al.*, 2010). The studied community shows evidences of local regression and degeneration due to anthropization phenomena, e.g.: the transgression of segetal and cultivated species linked to the soil use history and to the surrounding crops, the transgression of the species from the surrounding forests. This indicates the secondary succession tendency, blocked by mowing, grazing and other uses.

The study area contained 162 species (Tab. 1) with a record of 14 species (overlapping + rooting) casually found during a 5x5 cm quadrat survey. The maximum number of rooting species was 12, found casually in another similar quadrat. Critical specimen has been collected, classified and stored at the “*Herbarium Camerinenis*” (CAME), of the Camerino University.

Tab. 1 - 700 m² (35x20m) year round surveys from the Italian study site, showing Species list and general cover. Ligneous species are here only recorded when saplings or seedlings.

n.	Species list	Cover	n.	Species list	Cover	n.	Species list	ove
1	<i>Acer campestre</i> L.		55	<i>Daucus carota</i> L. subsp. <i>carota</i>	x	109	<i>Pteris hieracioides</i> L. subsp. <i>hieracioides</i>	x
2	<i>Acer pseudoplatanus</i> L.		56	<i>Echium vulgare</i> L. subsp. <i>vulgare</i>		110	<i>Plantago lanceolata</i> L.	
3	<i>Achillea millefolium</i> L.	x	57	<i>Elytrigia repens</i> (L.) Nevski		111	<i>Plantago major</i> L. subsp. <i>major</i>	
4	<i>Acinosa alpina</i> (L.) Moench subsp. <i>alpina</i>		58	<i>Epilobium tetragonum</i> L. (group)		112	<i>Poa bulbosa</i> L.	
5	<i>Agrimonia eupatoria</i> L. subsp. <i>eupatoria</i>		59	<i>Erigeron canadensis</i> L.		113	<i>Poa pratensis</i> L.	
6	<i>Ajuga reptans</i> (L.) Schreb. subsp. <i>chamaepitys</i>	r	60	<i>Erigeron sumatrensis</i> Retz.		114	<i>Poa trivialis</i> L.	
7	<i>Ajuga reptans</i> L.		61	<i>Erodium malacoides</i> (L.) L'Hér. subsp. <i>malacoides</i>		115	<i>Polygonum aviculare</i> L. subsp. <i>aviculare</i>	
8	<i>Allium vineale</i> L.	r	62	<i>Euphorbia helioscopia</i> L. subsp. <i>helioscopia</i>		116	<i>Potentilla reptans</i> L.	
9	<i>Alopecurus myosuroides</i> Huds.		63	<i>Euphorbia pepus</i> L.	r	117	<i>Prunus cerasifera</i> Ehrh.	
10	<i>Althaea hirsuta</i> L.	r	64	<i>Ficus carica</i> L.	r	118	<i>Pulicaria dysenterica</i> (L.) Bernh.	
11	<i>Anagallis arvensis</i> L. subsp. <i>arvensis</i>		65	<i>Galega officinalis</i> L.		119	<i>Ranunculus neapolitanus</i> Ten.	x
12	<i>Anisantha sterilis</i> (L.) Nevski		66	<i>Galium aparine</i> L.		120	<i>Ranunculus velutinus</i> Ten.	
13	<i>Anthemis cotula</i> L.		67	<i>Galium mollugo</i> L. subsp. <i>erectum</i> Syme		121	<i>Rapistrum rugosum</i> (L.) All.	
14	<i>Arctium minus</i> (Hill) Bernh.		68	<i>Geranium dissectum</i> L.	x	122	<i>Robinia pseudoacacia</i> L.	r
15	<i>Arenaria leptoclados</i> (Rchb.) Guss.		69	<i>Geranium pusillum</i> L.	r	123	<i>Rosa canina</i> L. (group)	r
16	<i>Arrhenatherum elatius</i> (L.) P. Beauv. ex J. Presl et C. Presl subsp. <i>elatius</i>	x	70	<i>Himantoglossum adriaticum</i> H. Baumann	r	124	<i>Rubus catescens</i> DC. (group)	r
17	<i>Arthemisia verlotiorum</i> Lamotte		71	<i>Holcus lanatus</i> L.		125	<i>Rumex crispus</i> L.	
18	<i>Arum italicum</i> Mill. subsp. <i>italicum</i>	r	72	<i>Hypericum perforatum</i> L. subsp. <i>veronense</i> (Schränk) Ces.		126	<i>Rumex sanguineus</i> L.	
19	<i>Avena fatua</i> L. (group)		73	<i>Hypochaeris aclyrophorum</i> L.		127	<i>Sanguisorba minor</i> Scop. subsp. <i>balearica</i> (Bourg. ex Nyman) M.-Garm. et C. Navarro	
20	<i>Ballevalia romana</i> (L.) Sweet	r	74	<i>Imula conyzae</i> (Griess.) Meikle		128	<i>Schedonorus pratensis</i> (Huds.) P. Beauv. subsp. <i>apenninus</i> (De Not.) H. Scholtz et Foggi	
21	<i>Bellis perennis</i> L.	x	75	<i>Kickxia spuria</i> (L.) Dumort.	r	129	<i>Sherardia arvensis</i> L.	
22	<i>Blackstonia perfoliata</i> (L.) Huds. subsp. <i>perfoliata</i>	r	76	<i>Knautia integrifolia</i> (L.) Bertol. subsp. <i>integrifolia</i>		130	<i>Silene latifolia</i> Poir. subsp. <i>alba</i> (Mill.) Greuter et Burdet	
23	<i>Brachypodium rupestre</i> (Host) Roem. et Schult. subsp. <i>rupestre</i>		77	<i>Lactuca saligna</i> L.		131	<i>Sonchus asper</i> (L.) Hill subsp. <i>asper</i>	
24	<i>Bromopsis erecta</i> (Huds.) Fourr. subsp. <i>erecta</i>		78	<i>Lactuca serriola</i> L.	x	132	<i>Sonchus oleraceus</i> L.	x
25	<i>Bromus gussonei</i> Parl.		79	<i>Lamium maculatum</i> L.		133	<i>Stachys sylvatica</i> L.	
26	<i>Bromus hordeaceus</i> L. subsp. <i>hordeaceus</i>		80	<i>Lamium purpureum</i> L.		134	<i>Stellaria media</i> (L.) Vill. subsp. <i>media</i>	
27	<i>Bromus racemosus</i> L.		81	<i>Lapsana communis</i> L. subsp. <i>communis</i>		135	<i>Sulla coronaria</i> (L.) Medik.	
28	<i>Calamintha nepeta</i> (L.) Savi subsp. <i>nepeta</i>	r	82	<i>Lathyrus aphaca</i> L. subsp. <i>aphaca</i>		136	<i>Symphitum bulbosum</i> K.F. Schimp.	r
29	<i>Campamula rapunculoides</i> L.		83	<i>Lathyrus sphaericus</i> Retz.		137	<i>Tanacetum parthenium</i> (L.) Sch. Bip.	r
30	<i>Capsella rubella</i> Reut.		84	<i>Lathyrus sylvestris</i> L. subsp. <i>sylvestris</i>		138	<i>Taraxacum officinale</i> Weber ex F.H. Wigg. (group)	
31	<i>Carduus pycnocephalus</i> L. subsp. <i>pycnocephalus</i>		85	<i>Legosia speculans-veneris</i> (L.) Chaix	r	139	<i>Thlaspi alliaceum</i> L.	
32	<i>Carex divulsa</i> Stokes		86	<i>Lepidium campestre</i> (L.) R. Br.	r	140	<i>Thlaspi perfoliatum</i> L. subsp. <i>perfoliatum</i>	
33	<i>Carex flacca</i> Schreb. subsp. <i>erythrostachys</i> (Hoppe) Holub.	r	87	<i>Leucanthemum vulgare</i> (Vail.) Lam. subsp. <i>vulgare</i>		141	<i>Thymus longicaulis</i> C. Presl subsp. <i>longicaulis</i>	
34	<i>Cataglyphis rigidum</i> (L.) C.E. Hubb. ex Dony subsp. <i>rigidum</i>		88	<i>Linaria vulgaris</i> Mill. subsp. <i>vulgaris</i>		142	<i>Tilia platyphyllos</i> Scop. subsp. <i>platyphyllos</i>	r
35	<i>Centaurea nigrescens</i> Willd. subsp. <i>neapolitana</i> (Boiss.) Dostál	r	89	<i>Linum bienne</i> Mill.		143	<i>Tordylium apulum</i> L.	
36	<i>Centaureum erythraea</i> Rafin subsp. <i>erythraea</i>	r	90	<i>Linum corymbulosum</i> Rchb.		144	<i>Torilis arvensis</i> (Huds.) Link subsp. <i>arvensis</i>	
37	<i>Cephalaria transylvanica</i> (L.) Roem. et Schult.	x	91	<i>Lolium perenne</i> L.		145	<i>Tragopogon dubius</i> Scop.	
38	<i>Cerastium glomeratum</i> Thuill.	x	92	<i>Malva sylvestris</i> L. subsp. <i>sylvestris</i>	r	146	<i>Tragopogon porrifolius</i> L. subsp. <i>porrifolius</i>	
39	<i>Cerastium brachypetalum</i> subsp. <i>tenoreanum</i> (Ser.) Soó & Jáv., gen.	r	93	<i>Matricaria chamomilla</i> L.		147	<i>Tragopogon samaritanii</i> Heldr. et Sartori ex Boiss.	
40	<i>Chenopodium album</i> L. subsp. <i>album</i>	r	94	<i>Medicago lupulina</i> L.		148	<i>Trifolium campestre</i> Schreb.	x
41	<i>Cichorium intybus</i> L. subsp. <i>intybus</i>	x	95	<i>Medicago minima</i> (L.) L.		149	<i>Trifolium dubium</i> Sibth.	r
42	<i>Cyclamen hederifolium</i> Aiton	r	96	<i>Medicago orbicularis</i> (L.) Bartal.		150	<i>Trifolium pratense</i> L. subsp. <i>pratense</i>	
43	<i>Cirsium vulgare</i> (Savi) Ten.		97	<i>Medicago polymorpha</i> L.	x	151	<i>Trifolium repens</i> L. subsp. <i>repens</i>	
44	<i>Clematis vitalba</i> L.		98	<i>Medicago sativa</i> L.	r	152	<i>Trifolium resupinatum</i> L.	x
45	<i>Coltsea arborescens</i> L.		99	<i>Mentha longifolia</i> (L.) Huds.		153	<i>Trifolium squarrosum</i> L.	x
46	<i>Conium maculatum</i> L.		100	<i>Moehringia pentandra</i>	r	154	<i>Tripleurospermum inodorum</i> (L.) Sch. Bip.	r
47	<i>Convolvulus arvensis</i> L.		101	<i>Miscari comosum</i> (L.) Mill.	r	155	<i>Urtica dioica</i> L. subsp. <i>dioica</i>	
48	<i>Cota tinctoria</i> (L.) J. Gay subsp. <i>australis</i> (R. Fern.) Oberpr. et Greuter		102	<i>Oenanthe pimpinelloides</i> L.		156	<i>Verbena officinalis</i> L.	
49	<i>Crataegus monogyna</i> Jacq.		103	<i>Ornithogalum divergens</i> Boreau		157	<i>Veronica arvensis</i> L.	
50	<i>Crepis pulchra</i> L.		104	<i>Orobancha ramosa</i> L. subsp. <i>ramosa</i>		158	<i>Veronica persica</i> Poir.	
51	<i>Crepis sancta</i> (L.) Bab. subsp. <i>sancta</i>		105	<i>Ostrya carpinifolia</i> Scop.		159	<i>Vicia loiseleurii</i> (M. Bieb.) Litv.	
52	<i>Crepis vesicaria</i> L.	x	106	<i>Papaver rhoeas</i> L. subsp. <i>rhoeas</i>	r	160	<i>Vicia sativa</i> L. subsp. <i>macrocarpa</i> (Moris) Arcang.	
53	<i>Crucjata laevipes</i> Opiz		107	<i>Pastinaca sativa</i> L. subsp. <i>urens</i> (Req. ex Godr.) Čelák		161	<i>Vicia sativa</i> L. subsp. <i>nigra</i> (L.) Ehrh.	
54	<i>Daucylis glomerata</i> L. subsp. <i>glomerata</i>	x	108	<i>Phleum bertolonii</i> DC.		162	<i>Vulpia hystrix</i> (All.) Link	

X = ≥ 10%, r = rare, blank = < 10%

The SIGNAL experiments have been conducted following the shared project protocol (JENTSCH *et al.*, 2013a, b) to study the effects of extreme drought simulated events on mesic grasslands. It focused on the interaction of three main branches of research that have never been combined together in ecology studies: biodiversity experiments, research on the impact of climate change, and the impact of invasive alien species under different mowing regimes.



Figure 90 - Covers for drought extreme events simulation; in summer.

Replicating field experiments across such a varied landscape provides an excellent and unique opportunity to assess and predict the local degree of future grassland vulnerability in interacting global change drivers. Additionally, running the experiments under contrasting climates and with different species will provide an unmatched potential for generalizations and ecological reasoning. The experiments have been designed to produce regionally differentiated decision support for policy in agriculture and biodiversity conservation. In an approach to study assembly rules (WELLSTEIN *et al.*, 2014a, 2015), the fine-scale patterns of species combinations (rooting individuals) were sampled in 2.80 m X 0.40 m blocks, subdivided into 448 micro-quadrats of 25 cm² (5 cm X 5 cm). To account for within site heterogeneity, six blocks were sampled at each site. Specific leaf area (SLA), plant height and seed mass were assessed, using literature sources and direct measurements, for all recorded vascular herbaceous species. Based on these traits, Rao's functional diversity was calculated for each micro-quadrat and compared to a null model. The latter was obtained by randomization, maintaining the local species richness and abundances as recorded in the field and assigning traits random-wise to each species' combination. Deviation of functional diversity from random expectation was interpreted as trait divergence or trait convergence. Several occurrences of trait-based assembly rules could be detected across countries. The Italian site showed mostly convergence for SLA, height and seed mass. Assembly rules can be contrasting and context dependent at different grassland sites and climatic differences are often masked by local factors such as disturbance regime or soil heterogeneity. The field experiment on the grasslands productivity also serves to assess the damage potential of two neophytes, *Lupinus polyphyllus* and *Senecio inaequidens*.

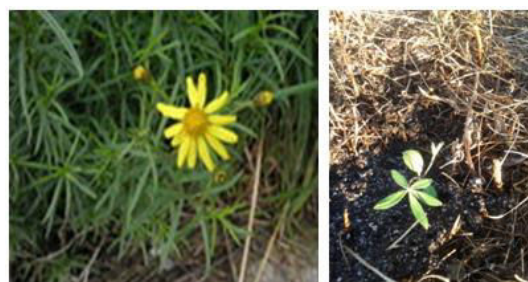


Figure 91 – The aliens plants: a *Senecio inaequidens* sapling to the left; and a *Lupinus polyphyllus* seedling to the right.

Both the alien species were germinated in laboratory and planted in the plots using a common standard procedure, including the final destruction before the dispersion of propagules, to avoid invasiveness.

The drought manipulation was conducted using differing onset dates and durations across Europe according to the local seasonality and the local 1000-year extreme drought event (according to JENTSCH *et al.*, 2007).

Resilience

Resilience study concerning community facing to alien species invasion problems, especially on *Lupinus polyphyllus* and *Senecio inaequidens*. These species are considered as common exotic weed of these systems in Europe, listed in national Black Lists of invasive species. Both species experiments showed a high resilience of these systems facing against these species invasion in our site. Concerning the first one, this can be explained as expected, because local climate and soil conditions are not suitable for this species due to not fresh and acidic conditions. *S. inaequidens* DC. experience was also unsuccessful, due to Snails and lymph selective predation, so that only disturbed situations which exclude such factor should be suitable for this species invasion.

Biodiversity

We confirmed the high α -Biodiversity hypothesis about our study site. The high overall richness in our study site (162 species) cannot be taken as unique value of ecological importance. As semi-natural secondary system, this high α -biodiversity value just confirms the strong human perturbation. Thus, whether a plant community stands up well to stress and disturbance depends not so much on the total number of species it contains but on the actual identities and characters of the species of which it is composed. This is determined by the ecological history of the site and the type of disturbance it may have suffered in the past (according to SANKARAN and MCNAUGHTON, 1999).

Management effects

It was generally carried out in two ways as:

- 5 cm X 5 cm quadrats relevées approach
- 1.20 m X 0.40 quadrats relevées approach

We sampled fine-scale patterns of species combinations, distinguishing roteed from only covering specimens. The assembly rules, guided by traits, have been then compared across European grasslands differing in climate, soil and land use history (WELLSTEIN *et al.*, 2014, 2015). Specific leaf area (SLA), plant height and seed mass were assessed, using literature sources and direct measurements, for all recorded vascular herbaceous species. Based on these traits, Rao's functional diversity was calculated for each micro-quadrat and compared to a null model. We used Schamp's method (SCHAMP *et al.* 2008) for randomization: keeping the abundances of species and the local species richness as in the field and assigning traits at random to each species combination. Deviation of functional diversity from random expectation was interpreted as trait divergence or trait convergence. Our site showed mostly convergence for SLA, height and seed mass. Several occurrences of trait-based assembly rules could be detected across countries. The strongest deviations from randomness in terms of seed mass were found in the Turkish grassland (driest one). In Bulgaria, Hungary, France and Germany, by contrast, we detected convergence of seed mass. Strong convergence of plant height appeared in tall mesic grasslands of Germany and France, while this trait showed random pattern in dry grasslands. The Turkish grassland showed convergence for SLA. Similar tendency occurred at the German and the Italian sites while those of France and Bulgaria mostly showed random patterns. Italian grasslands (spatially very close) showed both convergence and divergence of seed mass indicating heterogeneous environmental conditions and/or complex site history. We sampled fine-scale patterns of species combinations (rooting individuals) in six 1.20 m X 0.40 m blocks, subdivided into micro-quadrats of 100 cm², for each treatment (control, drought) at each site in two years (2013, 2014). Following WELLSTEIN *et al.*, (2015)

based on the key plant-traits specific leaf area (SLA), height and seed mass we calculated. We calculated also the Rao's functional diversity (FD) and further diversity indices for each micro-quadrat and compared them to a null model using the randomization method of SCHAMP *et al.* (2008). The deviation of FD from random expectation was interpreted as trait divergence or convergence. Strong seed-mass divergence in the dry Turkish grassland pointed towards complex disturbance history, while the other countries showed convergence. Plant-height convergence most likely indicated the importance to have similar best traits in productive grasslands (FR, GE) or trait-similarity due to environmental filters (HU, IT) as does the strong SLA-convergence in Italy. We conclude (WELLSTEIN *et al.*, 2015) that assembly rules can be contrasting and context dependent at different grassland sites and climatic differences are often masked by local factors such as disturbance regime or soil heterogeneity. Experimental extreme drought led to a tendency towards trait-convergence in seed mass in Italy probably constraining the regeneration niche. The tendency of SLA-divergence in France could indicate a tempering of competitive situations. Apart from that, assembly rules were remarkably stable under drought as we found (WELLSTEIN *et al.*, 2015). Analyzing the gradient from moist to driest national sites, the Trait-based studies of species assembly can reveal mechanisms of species coexistence. European grasslands support a rich flora with high small-scale species density, mirroring intricate coexistence mechanisms. These mechanisms might show differences related to climate, soil conditions and disturbance history of a site. According to VIRÁGH *et al.* (2008) and BARTHA *et al.* (2004), presence of plant species was sampled in 40 cm x 280 cm grids of 5 cm x 5 cm contiguous microquadrates after one month of drought treatment. Structural complexity of vegetation was measured by the diversity of species combinations. Constraints on species co-occurrence (spatial dependence, assembly rules) were evaluated by the joint entropy of *species x species* multiway contingency table (*Associatum*). Extreme events are challenges to local coexistence of plant species. According to theory (JUHÁSZ-NAGY and PODANI, 1983; BARTHA *et al.*, 1998), coenostate descriptors follow opposite trends if measured as a function of spatial resolution (see above). We expect decreasing complexity and slightly increasing spatial dependence due to extreme stress. Furthermore, we hypothesize that mesic site will be more vulnerable to the experimental drought. To analyze this, extreme droughts were induced by rain-out shelters, monitoring the subsequent recovery of fine-scale vegetation structure.. Short term effects of experimental drought showed that structural complexity of our grasslands remained similar to the pretreatment coenostates; and that the spatial dependence increased slightly indicating the initial phase of some reassembly processes. Consisting in a desertification-like phenomenon, indicated by the start of a degeneration process in the community. This can affect biomass and quality productivity of these productive systems, but in other hand the type of uses and management can promote or limit this degeneration trend. Comparing this results with the Hungarian site, we observed that the structural complexity remained similar to the pretreatment coenostates; and the spatial dependence did not vary at the xeric site but increased slightly at the mesic site indicating the initial phase of some reassembly processes (BARTHA *et al.*, 2013). This experience activity concerned fieldworks (field plant surveys, climatic data gathering), cooperation in data elaboration and interpretation, participation to congresses and publications. This experience was important in order of understand similar grassland communities in estuaries, and to elaborate a more calibrated methodology from fieldworks and quadrats paying attention on Spatial pattern of species richness, microvariations, *associatum*, and the compositional diversity. In addition this experience was important also in order to understand the role of invasive species and to understand the variation of secondary communities under different human pressure and in climatic changes.

Others experiences

A similar experience, about micromosaic, microvariation study was carried out studying the *Salvia officinalis* communities from Abruzzo region, Central Adriatic Italy, (CIASCHETTI *et al.*, 2018). The experience in Sulmona valley, Abruzzo, central Italy (CIANFAGLIONE, 2014), the experience in Italian Danube river basin (Central and Eastern Italian Alps) (in progress). And

the experience in Poland (SENDER *et al.*, 2014; 2017) was useful to refine the knowledge on plant zonation, species distribution and ecological assessment of species and communities. Other experience in France (i.e.: CHALUMEAU *et al.*, 2016; PERRIN *et al.*, 2018) let the opportunity to develop a finer plant association study, new associations describing; some related works are in progress.

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EXTENDED SUMMARIES

IN FRENCH (RESUMEE LONG EN FRANCAIS)

Introduction

L'Europe a une longue tradition documentée en matière de science et de cartographie de la végétation. Il est important de rappeler la création de la Station internationale de Géobotanique Méditerranéenne et Alpine (SIGMA) par Josias Braun-Blanquet au début du XX^e siècle. La Directive européenne Habitats-Faune-Flore de 1992 a attiré l'attention sur les habitats d'intérêt communautaire, nécessitant le développement de connaissances dans les domaines de la répartition et de la cartographie des habitats. Dans le cadre de la Stratégie nationale pour la biodiversité 2011-2020, le ministère en charge de l'Environnement a lancé à partir de 2011 un programme national de cartographie des habitats terrestres intitulé "Cartographie nationale des habitats terrestres (CarHAB)", en partenariat avec diverses structures institutionnelles et universitaires françaises. Le projet CarHAB a pour objectif de produire une cartographie des végétations de la France au 1:25 000, en suivant les approches et les concepts de la phytosociologie paysagère ou phytosociologie dynamico-caténale.

Cette thèse intitulée « Plant landscape and models of French Atlantic estuarine systems » (Paysage végétal et modèles des systèmes estuariens atlantiques françaises) a été financée par le Ministère de la Transition écologique et solidaire, dans le cadre du programme national de cartographie des habitats naturels et semi-naturels (CarHAB) (convention 2100992970) et a été réalisée en cotutelle entre l'Université de Camerino (Italie) et l'Université de Bretagne Occidentale (France).

Les milieux estuariens ont été retenus comme aires d'étude dans le programme CarHAB pour mieux comprendre l'originalité de leurs végétations, les trajectoires dynamiques de leurs végétations, liées au paysage, à la biodiversité, et à l'usage du sol et des eaux.

Les estuaires constituent une source importante de services écosystémiques. Ils sont des écosystèmes très productifs en biomasse, très importants pour la biodiversité et pour les utilisations humaines. En général, les environnements estuariens sont caractérisés par des marées importantes et des courants d'eau parfois violents, avec de fréquentes variations des inondations et des fronts de salinité qui dépendent de cycles quotidiens et saisonniers des marées, et des apports fluviaux. Ils peuvent avoir subi au cours des siècles certains changements suite à la pression anthropique. Ces changements peuvent avoir créé d'une part des écosystèmes semi-naturels ou artificiels et d'autre part peuvent limiter ou menacer la fonctionnalité des systèmes estuariens et leurs services, en modifiant la qualité physico-chimique de l'eau, le fonctionnement hydraulique, la composition spécifique, la géomorphologie et les formes du paysage. Généralement, les estuaires incluent des complexes d'habitats naturels et semi naturels, de l'océan aux eaux douces (gradient amont/aval) et des prairies inondables aux forêts

(lit mineur-majeur).

Problématiques et objectifs de recherche

Les objectifs de cette recherche sont de développer un modèle prédictif spatio-temporel fondé sur la végétation actuelle et potentielle des estuaires, en suivant une approche dynamico-caténale. Cette approche a pour finalité de représenter trois niveaux d'organisation de la végétation : communautés (associations), dynamiques (séries) et paysage (geoséries).

Les principales questions de recherche posées sont les suivantes :

- Quelles caractéristiques géographiques et écologiques influencent les modèles de la végétation dans les estuaires ?
- Comment classer les types d'estuaires selon les caractéristiques de la végétation (traits, distribution et diversité) et leurs modèles ?
- Est-il possible de définir un modèle commun générique de gradients écologiques et des paysages végétaux estuariens ?

Le travail de cartographie est réalisé pour évaluer les surfaces à partir d'unités tessellaires (sigmétums) et caténales (géosigmétums). Cela pose quelques questions supplémentaires sur la végétation potentielle et réelle :

- Comment les communautés secondaires pourraient-elles contribuer à caractériser des séries de végétation ?
- Dans quelle mesure les communautés de végétation actuelles sont-elles en équilibre avec la dynamique naturelle ou anthropique ?

Cette thèse a aussi pour objectif d'étudier les systèmes écologiques et géographiques, afin d'approfondir la connaissance de la végétation et des écosystèmes, dans le but de mettre en place une méthodologie symphytosociologique et cartographique de la végétation des systèmes estuariens atlantiques.

Concepts généraux et définitions

La phytosociologie est la science des communautés végétales. L'unité d'étude de base de la phytosociologie classique est l'association végétale qui constitue une communauté homogène des plantes dans une unité environnementale homogène. L'association végétale (ou phytoassociation) est une communauté végétale en équilibre avec son environnement, caractérisée par une écologie, une composition floristique déterminée et des phénomènes synécologiques qui permettent de considérer chaque association du point de vue physiologique, floristique, écologique, dynamique et historique. La phytosociologie contemporaine est la science des groupements végétaux, c'est-à-dire de unités syntaxonomiques (syntaxons), qui sont organisés hiérarchiquement, suivant plusieurs niveaux.

Dans les associations végétales, les dynamiques progressives sont liées aux successions primaires ou secondaires. Elles sont négatives quand elles sont liées aux phénomènes de régression et de dégénération. Elles sont stables quand elles sont liées à la fluctuation (anthropique ou naturelle).

Dans les séries de végétation les dynamiques positives sont orientées en direction de la tête de série, pour passer de l'état actuel à l'équilibre environnemental supposé supérieur. Au contraire, les dynamiques négatives ont tendance à s'éloigner de cet équilibre plus élevé (de la tête de série). Les associations végétales constituent l'analyse de premier niveau du paysage végétal. La symphytosociologie ou phytosociologie paysagère appréhende l'ensemble des associations végétales. Elle se concentre sur la description et la classification des séries de végétation dans un système ordonné. Par sa nature holistique, ce système intégratif est utile pour développer des outils de surveillance des écosystèmes, de bio-évaluation et d'évaluation patrimoniale et des menaces sur la biodiversité. Dans le domaine l'aménagement du territoire, il est possible de mesurer l'état de l'environnement et d'évaluer les menaces à partir du degré d'artificialisation ou de naturalité des paysages.

La phytosociologie dynamico-caténale permet d'intégrer la dynamique de la végétation en décrivant les trajectoires des séries de végétation. Depuis les années 70, la nouveauté a été marquée par la plus forte intégration des données géographiques, des paysages, de l'utilisation du sol et des données écologiques, en créant des cartes thématiques fondées sur la végétation. Les études phytosociologiques intégrées correspondent à une approche spatio-temporelle de la végétation (cartes phytosociologiques intégrées) ou à des thématiques (écologique, sociale, agronomique, géographique, géologique, pédologique, climatique, faunistique...). L'intégration de ces thématiques rappelle la définition de « géoarchitecture », terme utilisé par l'architecte Le Corbusier au début du XX^e siècle.

Il est possible de distinguer des sous-types de cartes phytosociologiques : les cartes de la végétation réelle (cartes des unités syntaxonomiques); et les cartes de la végétation potentielle (cartes des unités syntaxonomiques climaciques). L'intégration de ces deux types de cartes de végétation correspond à la cartographie intégrée de la végétation : la végétation est intégrée dans le temps et l'espace, et la végétation actuelle est représentée au sein de la végétation potentielle. Les cartes de végétation intégrées écologiques, sont intégrées à d'autres couches thématiques (cartes pédologiques, géologiques ...).

Les cartes géosymphytosociologiques (cartes des géosigmetums) correspondent aux cartes des complexes de végétation. D'un point de vue morphologique, un estuaire correspond à la portion d'un fleuve où les effets de la mer (ou océan) sont sensibles. Dans les estuaires, les principaux facteurs écologiques sont dus aux conditions des flux hydro-sédimentaires et à leurs caractéristiques chimiques, physiques et biologiques. Les variations des flux d'eau provoquent des dynamiques de sédimentation et d'érosion et également des variations de salinité. Les estuaires tidaux sont caractérisés normalement par des plus longues surfaces qui correspondent

aux plus hauts niveaux des marées. La masse d'eau salée en mouvement est appelée marée de salinité, tandis que la masse d'eau douce située plus en amont correspond à la marée dynamique. Dans les estuaires tidaux, la portion des eaux plus en amont est caractérisée par une masse d'eau douce mais qui se déplace selon les cycles des marées. Les dynamiques estuariennes sont influencées par les cycles d'inondation saisonniers (en aval), et par l'apport des eaux du bassin versant (en amont). Les lits, les méandres, les marécages, les berges et les terrasses des estuaires sont toujours soumis aux dynamiques des courants qui peuvent les remanier. Cette instabilité écologique se traduit par des environnements qui sont en permanente instabilité et sujets à des perturbations récurrentes ou occasionnelles qui influent l'ensemble de l'expression biologique, y compris la végétation. Les estuaires s'organisent selon un gradient géographique et géomorphologique entre terre et mer, donc en transition entre un milieu salé et plus exposé aux vents marins, et un milieu d'eau douce plus abrité et climatiquement moins doux. Dans les grands estuaires, l'influence des fleuves est plus marquée par des masses d'eaux fluviales plus importantes. Les facteurs principaux qui caractérisent les estuaires et leurs gradients écologiques sont la salinité et l'humidité des sols. D'autres facteurs physiques peuvent déterminer des différences, des particularités, ou des exceptions : la granulométrie du substrat, la pente, l'influence des vents marins, la variation microclimatique, l'impact humain.

Chaque estuaire représente un système original, à cause d'un assemblage à chaque fois unique de ses caractéristiques géographique, écologique et dynamique, qui se combinent à l'impact anthropique présent et passé.

Dans les estuaires, les gradients écologiques suivent des variations géographiques et morphologiques selon deux directions : gradients longitudinaux (de l'aval à l'amont) et gradients transversaux (du lit mineur au lit majeur). Dans les deux cas, en allant vers des niveaux topographiques plus élevées, la salinité diminue en même temps que l'humidité du sol, et on retrouve une tendance commune relative à l'expression de la végétation (des vases et prés salés, aux forêts de frêne majeur et chêne pédonculé...). Dans ces deux directions (longitudinale et transversale), l'influence des marées de salinité tend à être moins importante en amont ; en revanche les précipitations (avec la nappe phréatique) augmentent leur empreinte sur le système estuarien.

Le gradient topographique transversal (lit mineur-majeur) correspond à un gradient de diminution d'humidité (ou d'inondation) et de la salinité. En suivant ces variations, on peut individualiser les compartiments géomorphologiques suivants : canal principal, slikke, schorre et plaine alluviale.

Selon le gradient topographique longitudinal, de l'embouchure en amont, on peut distinguer trois compartiments de salinité : eaux salées, eaux saumâtres, et eaux douces. Ces compartiments peuvent être subdivisés en zones de salinité aval-amont : zone euhaline (mixoeuhaline) avec plus de 30 psu ; zone polyhaline entre 30 et 18 psu ; zone mésohaline, entre 18 et 5 psu ; zone oligohaline, entre 5 et 0,5 psu, eaux douces avec moins de 0,5 psu (le psu est l'unité de mesure de la salinité, il s'exprime en grammes de sel par litre d'eau).

Les estuaires peuvent être définis comme des écosystèmes, mais aussi comme des complexes d'écosystèmes caractérisés par des écotones fluides, avec des limites mouvantes dans le temps et l'espace. Le comportement d'un estuaire change beaucoup selon la saison, l'emplacement, la force des marées, les flux fluviaux, les précipitations, les vents et les courants du large.

L'expression de la biodiversité estuarienne est complexe à cause de la présence des caractéristiques qui coexistent mais qui sont apparemment antagonistes (par exemple l'influence des eaux salées et des eaux douces sur la même surface, ou des conditions de sécheresse climatique et à la fois aquatiques). Cette complexité écologique induit une certaine complexité des habitats et donc des végétations. Par conséquent, les gradients estuariens peuvent être très variables et multidirectionnels en reflétant la complexité de chacun de ces systèmes. La présence des espèces, des communautés végétales et les limites de végétation peuvent être grossièrement définies par de très longues analyses basées sur les masses aquatiques en mouvement, en prenant comme référence le canal principal. En tant que producteurs primaires dans l'écosystème, les plantes et les communautés végétales sont particulièrement sensibles aux phénomènes qui touchent le milieu. Eu égard à leurs caractéristiques physiologiques et biologiques, elles sont considérées des bon bio-indicateurs, spécialement pour les milieux aquatiques et mésiques, comme c'est dans le cas des estuaires. Par conséquent, l'étude des végétations permet de réaliser des suivis sur les changements globaux, à court et à long terme, car les plantes sont strictement liées à l'expression de la biodiversité et donc aux conditions environnementales.

Zone d'étude

La zone d'étude correspond à la façade atlantique française, située entre le Pays basque (frontière ibéro-française) et la Flandre (frontière belgo-française), caractérisée par un climat de type océanique.

Les plus grands estuaires sont ceux de la Gironde, la Loire, la Seine et la Charente.

En Basse-Normandie, les estuaires appelés aussi hâvres sont nombreux : Vanlée, Regnéville, Blainville, Geffosses, Surville, Saint-Germain-Sur-Ay, PortBail et Carteret.

En Picardie et Nord-Pas-de-Calais se trouvent les es-tuaires de la Somme, l'Authie, la Canche, la Liane, Wimmereux, la Slack, Calais, l'Aa et Dunkerque Port.

Les autres estuaires d'Aquitaine sont ceux de l'Adour, le Courant de Mimizan, la Nivelle et la Bidasoa.

En Bretagne, plusieurs petits estuaires sont présents : Rance, Blavet and Scorff, Laïta, Abers (Aber Vrac'h, Aber Benoît, Aber Ildut), Elorn, Aulne, Vilaine, et Ria d'Étel.

Matériels et méthodes

Nous avons nommé les séries de végétations avec le nom de l'association tête de série la plus représentative et les geoséries avec le nom de l'association tête de série la plus représentative. Pour les faciès secondaires, nous avons cherché à identifier la végétation potentielle. Un travail préliminaire a été conduit sur l'ensemble des estuaires (analyse bibliographique, photos aériennes, cartes topographiques, cartes des laisses de mer, cartes thématiques liées à la végétation, aux habitats, à l'usage du sol et aux aires protégées). Il nous a permis de synthétiser les données disponibles concernant les facteurs biotiques et abiotiques et de définir une première caractérisation écologique et un premier modèle du système estuarien.

Une considération spéciale a été portée à la caractérisation de la végétation des estuaires et à sa cartographie, ainsi qu'à l'observation du rôle des gradients écologiques, des dynamiques des végétations et à la recherche de la compréhension des contraintes liées aux usages. Une sélection d'estuaires a été retenue pour réaliser des relevés de terrain et pour élaborer la typologie et la cartographie des séries et des géoséries de végétation.

Des relevés phytosociologiques et des géosymrelevés ont été réalisés pour identifier les différentes geoséries et geopermaséries, pour décrire la distribution de la végétation dans le paysage, et pour souligner les éventuels éléments synendémiques ou les éléments invariants entre estuaires. L'exploitation cartographique des données nous a permis d'élaborer un modèle spatial générique permettant de représenter l'organisation de la végétation en fonction des gradients écologiques associés. Il n'a pas été toujours possible de décrire toutes les trajectoires et les dynamiques des végétations, en raison du manque de certaines données historiques ou parce que l'usage du sol est tellement marqué sur de larges surfaces au point d'altérer l'expression de la végétation ou même les formes du paysage et donc de la potentialité de la végétation (drainage, érosion, déforestation, désertification, introduction d'espèces exotiques...).

L'approche suivie permet d'intégrer les cartes des séries et des géoséries de végétation (végétation potentielle) avec les relevés phytosociologiques et symphytosociologiques (végétation réelle) qui décrivent la composition phytocoenotique des sigmetums cartographiés. Des cas particuliers ont été représentés par des symboles sur les cartes ou sont décrits dans la notice. Les cartes de végétation ont été réalisées en utilisant le logiciel QGIS (version 2.18.14). L'analyse ombrothermique, climatologique et bioclimatologique a été réalisée en exploitant les données de Météofrance et de Worldclim, pour l'encadrement des estuaires et pour analyser les micro-variations climatiques dans les estuaires.

Résultats et discussion

Sur un total de 36 estuaires identifiés dans l'étude préliminaire, les relevés phytosociologiques et symphytosociologiques ont été effectués sur 8 complexes estuariens (Charente, Loire, Vilaine, Etel, Blavet-Scorff, Laïta, Aulne et Elorn). Les travaux de terrain ont été effectués sur

une superficie totale de 98315 ha. L'analyse des relevés phytosociologiques et des synrelevés a permis de mettre en évidence 2 séries et 4 géopermaseries, correspondant à 131 associations, 60 alliances, 43 ordres et 28 classes phytosociologiques. Trois estuaires ont été retenus pour réaliser la cartographie des séries et geoséries de végétation (Loire, Laïta et Aulne). Au total, 74 433 ha ont été cartographiés, représentant 2 séries et 4 géopermaséries de végétation.

L'analyse phytosociologique ne prétend pas être exhaustive, même si un grand nombre des associations primaires et secondaires, y compris les plus rudérales et anthropiques ont été recensées.

Dans les estuaires, de l'embouchure à la portion d'eau douce, on peut distinguer certaines variations et exceptions liées aux caractéristiques géomorphologiques locales. La variation principale fait suite au confinement des estuaires et à la continuité associée (latérale, longitudinale et verticale). En effet, plus les estuaires sont du type confiné, moins les séquences des séries de végétation sont évidentes (les séries et les géoséries tendent à devenir de plus en plus linéaires, discontinues et minces), jusqu'à ne pas permettre l'expression d'une ou de plusieurs séries, ce qui influence la richesse de la communauté et les phénomènes de transgression.

En tenant compte que le lit majeur correspond à la plus large surface inondable par l'estuaire, les questions de confinement et de continuité se réfléchissent aussi sur l'impact anthropique : rives artificielles, barrages, drainages, poldérisation... Ces modifications bloquent ou influencent l'hydrodynamique et la géomorphologie, et provoquent des exceptions qui concernent l'expression de la végétation.

L'analyse phytosociologique et symphytosociologique et la cartographie de la végétation nous a permis de valider l'hypothèse initiale de zonation écologique des estuaires et de l'adapter aux séries, geoséries et geopermaséries, selon le principe cartographique de la généralisation.

Dans les zones plus salées du lit mineur au lit majeur on trouve la végétation des vases et prés salés (*Atriplici prostratae-Elymeto atherici* geopermasigmetum), les saulaies marécageuses à *Salix atrocinera* (*Salix atrocinerea* geosigmetum), et les forêts de *Fraxinus excelsior* (*Fraxinus excelsior* geosigmetum). Plus en amont, les saulaies à *Salix atrocinera* tendent à être remplacées par des saulaies à *Salix fragilis* (*Saliceto fragilis* sigmetum) et plus en amont par des saulaies à *Salix alba* (*Saliceto albae* sigmetum). Dans le lit mineur, la végétation peut s'exprimer seulement dans les conditions les plus abritées ou résiduelles, de manière linéaire ou ponctuelle, à cause de courants très forts et des changements des fronts des eaux. En raison de ces caractéristiques particulières, de la fréquente probabilité d'accession mixte des eaux douces à plusieurs niveaux, la représentation cartographique des végétations aquatiques a été rattachée au *Lemneto minoris* geopermasigmetum. On y a inclus les végétations aquatiques des méandres, sources et flaques latérales du lit mineur au lit majeur, qui regroupent toutes les végétations primaires aquatiques qui peut être subdivisée en trois sous-groupes (selon le caractère plutôt salé, saumâtre ou doux). La continuité verticale et les relatives exceptions naturelles influencent

l'expression des végétations. À titre d'exemple, citons l'influence des accessions naturelles d'eau douce dans les environnements salés, ou la possibilité d'une végétation marécageuse dans le lit majeur de la rivière ou des prairies et marais peu ou non salés, asséchants et peuvent présenter même un certain affleurement de sel pendant la saison sèche (salants).

Dans la partie salée, la géomorphologie et l'hydrodynamique influencent l'expression de la végétation en fonction du type de substrat et du type morphologique de l'embouchure de l'estuaire. Les variations liées à la granulométrie du substrat dépendent de la stabilité (balance entre sédimentation et érosion). Si l'oscillation des dépôts et de l'érosion n'est pas assez forte pour remodeler continuellement la surface, la végétation peut s'installer plus facilement ; la vase peut se déposer même entre les galets et le sable et favorise l'installation des végétations des vases et prés salés. L'influence (transgression et contacts) des sables crée une variante de vase et prés salés riche en espèces typiques des plages et des dunes. Le même phénomène se produit en présence d'affleurements rocheux ou de précipices et les espèces liées. Si les dépôts se déplacent, on peut trouver une absence presque totale de végétation, des spécimens dispersés et moins développés, des fragments de végétation influencés par des dépôts plus stables ou par des accessions d'eau douce, comme cela a été noté dans les estuaires de la Loire inférieure, la Ria d'Étel, la Laïta, le Blavet-Scorff et la Vilaine.

Si le fleuve est très ouvert sur la mer, ou si le flux de la marée est supérieur à celui du fleuve, l'estuaire se comporte plus comme une anse maritime (c'est le cas de la ria d'Étel) ; on peut remarquer plus facilement une végétation des eaux salées et les roselières mésohalines à oligohalines à scirpes n'apparaissent que ponctuellement.

Dans les zones perturbées par les activités humaines, de larges portions sont dépourvues de l'expression des séries. Dans d'autres cas il y a eu une modification des séries de végétation (décalage) vers l'amont ou vers l'aval, à cause d'un changement du front d'inondation ou de salinité qui peut causer aussi le dépérissement des plantes et la dégénération ou la régression des communautés végétales (Loire et Charente). Dans d'autres cas, sur des zones salées ou saumâtres, à cause des barrages qui empêchent ou ralentissent la remontée du sel, on peut observer une présence plus importante d'*Alnus glutinosa*, au lieu des forêts de *Salix atrocinerea* (dans des conditions plus marécageuses) ou même des forêts de *Fraxinus excelsior* (dans les conditions moins marécageuses). On a observé ce phénomène dans la partie inférieure de l'Erdre dans l'estuaire de la Loire et près de la Chapelle du Folgoat (Landévennec), près de l'ancien moulin à marée, dans l'estuaire de l'Aulne. Pareillement, on peut rencontrer des roselières et autres formations herbacées d'eaux douces dans les estuaires de la Ria d'Étel et de la Laïta, dans les zones salées, en l'amont des barrages latéraux. Dans l'estuaire de la Vilaine, en amont du barrage d'Arzal on retrouve dans le lit principal une végétation aquatique d'eau douce dans une ancienne zone halophile. Le barrage de Guily Glaz, réalisé dans l'estuaire de l'Aulne pour limiter l'impact des inondations sur le bassin versant, rentre dans la zone oligohaline en réduisant les surfaces et l'expression des végétations liées aux marées

dynamiques. Le décalage des séries des saulaies (à *Salix atrocinerea* et à *Salix fragilis*) vers les deux berges de l'estuaire de la Loire, entre Saint-Nazaire et Donges et à Nantes est observé, en conséquence de l'accumulation artificielle des sédiments suite à l'approfondissement du chenal dans l'estuaire à des fins de canalisation pour la navigation.

Conclusion et perspectives

En s'intégrant au sein du programme CarHAB, cette thèse a permis de proposer une première typologie phytosociologique et sériale, une méthodologie de cartographie et une caractérisation des modèles (générique et par estuaire) sur la distribution et l'organisation des végétations estuariennes atlantiques françaises. Ces éléments peuvent être utilisés à petite et à grande échelles et semblent transposables aux autres estuaires atlantiques.

Une perspective à développer concerne l'acquisition des données de terrain de manière inductive, en mobilisant des outils de mesure des gradients écologiques (salinité, pH, humidité), pour réaliser des modèles quantitatifs qui permettraient de rechercher des corrélations mathématiques avec les modèles déductifs déjà produits, et les appliquer sur les variations de la végétation détectable sur le terrain ou par télédétection.

La mise en place de suivis diachroniques des végétations permettrait de compléter la connaissance floristique, de la β -biodiversité, la syntaxonomie et la chorologie des végétations estuariennes. Il serait intéressant de corréliser les données de la distribution des végétations avec des suivis liés à la présence des microorganismes, du plancton, et des variations en productivité de biomasse.

Sur des sites tests, il serait intéressant de donner à chaque série de végétation la possibilité d'exprimer librement ses dynamiques naturelles pour les applications relatives à la gestion et à la conservation des habitats, afin de pouvoir mieux comprendre la potentialité du paysage végétal et pour optimiser les méthodologies d'évaluation de l'impact anthropique, en mobilisant les concepts de naturalité, d'artificialisation et de résilience.

Une perspective de recherche, déjà lancée dans le cadre du programme CarHAB, concerne l'utilisation de fonds blancs écologiques pour faciliter les divisions tessellaires. Le laboratoire ISTHME de l'Université de Saint-Étienne a organisé un test pour identifier les indicateurs les plus pertinents à modéliser dans le contexte de la délimitation spatiale de la végétation et d'autres recherches menées dans le cadre du projet CarHAB. Cela permet d'identifier des repères écologiques qui pourraient faciliter la reconnaissance des limites de la végétation et chercher à automatiser le plus possible les techniques de travail. Une autre perspective concerne le raffinement de la cartographie des végétations et de la symphytosociologie en compétences numériques, en faisant appel à l'imagerie satellitaire et à la télédétection, constituent un domaine intéressant à développer, afin de fournir des données plus qualitatives et quantitatives permettant de comparer et pour compléter notre analyse et de développer des applications à

l'aménagement. Nos travaux se concentrent *a priori* sur des environnements et habitats d'importance internationale (habitats « Natura2000 » et convention Ramsar). Le même habitat pourrait être représenté par des associations de plantes de différentes valeurs écologiques, indiquant des degrés d'artificialisation et de rareté différents. Pour cette raison, un suivi phytosociologique et symphytosociologique plus approfondi pourrait permettre de mieux comprendre l'évolution et d'évaluer le patrimoine naturel, en se basant non seulement sur la présence d'espèces, mais également sur les associations végétales et les conditions stationnelles des séries de végétation.

IN ITALIAN (RIASSUNTO ESTESO IN ITALIANO)

Introduzione

L'Europa ha una lunga tradizione documentata nel campo della scienza e della cartografia della vegetazione, in particolare facendo seguito all'istituzione della stazione internazionale Geobotanica mediterranea e alpina (SIGMA) di Josias Braun-Blanquet agli inizi del XX secolo. Nel frattempo, la direttiva europea Habitat-Fauna e Flora del 1992 ha richiamato l'attenzione sugli habitat di interesse comunitario, che richiedono lo sviluppo di conoscenze nelle aree della distribuzione e della mappatura degli habitat. Come parte della strategia nazionale per la biodiversità 2011-2020, il Ministero dell'ambiente francese ha lanciato nel 2011 un programma nazionale di mappatura degli habitat terrestri dal titolo "Mappatura Nazionale degli habitat terrestri naturali e semi naturali (CarHAB)", in collaborazione con varie strutture istituzionali e accademiche francesi. Il progetto CarHAB è stato istituito per produrre una mappa della vegetazione di Francia 1:25 000, seguendo gli approcci e i concetti di fitosociologia e fitosociologia del paesaggio o Dinamico-caténale.

Questa tesi dal titolo «Plant landscape and models of French Atlantic estuarine systems» (Paesaggio vegetale e modelli dei sistemi estuari dell'Atlantico francese) è stata finanziata dal Ministero francese per la transizione ecologica e solidale, come parte del programma nazionale di mappatura degli habitat naturali e semi-naturali (CarHAB, convenzione numero 2100992970) ed è stata condotta a seguito di un programma di dottorato di ricerca sotto la supervisione congiunta tra l'Università di Camerino (Italia) e l'Università di Bretagna occidentale (Francia).

Gli estuari sono stati selezionati come aree di studio del programma CarHAB per comprendere meglio l'originalità della loro vegetazione, le traiettorie dinamiche della vegetazione, il tutto legato al paesaggio alla β -biodiversità, all'uso del suolo e delle acque. Gli estuari sono un'importante fonte di servizi eco-sistemici. Essi, sono ecosistemi molto produttivi in biomassa e rappresentano sistemi molto importanti per la biodiversità e per gli usi umani. In generale, gli ambienti estuari sono caratterizzati da elevate correnti d'acqua e maree talvolta violente, con frequenti allagamenti e fronti di salinità che dipendono cicli giornalieri e stagionali delle maree, e dagli apporti acquiferi dei bacini imbriferi trasportati dai fiumi.

Gli estuari possono aver subito cambiamenti anche molto importanti nel corso dei secoli a causa della pressione umana. Questi cambiamenti possono aver creato una quota di ecosistemi semi-naturali o artificiali, ma possono aver anche limitato o compromesso la funzionalità dei sistemi e servizi estuari, cambiando la qualità fisica e chimica delle acque, manomettendo il funzionamento idraulico, la composizione specifica, la geomorfologia e le forme del paesaggio. Generalmente gli estuari rappresentano un complesso di habitat naturali e semi naturale, dagli oceani (o mari) fino all' acqua dolce (gradiente valle/monte), paludi e foreste (gradiente letto minore-maggiore).

Questioni e obiettivi di ricerca

Questa tesi si pone come obiettivi di ricerca quello di sviluppare un modello predittivo spazio-temporale basato sulla vegetazione attuale e potenziale di estuari, seguendo un approccio Dinamico-catenale. Questo approccio ha lo scopo di rappresentare tre livelli di organizzazione della vegetazione comunità (associazioni), dinamiche (serie) e paesaggio (geoserie).

Le principali domande di ricerca poste sono:

- Quali caratteristiche geografiche ed ecologiche influenzano i modelli di vegetazione negli estuari?

- Come classificare gli estuari in base alle caratteristiche della vegetazione (traits, distribuzione e diversità) e ai loro modelli?

- È possibile definire un modello comune generico dei gradienti ecologici e dei paesaggi vegetali degli estuari?

Il processo di cartografia viene eseguita per valutare le superfici partendo da unità tessellari (sigmeti) e catenali (geosigmeti). Ciò pone alcune domande aggiuntive sulla vegetazione potenziale e attuale:

- In che modo le comunità secondarie possono aiutare a caratterizzare le serie di vegetazione?

- In quale misura le attuali comunità di vegetazione sono in equilibrio con le dinamiche naturali o antropiche?

Questa tesi si propone anche di studiare i sistemi ecologici e geografici, al fine di approfondire la conoscenza della vegetazione e degli ecosistemi, al fine di sviluppare una metodologia sinfitosociologica e cartografica della vegetazione dei sistemi estuari atlantici.

Concetti generali e definizioni

La fitosociologia è la scienza delle comunità vegetali, quindi della sociologia vegetale. L'unità di base degli studi nella fitosociologia classica è l'associazione vegetale che costituisce una comunità omogenea di piante in un'unità ambientale omogenea. L'associazione vegetale (o fitoassociazione) è una comunità vegetale in equilibrio con l'ambiente, caratterizzato da una determinata ecologia, composizione floristica e fenomeni sinecologici che permettono di considerare ogni associazione da un punto di vista fisionomico, floristico, ecologico, dinamico e storico. La fitosociologia contemporanea è la scienza delle comunità vegetali, vale a dire unità sintassonomiche (sintaxa), che sono organizzati a vari livelli, gerarchicamente.

Nelle associazioni vegetali, le dinamiche progressive sono collegate alle successioni primarie o secondarie. Le dinamiche sono invece negative quando sono correlate a fenomeni di regressione e degenerazione. Sono stabili quando sono correlati alla fluttuazione (antropica o naturale).

Nelle serie di vegetazione le dinamiche positive sono orientate verso le successioni, passando dallo stato attuale ad uno con equilibrio ambientale presumibilmente più elevato. Al contrario, le dinamiche negative tendono ad allontanarsi da questo più alto equilibrio (testa di serie). Le associazioni vegetali costituiscono l'analisi di primo livello del paesaggio vegetale. La Sinfitosociologia (o fitosociologia del paesaggio) comprende lo studio dell'insieme di associazioni vegetali. La fitosociologia del paesaggio si concentra sulla descrizione e classificazione delle serie di vegetazione in un sistema ordinato, alla ricerca di un sistema gerarchico standard. Per sua natura olistica, questo sistema integrativo è utile per sviluppare strumenti per il monitoraggio degli ecosistemi, del patrimonio naturale e delle minacce alla biodiversità. Nel campo della pianificazione territoriale, è possibile misurare lo stato dell'ambiente e valutare le minacce in base al grado di uso del suolo e delle risorse naturali, seguendo il grado di artificialità o naturalità del paesaggio.

La fitosociologia dinamico-catenale consente di integrare le dinamiche della vegetazione descrivendo le traiettorie delle serie di vegetazione. A partire dagli anni '70, la novità è stata caratterizzata da una maggiore integrazione dei dati geografici, paesaggi, uso del suolo e dati ambientali attraverso la creazione di mappe tematiche basate sulla vegetazione.

Gli studi fitosociologici integrati corrispondono ad un approccio spazio-temporale alla vegetazione (carte fitosociologiche integrate) o integrato nelle tematiche (ambientali, sociali, agronomiche, geografiche, geologiche, suolo, clima, faunistiche...). L'integrazione di questi temi richiama tra l'altro, la definizione di "geoarchitettura", termine usato dall'architetto Le Corbusier all'inizio del XX secolo.

È possibile distinguere sottotipi di mappe fitosociologiche: mappe di vegetazione reale (mappe delle unità di sintassonomiche); e mappe della vegetazione potenziale (mappe di unità sintassonomiche climatiche). L'integrazione di questi due tipi di mappe della vegetazione corrisponde alle carte della vegetazione integrata, ove la vegetazione è integrata nel tempo e nello spazio, e la vegetazione attuale è rappresentata nell'ambito della vegetazione potenziale. Le mappe della vegetazione integrate ecologiche sono invece integrate con altri aspetti tematici (mappe del suolo, mappe geologiche...).

Le mappe geosinfitosociologiche (mappe di geosigmeti) corrispondono alle mappe di complessi di vegetazione.

Da un punto di vista morfologico, un estuario è la porzione di un fiume in cui gli effetti del mare (o oceano) sono rimarcabili. La foce o bocca è la parte di un estuario che sfocia nel mare. Negli estuari, i principali fattori ambientali sono dovuti alle condizioni dei flussi e dalle proprietà chimiche, fisiche e biologiche delle acque. Le variazioni nel flusso dell'acqua determinano le dinamiche di sedimentazione ed erosione, nonché le variazioni nella salinità.

Gli estuari tidali (o di marea) sono tipicamente caratterizzati su aree più estese, seguendo i livelli di marea più alti. La porzione estuaria più a valle è composta principalmente di acqua salata, ed è influenzata dalla cosiddetta marea di salinità, mentre la porzione situata più a monte, con acque dolci, corrisponde alla zona influenzata dalla marea dinamica. Le dinamiche degli estuari sono ad ogni modo influenzate dai cicli stagionali legati alle inondazioni dovute dalle

maree (a valle) e dall'afflusso di acqua dal bacino imbrifero (a monte). I letti, i meandri, le paludi, le sponde e le terrazze degli estuari sono sempre soggetti alla dinamica delle correnti che possono rimodellarli.

Questa dinamicità ecologica si riflette in ambienti continuamente instabili, soggetti a disturbi ricorrenti od occasionali che influiscono su tutte le espressioni biologiche, inclusa la vegetazione. Gli estuari rappresentano un gradiente geografico e geomorfologico tra terra e mare, in transizione da un ambiente salato e più esposto ai venti marini, verso ambienti d'acqua dolce, più riparati e meno miti. Nei grandi estuari, l'influenza dei fiumi è più pronunciata a causa dei corpi fluviali più grandi e quindi più impattanti.

I principali fattori che caratterizzano gli estuari e i loro gradienti ecologici sono la salinità e l'umidità del suolo. Altri fattori fisici possono determinare differenze, peculiarità o eccezioni: dimensioni del substrato, pendenza, venti marini, variazioni microclimatiche, impatto umano.

Ogni estuario rappresenta un sistema originale, a causa di una combinazione unica delle sue caratteristiche geografiche, ecologiche e dinamiche, che si combinano con l'impatto umano presente e passato.

Negli estuari, i gradienti ecologici seguono variazioni geografiche e morfologiche in due direzioni: longitudinale (da valle a monte) e trasversale (dal letto minore al maggiore). In entrambi i casi, si va da livelli topografici più bassi verso livelli più alti, di conseguenza la salinità diminuisce, così come diminuisce il tenore di umidità del suolo. Seguendo la direzione dei livelli topografici, più si va in alto e più si può riscontrare una tendenza comune ad ambo le direzioni riguardo l'espressione della vegetazione (dalle paludi e prati salati, fino alle foreste di frassino maggior e farnia). Nelle due direzioni (longitudinale e trasversale) l'influenza delle maree tende ad essere meno importante più a monte; mentre, le precipitazioni (con la falda freatica) vanno invece ad aumentare la loro impronta.

Il gradiente topografico trasversale (letto minore-maggiore) corrisponde a un gradiente di diminuzione dell'umidità (o inondabilità) e similmente accade anche per la salinità. Seguendo queste variazioni, possiamo individuare i seguenti compartimenti geomorfologici: canale principale, slikke, Schorre e pianura alluvionale.

Secondo il gradiente topografico longitudinale, dalla foce a monte si possono distinguere tre comparti di salinità: acqua salata, acqua salmastra e acqua dolce. Questi compartimenti possono essere suddivisi in aree di salinità, da valle a monte: zona eualina (mixoeualina) con più di 30 psu; zona polialina tra 30 e 18 psu; zona mesoalina, tra 18 e 5 psu; zona oligoalina tra 5 e 0,5 PSU, zona di acque dolci con meno di 0,5 psu (PSU è l'unità di misura della salinità, espressa in grammi di sale per litro di acqua).

Gli estuari possono essere definiti come ecosistemi, ma nel contempo anche come complessi di ecosistemi caratterizzati da ecotoni fluidi, con confini delimitati nel tempo e nello spazio.

Il comportamento di un estuario varia notevolmente a seconda della stagione, della posizione, della forza delle maree, del flusso fluviale, dalle precipitazioni, dal vento e dalle correnti di alto mare.

L'espressione della biodiversità estuaria è complessa a causa della presenza di caratteristiche che coesistono ma che appaiono antagoniste (ad esempio l'influenza di acqua salata e acqua dolce sulla stessa superficie, o l'alternarsi di condizioni di siccità ed acquatiche). Questa complessità ecologica induce una certa complessità degli habitat e quindi della

vegetazione. Di conseguenza, i gradienti di estuari possono essere altamente variabili e multidirezionali, riflettendo la complessità di ciascuno di questi sistemi. La presenza di specie, comunità vegetali e limiti vegetazione può essere approssimativamente definita da analisi protratte nel tempo e basate su corpi idrici, prendendo come riferimento il canale principale. Come produttori primari nell'ecosistema, le piante e le comunità vegetali sono particolarmente sensibili ai fenomeni che caratterizzano l'ambiente, e per le loro caratteristiche fisiologiche e biologiche sono considerati buoni bioindicatori (talvolta noti come macrofite) soprattutto per gli ambienti acquatici e mesici, come nel caso degli estuari. Infatti, lo studio della vegetazione consente la caratterizzazione nel breve termine dell'ambiente e il monitoraggio dei cambiamenti globali nel lungo termine, perché le piante sono strettamente legate all'espressione della biodiversità e quindi alle condizioni ambientali, funzionando come bioindicatori.

Area di studio

L'area di studio corrisponde alla costa atlantica francese, situata tra il Paese Basco (confine iberico-francese) e le Fiandre (confine franco-belga) e caratterizzata da un clima oceanico.

Tra i più grandi estuari studiati ci sono: Gironda, Loira, Senna e Charente.

Tra gli altri di Basse-Normandie (hâvres): Vanlée, Regnéville, Blainville, Geffosses, Surville, Saint-Germain-Sur-Ay, PortBail e Carteret.

Tra gli estuari della Piccardia e del Nord-Pasdo di Calais: Somme, Authie, Canche, Liane, Wimmereux, Slack, Calais, Aa e Porto di Dunkerque.

Tra gli altri estuari dell'Aquitania: Adour, Courant de Mimizan, Nivelle e Bidasoa.

Tra gli estuari della Bretagna: Rance, Blavet e Scorff, Laïta, Abers (I-Vrac'h, II-Benoit, III-Ildut), Elorn, Aulne, Vilaine e Ria d'Étel.

Materiali e metodi

Le serie di vegetazione sono state nominate a seguito dell'associazione testa di serie, mentre le geoserie a seguito del nome dell'associazione testa di serie più rappresentativa. Per le facies secondarie, abbiamo cercato di identificare la vegetazione potenziale. Il lavoro preliminare è stato condotto su tutti gli estuari (analisi bibliografica, foto aeree, mappe topografiche, mappe della zona intertidale, mappe tematiche legate alla vegetazione, carte degli habitat, dell'uso del suolo e delle aree protette), consentendoci di sintetizzare i dati disponibili sui fattori biotici e abiotici; e anche per definire una prima caratterizzazione ecologica, un primo modello del sistema estuario e di creare un primo database per avere elementi iniziali di ipotesi, riflessione e discussione al riguardo.

Particolare attenzione è stata data alla caratterizzazione della vegetazione e alla sua cartografia; nonché all'osservazione del ruolo di gradienti ecologici, alle dinamiche della vegetazione e per la comprensione della pressione antropica esercitata. Una selezione di estuari è stata effettuata di conseguenza per svolgere indagini sul campo, per sviluppare la tipologia e la cartografia delle serie e geoserie di vegetazione.

I rilievi fitosociologici e i geosinrilievi sono stati realizzati per identificare le diverse serie, geoserie e geopermaserie, per descrivere la distribuzione della vegetazione nel paesaggio,

ed eventualmente evidenziare eventuali elementi sinendemici o al contrario, eventuali somiglianze (elementi invariati) tra estuari. L'elaborazione cartografica dei dati ci ha permesso di sviluppare un modello spaziale che consente di rappresentare l'organizzazione generale della vegetazione estuaria in base ai gradienti ecologici associati. Non è stato sempre possibile descrivere tutte le traiettorie e le dinamiche della vegetazione, a causa della mancanza di dati storici o perché l'uso del suolo è così marcato su ampie superfici al punto da alterare l'espressione della vegetazione o le forme del paesaggio e quindi la potenzialità della vegetazione (drenaggio, erosione, deforestazione, desertificazione, perdita di specie naturali o introduzione di specie esotiche...).

L'approccio seguito in questa tesi permette di integrare la carta della vegetazione potenziale (rappresentata tramite serie, geoserie e geopermaserie di vegetazione) con i rilievi sinfitosociologici e fitosociologici (vegetazione reale) descrivendo la composizione delle varie unità mappate. Casi speciali possono essere rappresentati con simboli sulle carte o descritti nelle descrizioni testuali. Le mappe della vegetazione sono state realizzate utilizzando il software QGIS (versione 2.18.14).

Analisi ombrotermiche, climatiche e bioclimatiche sono state eseguite utilizzando dati di provenienti dalle banche dati MeteoFrance e WorldClim, con lo scopo di inquadrare gli estuari e analizzare le variazioni microvariazioni climatiche negli estuari.

Risultati e discussione

Su un totale di 36 estuari identificati nello studio preliminare, 8 estuari sono stati selezionati per le indagini fitosociologiche e sinfitosociologiche (Charente, Loire, Vilaine Etel, Blavet Scorff, Laïta, Alder e Elorn). I rilievi sul campo hanno coinvolto una superficie totale di 98315 ettari. L'analisi dei dati e fitosociologiche *synrelevés* permesso di evidenziare due géopermaseries serie e 4, corrispondenti a 131 associazioni, 60 alleanze, ordini 43 e 28 classi fitosociologiche. Tre estuari sono stati selezionati per costruire la serie mappatura e geoserie vegetazione (Loire Laïta e Alder). In totale, 74,433 ettari sono stati mappati, pari al 2 serie e 4 géopermaseries vegetazione.

L'analisi fitosociologica non pretende di essere esaustiva, anche se un gran numero di associazioni primarie e secondarie, comprese le cenosi più ruderali e antropiche sono stati esaminati.

Negli estuari, dalla foce alla porzione dulciacquicola possono essere distinte alcune varianti ed eccezioni relative alla geomorfologia locale. La variazione principale fa seguito al confinamento degli estuari e alla continuità associata (laterale, longitudinale e verticale). Infatti, più gli estuari sono di tipo confinato, meno le sequenze delle serie di vegetazione sono evidenti (le serie e geoserie tendono a mostrarsi più lineariformi, discontinue, sfumate e sottili), fino a non permettere più l'espressione di una o più serie, influenzando la ricchezza delle comunità vegetali e i fenomeni di trasgressione.

Considerando che la pianura alluvionale è la più grande zona allagabile, i problemi di confinamento e di continuità si riflettono dunque sull'impatto umano, a seguito di arginature artificiali, dighe, drenaggi, bonifiche e riempimento. Questi cambiamenti bloccano o influenzano l'idrodinamica e la geomorfologia, con le conseguenti eccezioni relative all'espressione della vegetazione.

L'elaborazione delle tabelle fitosociologiche e sinfitosociologiche, accanto all'elaborazione delle carte della vegetazione ci ha permesso di validare l'ipotesi iniziale di zonazione ecologica negli estuari e di adattarla alle serie, geoserie e geopermaserie, secondo il principio cartografico della generalizzazione.

Nelle zone più saline dal letto minore al maggiore, si installa la vegetazione delle paludi e praterie salate (*Atriplici prostratae-Elymeto atherici* geopermasigmeto), succedute dai saliceti paludosi a *Salix atrocinera* (foreste di *Salix atrocinerea* geosigmeto), inoltre le foreste di *Fraxinus excelsior* (foreste di *Fraxinus excelsior* forest geosigmeto). Più a monte, il *Salix atrocinera* tende ad essere sostituito da *Salix fragilis* (*Saliceto fragilis* sigmeto) e più a monte da *Salix alba* (*Saliceto albae* sigmeto). Nel letto minore dell'estuario, la vegetazione può esprimersi bene solo nelle condizioni più riparate, o residuali; sotto forma lineare o puntuale, a causa delle forti correnti e dei cambiamenti dei fronti delle acque. A causa di queste caratteristiche particolari e delle possibili accessioni miste di acqua dolce a vario livello, abbiamo semplificato la cartografia della vegetazione acquatica nel *Lemneto minoris* geopermasigmeto. È stato in esso inclusa la vegetazione acquatica delle pozze, dei meandri sorgenti, golene, e rivoli, comprendendo tutta la vegetazione acquatica primaria. Più in dettaglio, si possono distinguere tre sottogruppi di questa vegetazione (a seconda del carattere piuttosto salato, salmastro o dulciacquicolo). La continuità verticale e le relative eccezioni naturali influenzano l'espressione della vegetazione. Ad esempio, va citata l'influenza delle accessioni naturali di acqua dolce in ambienti salini, o la possibilità di vegetazione palustre nel letto maggiore o di prati umidi e paludi poco o non salate, che in estate si asseccano, potendo mostrare perfino un certo affioramento di sale durante la stagione secca (salinizzanti).

Nella parte salina, la geomorfologia e l'idrodinamica influenzano l'espressione della vegetazione in base al tipo di substrato e al tipo morfologico della foce. Le variazioni relative alla granulometria del substrato dipendono dalla sua stabilità (equilibrio tra sedimentazione ed erosione). Se l'equilibrio tra deposizione ed erosione non è abbastanza forte da poter rimodellare continuamente la superficie, la vegetazione può installarsi più facilmente; il fango può depositarsi anche fra i ciottoli e la sabbia, promuovendo l'installazione della comunità vegetale legata a paludi e parti umidi salini. L'influenza (trasgressione e contatti) della vegetazione delle sabbie crea una variante di questa comunità che si arricchisce di specie tipiche delle spiagge e dune. Stesso fenomeno accade in presenza di affioramenti rocciosi o strapiombi di terra e specie correlate. Se i depositi si spostano, potrebbe esserci un'assenza quasi totale di vegetazione, esemplari sparsi e meno sviluppati, frammenti di vegetazione influenzati da depositi più stabili o da accessioni di acqua dolce, come notato negli estuari della Loira, del Ria d'Étel, della Laïta, del Blavet-Scorff e della Vilaine.

Se il fiume è molto aperto sul mare, o se il flusso della marea è chiaramente maggiore di quello del fiume, l'estuario si comporta più come una baia di mare (questo è il caso di Étel); la vegetazione legata alle acque salate può essere osservata più facilmente e gli scirpeti oligoalini-mesoalini a *Schoenoplectus tabernaemontani* compaiono solo puntualmente.

Nelle aree disturbate dalle attività umane, a causa della deforestazione e dei diversi usi, delle vaste superfici possono non esprimere una testa di serie. In altri casi si è verificato un cambiamento nelle serie di vegetazione (spostamento) a monte o a valle, a seguito di un cambiamento del fronte di inondabilità o di salinità, fattori che possono anche causare la moria di alcune specie o la degenerazione e regressione delle comunità vegetali (Loire e Charente).

In altri casi, in zone salata o salmastre, a causa di dighe che impediscono o rallentano l'ascesa del fronte di salinità, si può notare una presenza marcata di *Alnus glutinosa* in sostituzione delle foreste a *Salix atrocinerea* (in condizioni più paludose) o anche foreste di *Fraxinus excelsior* (in condizioni meno paludose). Questo fenomeno è stato osservato nella parte inferiore dell'Erdre nell'estuario della Loira e vicino alla cappella di Folgoat (Landévennec), vicino al vecchio mulino a marea, nell'estuario dell'Aulne. Allo stesso modo, canneti e altre formazioni erbacee di acqua dolce possono essere trovati negli estuari di Ria d'Étel e Laïta, in zone di salinità, ma non più soggette a sale poiché site a monte delle dighe laterali. Nell'estuario della Vilaine, a monte della diga di Arzal, si trova oggi una vegetazione d'acqua dolce nel letto minore, in una ex zona alofila. La diga di Guily Glaz, costruita nell'estuario dell'Aulne per limitare l'impatto delle inondazioni sullo spartiacque, limita l'espansione delle acque nella zona oligoalina, riducendo le superfici e l'espressione della vegetazione legata alle maree dinamiche. Lo spostamento delle serie del salice (*Salix fragilis* e *Salix atrocinerea*) verso entrambe le sponde della Loira, tra Saint-Nazaire, Nantes e Donges si osserva come risultato dell'accumulo artificiale dei sedimenti dopo l'approfondimento del canale nell'estuario per scopi di canalizzazione a causa di navigazione.

Conclusione e prospettive

Come parte del programma CarHAB, questa tesi ha permesso di proporre una prima tipologia fitosociologica e seriale, una metodologia di cartografia e caratterizzazione di modelli (generali e per estuari estuari) sulla distribuzione e organizzazione della vegetazione degli estuari dell'Atlantico francese. Questi elementi possono essere utilizzati su piccola e grande scala e possono essere applicabili ad altri estuari dell'Atlantico.

Una prospettiva da sviluppare riguarda l'acquisizione induttiva dei dati sul campo, mobilitando strumenti per misurare i gradienti ecologici (salinità, pH, umidità), per produrre modelli quantitativi che consentano di ricercare correlazioni matematiche con i modelli deduttivi già prodotti e applicarli alle variazioni della vegetazione, rilevabili manualmente sul campo o mediante telerilevamento.

L'implementazione del monitoraggio diacronico della vegetazione completerebbe la conoscenza floristica, della β -biodiversità, sintassonomica e della corologia della vegetazione degli estuari. Sarebbe inoltre interessante correlare i dati della distribuzione della vegetazione con il monitoraggio relativo alla presenza di microrganismi, plancton e variazioni nella produttività della biomassa.

Sui siti test, sarebbe interessante dare a ogni serie di vegetazione l'opportunità di esprimere liberamente le sue dinamiche naturali per applicazioni legate alla gestione e alla conservazione degli habitat, al fine di comprendere meglio il potenziale del paesaggio vegetale e ottimizzare le metodologie per valutare l'impatto umano, mobilitando i concetti di naturalezza, artificializzazione e resilienza.

Una prospettiva di ricerca, già lanciata nell'ambito del programma CarHAB, riguarda l'uso di fondi bianchi ecologici e per facilitare le divisioni tessellari. Recentemente, il laboratorio ISTHME dell'Università di Saint-Etienne ha organizzato un test per identificare gli indicatori più rilevanti da modellare nel contesto della delineazione spaziale della vegetazione e di altre ricerche effettuate nell'ambito del progetto CarHAB. Questo consente di identificare

punti di riferimento ecologici che potrebbero facilitare il riconoscimento dei limiti della vegetazione e cercare di automatizzare il più possibile le tecniche di lavoro.

Un'altra prospettiva riguarda la rifinitura e la risoluzione della cartografia della vegetazione e della sinfitosociologia tramite competenze digitali, utilizzando programmi per computer, immagini satellitari e telerilevamento, per fornire più dati quantitativi e sviluppare il confronto con i dati qualitativi così da sviluppare ulteriori applicazioni per la gestione del territorio.

Il nostro lavoro si concentra principalmente su ambienti e habitat di importanza internazionale (habitat "Natura 2000" e Convenzione di Ramsar). Lo stesso habitat potrebbe essere rappresentato da associazioni di piante con diversi valori ecologici, che indicano diversi gradi di artificializzazione e rarità. Per questo motivo, ricerche fitosociologiche e sinfitosociologiche più approfondite potrebbe consentire di comprendere meglio l'evoluzione e valutare il patrimonio naturale, basato non solo sulla presenza di specie, ma anche sulle associazioni vegetali, e sulle serie di vegetazione

Titre : Paysage végétal et modèles des systèmes estuariens atlantiques français

Mots clés : estuaires atlantiques, gradients écologiques, modèles, habitats naturels et semi-naturels, (syn)phytosociologie, paysage végétal.

Résumé :

Les estuaires sont constitués d'une vaste mosaïque d'habitats naturels et semi-naturels. L'objectif de cette thèse est d'étudier les végétations et les paysages végétaux des systèmes estuariens atlantique en France, en essayant de comprendre le fonctionnement et les schémas de distribution des différentes unités de végétation. La présente étude tente de mettre au point un modèle théorique commun de fonctionnement et de gradients écologiques, afin de compléter la classification et la connaissance écologique des estuaires, et une aide au suivi et à l'évaluation de l'utilisation des sols, des impacts humains, en développant un modèle spatio-

temporel prédictif fondé sur la végétation réelle et potentielle, et en utilisant l'approche dynamico-caténale. Dans 8 estuaires sélectionnés, nous avons effectué des travaux sur le terrain pour une superficie totale de 98 315 ha, mettant en évidence 2 séries de végétation et 4 géopermaséries, correspondant à 131 associations végétales, 60 alliances, 43 ordres et 28 classes. Nous avons cartographié la végétation de trois estuaires représentatifs, ce qui représente une superficie totale de 74 433 ha. Un schéma synthétique des paysages végétaux estuariens est proposé, en intégrant les gradients géographiques et écologiques et les formes géomorphologiques.

Title : Plant landscape and models of French Atlantic estuarine systems

Keywords : atlantic estuaries, ecological gradients, models, natural and semi-natural habitats, (syn)phytosociology, plant landscape.

Abstract :

Estuaries generally include a wide mosaic of natural and semi-natural habitats. The objective of this thesis is to study the vegetation and Plant Landscape of French Atlantic estuarine systems, trying to understand the functioning and the plant distribution patterns. The present study tries to carry out a theoretical common model of functioning and ecological gradients, in order to make a basis to improve their classification and ecological studies, and to help the monitoring and assessment of land uses, land forms transformation and human impacts: developing a spatio-temporal predictive model

based on actual and potential vegetation, using the dynamico-catenal approach. The study area corresponds to the Atlantic French estuaries. In 8 selected estuaries, we undertook fieldworks for a total of 98315 ha, highlighting 2 vegetation series and 4 geopermaseries, corresponding to 131 plant associations, 60 alliances, 43 ordos and 28 classes. We mapped the vegetation of three representative estuaries for a total of 74433 ha. A synthetic scheme of estuary vegetation landscape is proposed, integrating geographical and ecological gradients as well as geomorphologic forms.