

Summary Sheet

Project name	PACTE: PAST to Current land-sea Continuum: socio-ecosystem Trajectories derived from a regional pilot site
Acronym	PACTE
Coordinator	PENAUD AURELIE
Research unit	UMR 6538 Géo-Océan
ISblue research units concerned	<p>Géo-Océan: Muriel Vidal, Clément Lambert, Evelyne Goubert, Jérôme Goslin, Axel Ehrhold</p> <p>LEMAR : Jill Sutton, Mélanie Raimonet, Yves-Marie Paulet, Aude Leynaert, Gaspard Delebecq, Olivier Ragueneau, Philippe Pondaven</p> <p>Ifremer (Dyneco-Pelagos): Raffaele Siano</p> <p>LETG Brest : Mathias Rouan</p>
External collaborations	<p>National</p> <p>SEDISOR – Plouzané : Sidonie Révillon</p> <p>UMR CRBC – Brest : Philippe Jarnoux, Jean-Baptiste Pressac</p> <p>LMBA – Brest : Pierre Ailliot, Jean-Marc Derrien</p> <p>Ifremer – Concarneau : Kenneth Mertens</p> <p>UMR EPOC – Bordeaux : Sabine Schmidt</p> <p>International collaborations</p> <p>University of Nevada - Department of Geography: Scott Mensing and his collaborators (students and researchers). PACTE team, in collaboration with the University of Nevada, plan to contact international teams working on coastal socio-ecosystems to organize one thematic school in 2024 and one international conference in 2025 at the IUEM.</p> <p>University of Copenhagen: This pioneering laboratory in the study of ancient DNA uses validated and robust protocols for metagenomic analyses of past eukaryotic and prokaryotic communities. This paleogenetic task will therefore benefit of this collaboration.</p> <p>The project TREC (<i>TRaversing European Coastline</i>) led by EMBL and co-organised with Tara Foundation, Ifremer and EMBRC: Raffaele Siano has been appointed responsible for the coordination and sampling of about 30 coastal cores at the European-scale in 2023-2024. PACTE results will be contextualised in this European partnership.</p>
Total budget	~900 k€: at least 473 k€ (funded, asked, to be asked) + 408.22 k€ (requested to ISblue)
Budget ISblue	408.22 k€
ISblue Themes	<p>3. Sustainable coastal Systems</p> <p>→ New long-term strategies for the study of changes in land cover upon watershed areas surrounding coastal zones in a context of climate change, based on cross-referenced observations of fossilized pollen data observations and historical data on human practices and land uses.</p>

→ **Interdisciplinary reconstruction** (geography, sedimentology, (paleo)ecology, biogeochemistry, human sciences) of socio-ecosystemic trajectories (over the 2 last centuries, at least) at the local-scale to unravel climate-ecological-anthropic interactions and main driving mechanisms operating in environmental transformations.

→ **Data-driven and numerical model–data-coupled strategies** with the establishment of a new land-sea continuum model validated with instrumental data but also with sediment paleoreconstructions, constituting an original pioneering exploratory work.

5. Long-term observing systems for ocean knowledge

→ New monitoring actions upon ecological variables (dinocysts and diatoms, as well as pollen grains, environmental DNA) both at the SOMLIT-Ifremer **Lanvéoc station** and in surface sediments, as well as **cross-observations with protist and pollen quantifications in the water column (“Objectif Plancton”, Ifremer ROME observatory).**

→ Implementation of integrated observatories in the project.

For both themes

A Data management plan developed with research engineers (IUEM and CRBC) specialists of FAIR databases, in interaction with the RI Data Terra/Odatis.

Dissemination of knowledge in the framework of an **interdisciplinary thematic school** and **international conference**, as well as **invited professors, student exchanges**.

PROJECT SUMMARY

The PACTE project is an **interdisciplinary** study of the **macro-tidal estuarine** environment of the **Bay of Brest (BoB)**, a coastal ecosystem that has been exposed to strong **anthropogenic** pressures over the past decades, especially **in the aftermath of World War II (WWII)**. Using **sediment cores** retrieved in the BoB, PACTE aims at reconstructing past environmental changes at a high temporal resolution (subdecadal to annual) **over the past (at least two) centuries**, in order to create the first complete **chrono-systemic timeline** of main BoB socio-ecosystemic changes over the land-sea continuum. To do so, the project will combine several techniques. **Fossilized marine bio-indicators** and **biomolecular tools** will allow to analyse past changes in **protist** communities as a whole as well as past occurrences of **toxic** species. In parallel, changes in BoB **landscapes** will be investigated using **sedimentological** analyses and **pollen** tracers, while the sources and dispersion of **historical pollutions** (occasional or chronic) will be investigated using trace metals and lead (Pb) isotopes. All data obtained from BoB sediment cores will be gathered with **instrumental data** (issued by IUEM observatory services and watershed managers) as well as **historical chronicles** (ongoing PhD that started in October 2021 between IUEM and CRBC). In parallel, a **model of the land-sea continuum** will be developed and validated against current environmental data before being applied to the pre-WWII period. The model-data intercomparison will allow i) to establish and discuss robust **causal relationships** between the different eco-socio compartments established thanks to paleo-reconstructions, and ii) to simulate as accurately as possible **past to current trajectories**, then allowing to consider the simulation of future trajectories under different scenarios in a next future (perspectives post-PACTE). Working at the local spatial scale (BoB) is necessary to tackle the objectives of PACTE, especially in order to address **robust correlations** between driving forces and environmental changes. Considering the importance PACTE topics and expected outcomes carry **for coastal management worldwide**, we ambition that PACTE **methodologies** will be applicable at broader scales. In order to improve the capacity of the PACTE project approach (detailed complex socio-environmental river/coastal systems) to spread within the international coastal sciences community, PACTE team with the University of Nevada (i.e. team recognized for integrating “history-climate-ecology” inseparable-interconnected disciplines) plan to organize a joint **international thematic school** and an **international conference** at the IUEM. In addition, these results will be contextualised at the **European-scale** in the framework of the **2022-2024 project TREC (TRaversing European Coastline)** led by EMBL and co-organised with Tara Foundation, Ifremer and EMBRC, allowing for international exchanges (students and invited professors) over the duration of PACTE. The contribution of PACTE to ISblue teaching activities and the socio-economic environment involved in the **stakeholder committee** is fully taken into account in **PACTE expected outcomes**.

1 - Context and objectives

PACTE's institutional positioning

The main objective of PACTE is to highlight and model the magnitude of imbalances coastal ecosystems face while exposed to climate oscillations and human land uses and practices by exploring past (i.e. at least the two last centuries) to current socio-ecosystemic trajectories in the Bay of Brest (BoB).

Studying causal relationships between natural and anthropological forcing of a socio-ecosystem is a complex interdisciplinary field that requires crossbreeding notions and concepts developed in different disciplinary fields (i.e. geomorphology, sedimentology, (paleo)ecology, bio-geochemistry, hydrology, climate sciences, history) [1]. PACTE will focus on a **well-defined local-scale territory** to ensure that strong correlations between well-defined forcing agents will be identifiable. The BoB represents an ideal pilot site for this purpose as it belongs to the **Zone Atelier Brest Iroise (ZABri)**, part of the **Zones Ateliers (CNRS-INEE)** framework and of the **European (eLTER) and International (ILTER) Long-Term Ecological Research network**. This integrated study will be particularly relevant for wider global issues. We are planning international exchanges (invited professors, formation of students-doctors, thematic school, international conference) to develop relationships with the project participants in their respective disciplinary field, in addition to the information that will be transmitted through the eLTER-ILTER networks. In addition, non-academic partners and project stakeholders in PACTE ([Appendix 1](#)) will ensure that PACTE data and key findings will be shared and disseminated. PACTE PI, as a lecturer at the IUEM observatory and Géo-Océan laboratory, is focused on 3 missions that will fuel PACTE project : i) **research** (responsible of an analysis platform in palynology-micropaleontology since 2016), ii) **teaching-training** (co-coordinator of the SML (*Sciences de la Mer et du Littoral*) Master's program "Ocean Geosciences") and iii) **observation** (co-animator of a new 2021 transverse axis of the IUEM "*Historical dynamics*"), created under the impetus of the ZABri-Theme 4 ("*Human settlement dynamics and paleoenvironments*" coord. Y. Pailler-archeologist and PACTE PI between 2016 and 2021). PACTE will consolidate an interdisciplinary team devoted to past to future trajectories of socio-ecosystems at the land-sea interface in the context of strong anthropic pressures and climate change [2], and is related to ISblue thematic, especially to themes 3 and 5 (cf. pages 1-2) but also to theme 1 that relates to ocean and climate regulation.

Scientific context

The CNRS project "CAMOMI" (2015-2016, PIs A. Penaud and R. Siano) for "Convergences / Crossed approaches of molecular and micro-paleontological signals to decipher anthropic and climatic forcing in coastal environments (Bay of Brest)" constituted a stepping-stone for the present PACTE project.

Across the XXth and XXIst century, coastal ecosystems have been exposed to growing **anthropogenic pressures**, such as **urbanization** and **intensive agricultural** practices, and the subsequent release of fertilizers, phytosanitary products, and other **pollutants** [3]. In Brittany, **eutrophication** began with the post-World War II (WWII) regional model of intensive agriculture that has been shown to be responsible for **high nutrient** input to coastal waters [4]. In the near future, elevated levels of eutrophication in coastal zones, resulting from the leaching of phosphorus- and nitrogen-enriched agricultural soils, are expected to increase in response to the projected influence of **climate change** [2] and to yield changes in **biodiversity** at different trophic levels, including phytoplankton production and community structure [5]. The ensuing transformations can be evaluated by the analysis of **socio-ecosystem trajectories** [1,6] but deciphering between anthropogenic forcing and natural changes can only be made by focusing on periods when human pressure was also less prominent. Since instrumental data extends to a limited pluri-decadal time range, the resort to retro-observation within **estuarine sediment archives** is essential since it offers the opportunity to reconstruct **land-sea sediment transfers** at high temporal resolution, greatly extending the instrumental record. Using this approach, recent BoB paleo-reconstructions conducted in the most eutrophic part of the BoB, the Daoulas Estuary (Fig. 1), highlighted the paleo-ecological transformations of Daoulas watersheds and coastal waters from 1850 to present at sub-decadal resolution [7,8,9], with an unprecedented recurrence of toxic algal bloom events in recent years (cf. toxic dinoflagellate *Alexandrium minutum*) [8].

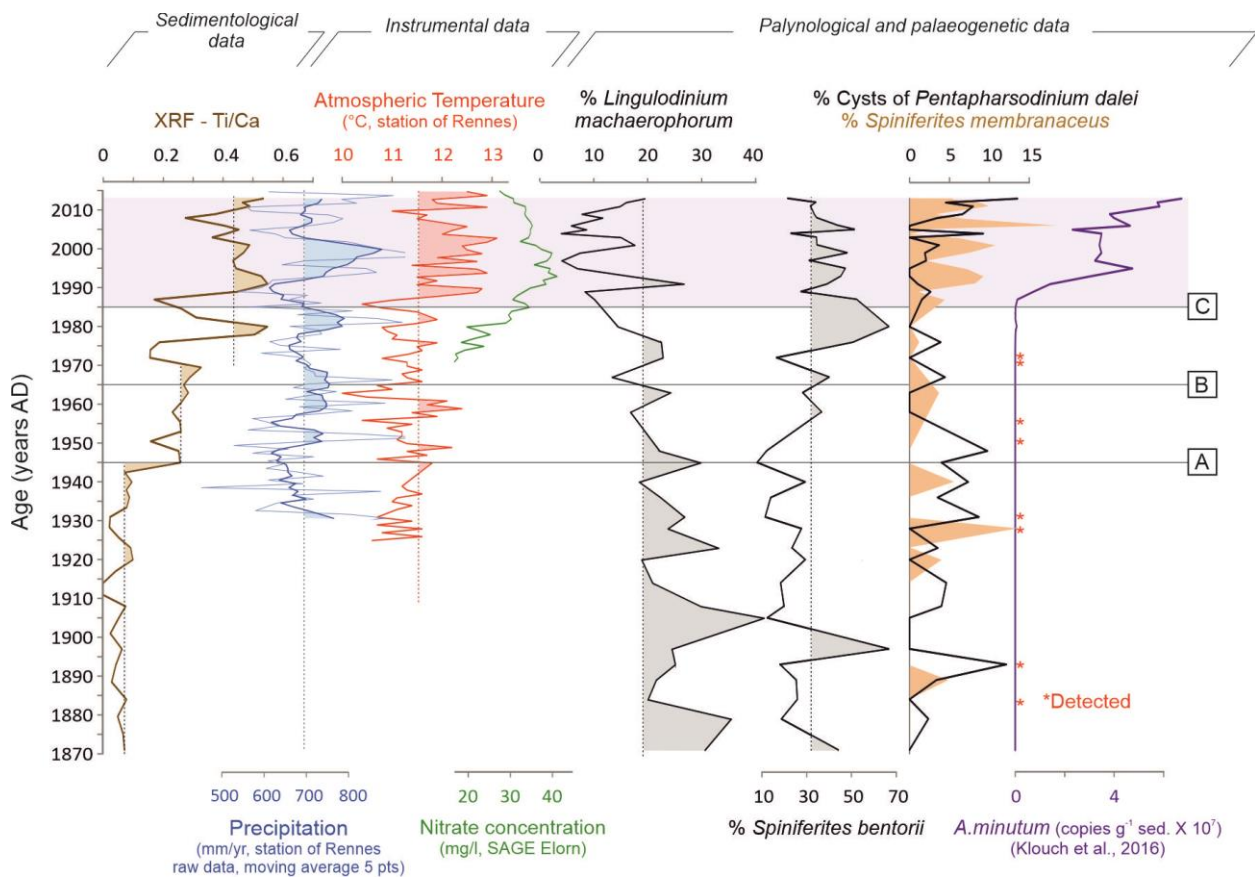


Figure 1: Figure built for a review on dinoflagellate cysts [10] written by the PACTE PI for the 60th anniversary special volume of the “Revue de Micropaléontologie”, integrating data over the last 150 years in the BoB highly anthropized estuary of Daoulas ([7] and [8] ; DE in Figure 3). Comparison between sedimentological (XRF-Ti/Ca), selected dinocyst (percentages of *L. machaerophorum*, *S. bentorii*, cysts of *P. dalei*, *S. membranaceus*), and ancient sedimentary DNA (*A. minutum*) data, with instrumental data (precipitation and atmospheric temperature at the Rennes meteorological station, nitrate concentration in Elorn watersheds).

Problem and originality

Can we capture in paleo-reconstructions inter-annual variability resulting from climate oscillations? Do anthropogenic-driven regional environmental changes and related feedbacks represent ruptures in the long-term functioning of ecosystems? Can we use instrument-historical data and paleo-reconstructions to build and validate regional models of the land-sea continuum?

The overall PACTE scope is to reconstruct the first “**chrono-systemic**” timeline of the **BoB socio-ecosystem** taking into account temporal differences between different BoB catchment areas, based on natural and human-related activities of its principal tributaries: the **Aulne** and **Elorn Rivers**. The **challenging fine-scale** (spatial: **Bay of Brest**; and temporal: **subdecadal to annual resolution**) integrative study of past recent changes deserves a particular attention in the understanding of present-day socio-ecosystemic transformations. **The originality of PACTE is to encompass together the entire range of tools** (i.e. historical archives, instrumental monitoring of river and coastal hydro-systems, modern chemical pollution, isotope and trace element analyses in sediment cores, present-day and fossilized coastal ecosystems, sedimentation rates, modelling) **and skills needed** to reconstruct modern environmental trajectories **and to discuss the land-sea continuum in an integrated manner from past to present**. Such crossing is rare, due to an excessive **disciplinary segmentation of knowledge**. In addition, numerous BoB **chronicles** and scientific **multi-proxy datasets** from land to sea that will be compiled and acquired in PACTE ensure the **parametrization and validation of a model of the land-sea continuum**, which was identified as a priority research topic in the last prospective of national CNRS institutions or groups (INEE, INSU, SIC, Ocean task force). **Cross-validation of (paleo)data (scientific or historic) with a land-sea model** is a novel aspect of PACTE given that river and estuarine models, known to successfully represent variations in water quantity and quality as well as ecosystem processes and eutrophication symptoms, do not consider variability at the temporal scale [11,12,13,14,15].

2 - Project description

2.1 Methods and workpackages

WP 1: Project coordination (A. Penaud and other WPs coordinators)

The coordination of research and outreach activities (Fig. 2) will include: i) the organization of exchanges between all participants, seminars and interdisciplinary training courses, ii) the networking with stakeholders (ZABrI and OSU-IUEM; public territorial development and management board of the Elorn (SBE-Elorn) and Aulne (EPAGA-Aulne) watersheds; “*Parc Naturel Régional d'Armorique*” (PNRA); Scientific and Cultural Mediation at the *Océanopolis Museum*) (Appendix 1), iii) the implementation of the data management plan, iv) the valorisation and dissemination of results and the training-research implication (cf. “3. Expected outcomes”).

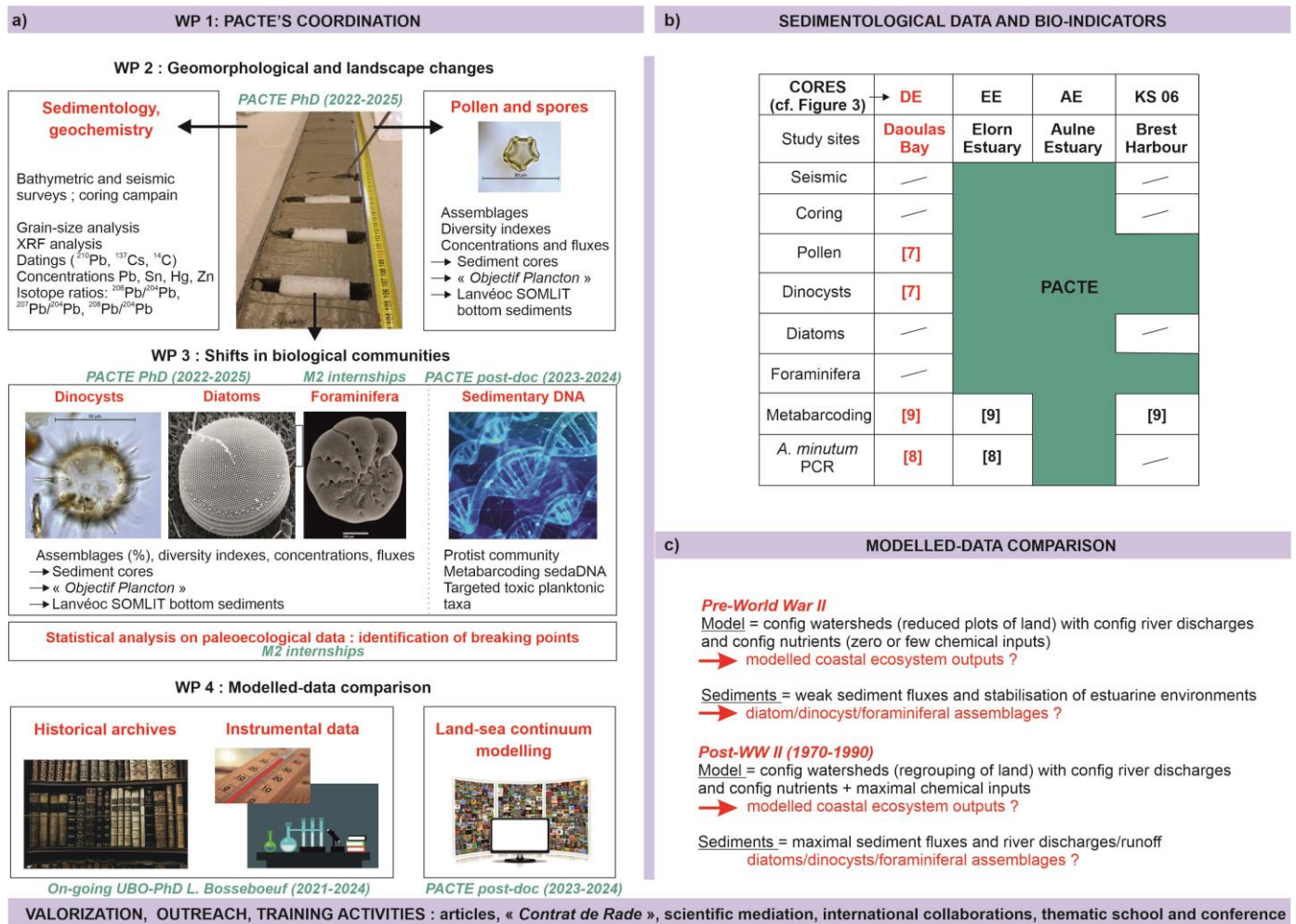


Figure 2: a) General PACTE organization into four work packages (WPs). b) Table gathering information about published data (into brackets) and data that need to be acquired in PACTE (cases coloured in green) and mainly related to new coring planned at the Elorn and Aulne mouths (cf. Fig. 3). c) Some questions and expected results for the final part of PACTE project after the modelled-data validation and intercomparison.

WP 2: Geomorphological and landscape changes (coord. J. Goslin and C. Lambert)

What are the main landscape transformations (vegetation, geomorphology, sediment flux) influenced by climate variability (precipitation, storminess, flood) and human activities over the past centuries?

2.1. Bathymetry and sediment core retrieval

a. Objectives

High-resolution **bathymetric and seismic surveys** will be conducted in the two main estuaries of the Aulne and Elorn (Fig. 3) with for objectives: i) to reconstruct a general stratigraphic framework of the sedimentary infilling of the two estuaries, ii) to ensure that the new cores will be recovered at the most appropriate locations as well as iii) to provide field-based data to the modelling part (WP 4; Fig. 2a). Bathymetric surveys will be made along a limited

number of transversal sections from upstream to the mouth of the estuaries. Bathymetric data in the shallower areas will be completed by the freely available Litto3D data. Sedimentological-geochemical data will allow evaluating major variations in runoff intensity (i.e. linked to vegetation cover and/or climate conditions) and pollution events, and will provide insights on past modifications in soil-use and vegetation cover (i.e. forests, hedgerows, cultures).

b. Methods

Bathymetry and seismic surveys - The surveys will be achieved using the coastal research vessel *Haliotis* for which a **proposal** will be submitted to the **CNFC (French national committee for the coastal oceanographic fleet)** in **January 2022**. The *Haliotis* is an oceanographic vessel (10 m long) specifically designed to work in shallow waters (down to 1-meter depth), ensuring an accurate imaging of estuarine bathymetries. Bathymetric data will be obtained by an interferometric lateral sonar allowing the simultaneous acquisition of bathymetric data and acoustic imagery of the seabed. These data will be processed using the Ifremer's software GLOBE (Global Oceanographic Bathymetry Explorer) in collaboration with the Ifremer's technical teams. Seismic data will be obtained on-board by the CHIRP sediment sounder. Data will be processed and corrected with in-house available routines (noise reduction, correction of boat movement, correction of tide effect) and further interpreted in the Kingdom-suite software environment.

Cores retrieval – New cores will be obtained at the **Elorn and Aulne mouths** (Fig. 2b) using lightweight portable **vibracoring** equipment deployed from a coring raft (equipment available at Ifremer). This consists of a vibrating needle attached to 80 mm irrigation aluminium pipes of up to 6 m length. This method allows retrieving multi-meter cores in one take in fine-grained environments with limited compaction (no re-entry, thus ruling out any chance of collapse of the coring hole by creeping). In order to ensure that the sedimentary interfaces are retrieved undisturbed, vibracores will be doubled by **interface cores**. These cores will complete the set of already available sediment cores in the Brest Harbour as well as in Elorn and Daoulas estuaries, while the Aulne estuary has never been studied yet (Fig. 3).

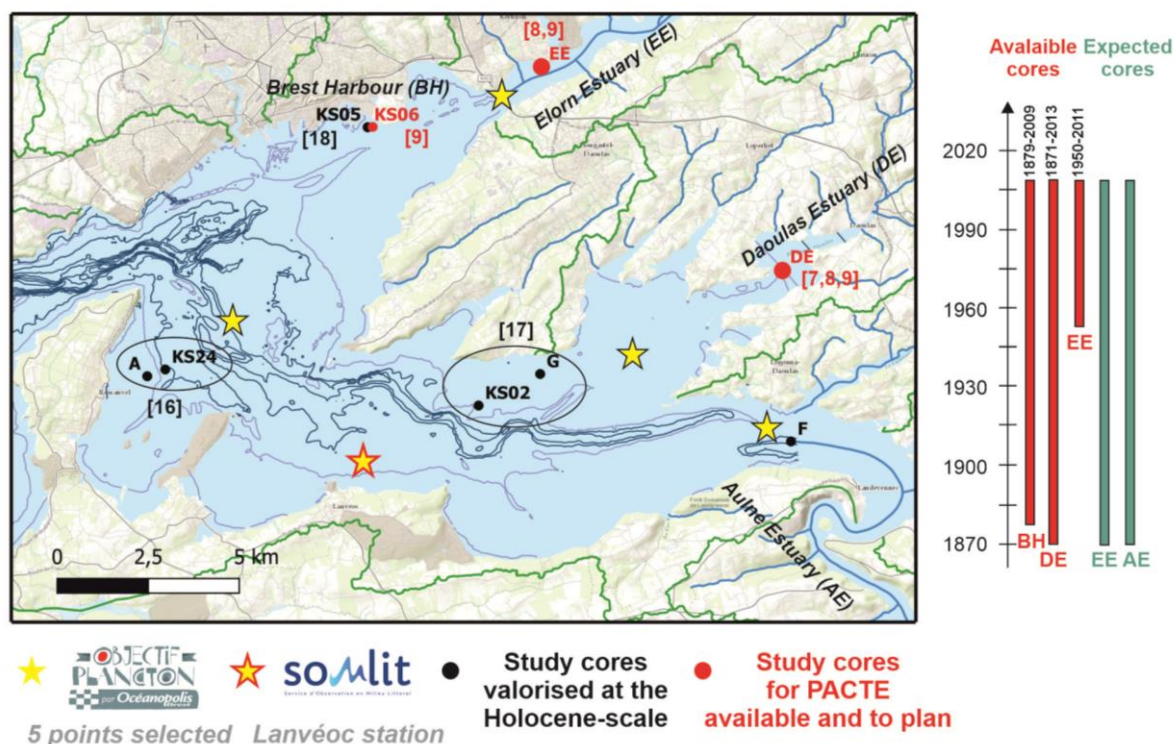


Figure 3: Map of the BoB (watersheds underlined in green, rivers in blue, and 10 m isobaths) evidencing the different coring sites studied for Holocene (in black) and Anthropocene reconstructions (in red, this project). Only DE coring site has been studied from a pluri bio-indicator approach. No study has been performed in the Aulne estuary and only sedaDNA analyses have been performed at the BH and EE sites (cf. Fig. 2b).

Core analysis – Cores will be analysed using in-house Ifremer and IUEM facilities. Major and trace elements will be determined using an X-ray fluorescence (XRF) core-scanner at a 1 mm resolution to determine major and trace elements. Following a treatment of sediment with 1N Hydrochloric acid (HCl) and 30% Hydrogen Peroxide (H₂O₂) to respectively remove carbonates and organic matter, grain-size will be measured every 1 cm using a Malvern Mastersizer laser granulometer. The **chronological framework** will be obtained by the use of ²¹⁰Pb and ¹³⁷Cs

(gamma spectrometry, Univ. Bordeaux, S. Schmidt) for the upper parts of the cores (the last century) and radiocarbon dates (AMS-¹⁴C) for their lower parts in case their base is older than the temporal coverage of the radionuclides. A geochemical approach (Pb, Sn, Hg, Zn concentrations and ²⁰⁶Pb/²⁰⁴Pb, ²⁰⁷Pb/²⁰⁴Pb, ²⁰⁸Pb/²⁰⁴Pb isotope ratios) will be used to **trace and quantify pollutions** with different origins (e.g. mining wastes, paint residues), in collaboration with the company SEDISOR (S. Révillon).

2.2. Pollen analysis

a. Objectives

Organic microfossils or **palynomorphs** (mainly pollen grains, spores and dinocysts) will be observed from the same palynological slides, thus allowing direct **land (paleo-landscape) - sea (paleohydrology)** correlations. Pollen assemblages are expressed as percentages or concentrations (number of individuals.cm⁻³), fluxes (number of individuals.cm⁻².yr⁻¹) and diversity indexes. This will be conducted on all cores (EE and KS06; new EE and new AE; Figs. 2b and 3). In addition, water samples will be analysed for their pollen content to increase knowledge regarding palynomorph fluxes in estuarine waters according to weather and sea conditions. For this, PACTE will benefit from the **participatory science program “Objectif Plancton”**, coordinated at the IUEM by P. Pondaven, in partnership with the “*Amicale des Plaisanciers des Marinas de Brest*” (APMB), IUEM and Ifremer. Note that five sampling locations have been determined in the framework of PACTE (yellow stars in Fig. 3). This operation aims at collecting planktonic data to study BoB coastal ecosystems through a long-term observation system with **three seasonal sampling campaigns** (April, June and September) of **BoB surface waters**. This modern pollen monitoring will be completed by the retrieval of surface sediments at the **Lanvéoc station** (yellow star surrounded in red in Fig. 3) a CNRS-INSU national research program SNO (*Services Nationaux d’Observation*) - SOMLIT (i.e. environmental, physical, and biogeochemical parameters currently registered on a bi-monthly basis in the framework of long-term monitoring survey at 2 sites in the BoB including the Lanvéoc station since 2010). The Lanvéoc station is generally used to study for the **benthic compartment** (microphytobenthos analysis).

b. Methods

The palynological protocol performed at IUEM-LGO will follow the international standardized procedure (https://www.epoc.u-bordeaux.fr/index.php?lang=fr&page=eq_paleo_pollens). Each sample of approximately two cm³ will be sieved at 150 µm and the fraction below 150 µm will then be processed with different stages of acid treatments (HCl and HF). The final residue will be mounted using glycerine jelly between slide and coverslip for pollen observation under a light microscope at X630 to X1000 magnification. An average of 300 pollen grains per sample will be counted after identification according to photographic atlases [19].

WP 3: Shifts in biological communities (coord. R. Siano and J. Sutton)

Do ancient protist community shifts coincide with hydrological perturbations of the BoB (e.g. fluvial and hydrodynamic processes, temperature and salinity changes, nutrient fluxes, eutrophication, and pollution)? Are the observed biological changes synchronous at the macro-scale of the BoB (Elorn versus Aulne watershed)?

3.1. Dinoflagellate cysts

a. Objectives

Dinocyst assemblages, concentrations, fluxes and diversity indexes will be conducted on all available cores (EE and KS06; new EE and new AE; Figs. 2b and 3). Cores KS06 and EE also benefit from paleogenetic analyses for protist community changes such as was done on core DE in the Daoulas Bay [9]. PACTE will therefore deliver a **synthesis on both “traditional” (palynology) and “innovative” (DNA in ancient sediments)** approaches based on the corpus of acquired paleoecological information. In addition, current monitoring evoked for pollen grains (*Objectif Plancton* samples and Lanvéoc Somlit-station) will also be conducted for dinocysts.

b. Methods

The palynological protocol for dinocyst extraction is the same as the one described for pollen grains. The final residue will be mounted using glycerine jelly between slide and coverslip for dinocyst observation under a light microscope at X400 to X630 magnification. An average of 300 dinocysts per sample will be counted after identification according to taxonomic atlases [20]. We also point to the **review on the dinocyst proxy** written by the PACTE PI for the 60th anniversary special volume of the *Revue de Micropaléontologie* [10]. This article reports how dinocysts were discovered, defined, and how they are generally applied in (paleo)ecological studies.

3.2. Siliceous paleo-reconstructions

a. Objectives

The assemblages of diatoms, marine organisms composed of intricate silica (SiO₂) skeletons, are very sensitive to environmental changes. Diatom species assemblages, biogenic silica (bSiO₂; wet alkaline digestion) and total Si (HF digestion) will be analysed on PACTE cores [21]. This will enable the quantification of the **ratio bSiO₂ versus total Si as a proxy for land-use change** [21].

b. Methods

Chemical (several steps using 1–5% NaPO₃, 10% HCl, and 30% H₂O₂) and physical (sieving at 20, 45, 63, 150 μm) will first be performed before microscope identification. Between 400 and 600 individual diatom valves will be morphologically characterized using microscopy (optical and scanning electron). Valve and fragment counting [22,23] as well as taxonomic references [24] will use established methods. Morphological characterization of diatom taxa is currently conducted in the CNRS-INSU national research programs SNO: **SOMLIT** (cf. section 2.2.a) and **PHYTOBS** (i.e. phytoplankton and microphytobenthos species determined and quantified in the water column and at the sediment surface) [25]. Sediment samples will also be geochemically characterized for bSiO₂ and total Si using the analytical facilities at the IUEM (“PACHIDERM” platform).

3.3. Benthic foraminiferal communities

a. Objectives

Foraminifera are unicellular eukaryotes, which can produce **skeletons of calcium carbonate** (CaCO₃) or **agglutinated** (chitinous organic matter and mineral grains). Assemblages of benthic species are associated with particular environmental conditions [26], depending on different parameter fluctuations as dissolved oxygen, organic matter [27], potentially toxic elements [28], salinities, or suspended matter load. Benthic foraminiferal assemblages, concentrations, fluxes and diversity indexes will be conducted on core KS06 as well as new EE and new AE cores (Figs. 2b and 3). In addition, other parameters (e.g. clustering for the identification of ecological groups, rank/frequency analysis, rates of morphological abnormalities) can be reconstructed to identify different **drivers (natural or anthropogenic)** and to **specify deterioration/restoration phases**.

b. Methods

Sediments will be washed on a sieve column to extract the specific grain-size fractions for foraminifera (63–125 μm and 125–500 μm). Each residue will be split to get a fraction of at least 300 benthic foraminiferal specimens that will be identified and counted. Specific identifications will be conducted according to reference publications and to the foraminiferal collection available at UBS (University of South Brittany). For each species, the state of conservation and the level of deformation will be specified.

3.4. Sedimentary ancient DNA (sedaDNA)

a. Objectives

Metabarcoding (analysis of barcode gene of taxonomic diversity) of sedaDNA will allow biodiversity analyses of protist paleocommunities on the new core collected at the Aulne River mouth (Figs. 2b and 3). Those data will be compiled with already available data for the Elorn and Daoulas rivers, as well as the Brest Harbour, to validate the hypothesis of the irreversible shift in protist community and species in the BoB that occurred after World War II and agricultural pollution [9]. Metagenomic analyses (analysis of barcode gene of functional diversity) on sedaDNA will be performed on the new collected core to test whether human pollution caused the emergence of new functional community (i.e. heterotrophs vs. autotrophs). Paleo-genomics data will be calibrated in time and compared to contemporary environmental data to assess: i) shifts in plankton community diversity and their anthropogenic drivers, ii) the emergence of novel functional biodiversity traits following ecosystem variations, iii) long-term dynamics of invasive species and biodiversity decline. Paleogenetic analyses in the BoB will be contextualised in the framework of the **TREC expedition (TRaversing European Coastline, 2023-2024)** led by EMBL and co-organised with Tara Foundation, Ifremer and EMBRC during which about **30 cores** will be collected in **polluted** (industrial, agricultural and WWII impacted sites) and **pristine European coastal sites**. This comparison will allow understanding if pollution-driven biological shifts observed in the BoB are a **common or unique pattern in the European context** across the last centuries.

b. Methods

SedaDNA will be extracted from sediment layers of the new core collected at the Aulne river mouth (ca. 100 samples for 1m core) using protocols previously validated [8,9] and applying specific precautions to avoid contamination with contemporary DNA (in the absence of a dedicated for ancient sedaDNA extraction in Brest, a special clean (RNA-free) laboratory at Ifremer will be dedicated to these analyses throughout the project). If possible, the same core used for dating, sedimentological and other bio-indicator analyses will be used. Otherwise, specific twin cores will be collected for paleogenetic analyses and dated to be comparable with other results. The amplification of the V4rDNA barcode region and an Illumina-MiSeq sequencing of the amplicons will be performed for metabarcoding analyses of protist communities [9]. In addition, qPCR analyses will be performed on ancient DNA extracts to detect long-term dynamic of toxic species (e.g. *Alexandrium minutum*) [8]. Shotgun sequencing of sedaDNA will be performed to allow metagenomic analyses of both eukaryotic and prokaryotic past communities. This task will be carried out in collaboration with the **University of Copenhagen (pioneer laboratory for ancient DNA study)**, using validated and robust protocols for this scope.

3.5. Statistical analysis

a. Objectives

Statistical analyses will be conducted for the detection of **tipping points** in paleoecological data. A first work between the LMBA (*Laboratoire de Mathématiques de Bretagne Atlantique*) and LGO was undertaken between May and September 2021 through the co-supervision (P. Ailliot and J-M. Derrien from LMBA and A. Penaud) of a 4th year engineering school internship (Anna Kerebel, INSA, Rennes): "*Analyse temporelle de series paléoécologiques*". This work, conducted in a statistical parametric framework (Gaussian case), allowed discussing the significance of a rupture according from a dedicated algorithm applied to the 1850 to present BoB paleoenvironmental data [7].

b. Methods

This first work opened perspectives for exploring methods of rupture detection in non-parametric settings and with multivariate analysis. Indeed, some of the time series are non-stationary with the presence of trends (e.g. related to climate change) and breaks (e.g. related to human impacts). Statistical tools and methods will be proposed to model the non-stationary components by focusing on the detection of breaks. In addition, analysis of relationships between time series will be performed. Since time series are highly dependent on both anthropogenic pressures and long-term climate variations, we will seek to model these relationships with regression or multivariate time series models and try to separate each of the effects.

WP 4: Modelled-data comparison (coord. M. Raimonet and Y-M. Paulet)

What is the socio-ecosystemic trajectory, or propagation of impacts along the land-sea continuum, in response to climate variability and direct anthropization? Can we understand human-environment interactions in a pilot site?

4.1. Instrumental data

We will gather data from **local observatory surveys** (e.g. temperature, salinity, nutrient concentrations, dissolved oxygen, phytoplankton biomass; SNO-SOMLIT and SNO-PHYTOBS), **participatory sciences** (*Ecoflux* and *Objectif Plancton*), and **national observatories** (e.g. AELB, *Banque Hydro*, REPHY, SAFRAN). We previously evoked that, in addition to the regular methodologies deployed at the Lanvéoc-SOMLIT station, surface sediments will also be collected to investigate present-day microfossil deposits in the BoB and their evolution on several years. This will additionally allow us to accurately understand proxies used for BoB sediment reconstructions in sediment cores.

4.2. Historical archives

a. Objectives

We aim at producing a detailed **chronicle of the evolution of human activities and modes of exploitation of natural systems** over the two centuries around the BoB. This historical work will focus on **maritime** (i.e. mainly fisheries and aquaculture), **fluvial**, **agricultural** and **industrial activities**. In parallel, the historical research will document **climate events** (storms, extreme temperatures, floods), at regional and global scales, either because they are **reported** (press and various chronicles) or **naturally recorded** (e.g. dendrochronology, sclerochronology). This will consist in a chronological frieze of the BoB and its watersheds: a tool linking a database to its spatial

representation. A series of **hypotheses, confirmations, and refutations** will be proposed to **interpret human activities and natural systems**, integrating **feedback loops**.

b. Methods

The extent of the field requires a **multi-dimensional methodological approach**. The archives of the SHD (Brest, Paris-Vincennes), administrative and scientific reports, and departmental archives of Finistère will constitute a first solid basis. The "agriculture" and "industry" series and sub-series of the departmental archives will allow us to link these activities. Meteorological, hydrographic and oceanographic data will be sought in the archives of specialized services (Météo-France, Shom). Finally, digitized regional newspapers (*La Dépêche de Brest* and *Ouest Éclair*) will be consulted. Inconsistencies arising from conflicting reports will be carefully studied to ensure the reliability of the historical sources. As part of the Brest archives was destroyed by bombing during WWII, the memory - still uncaptured - of many actors of the BoB will be requested, through the **enrichment of a participatory digital platform**, launched on November 2021 (historade.fr; [Appendix 2](#)), by Lucas Bosseboeuf (ongoing UBO PhD since October 2021), Laurence David (CNRS mapmaker-geographer), Yves-Marie Paulet (Biologist at UBO) and Philippe Jarnoux (Historian at UBO). This **participatory website** aims at: i) collecting data from scientists and BoB inhabitants, and ii) introducing the history of BoB to a wide audience. This task is already supported by the ZABrI, CNRS, IUEM, UBO, and the regional archive units (SHD, CRBC, Departmental archives of Finistère).

4.3. The modelled land-sea continuum

a. Objectives

The objective is the development of a **land-sea continuum model** adapted to the macrotidal estuarine-coastal site of the BoB, first by using current environmental data and second by running model-data intercomparisons with the paleo-reconstructions. Even if such modelling approaches have already been developed [29], the **intercomparison between paleoreconstructions and modelling outputs is the most original and “risky part”** of the project. A selection of model outputs will be studied along the land-sea continuum for the studied period: e.g. streamflow, water temperature, nutrient (N, P, Si) concentrations, ratios and fluxes, oxygen concentrations, suspended particulate matter, phytoplankton biomass (e.g. diatoms and dinoflagellates). **New integrative indicators**, such as the eutrophication index B_ICEP [30], will be tested and calculated from model outputs. Two main deliverables are: i) **cross-validation** of paleo-reconstructions and land-sea modelling indicators before and after WWII, ii) **land-sea continuum trajectories** after WWII with a retrospective analysis of river and estuarine ecosystem functioning and forcing drivers. If successful, these **proxies have the potential of powerful tool to “validate models”** in coastal systems over **past periods with no instrumental datasets**. After PACTE, the land-sea model may be used to simulate alternative scenarios of future socio-ecosystemic trajectories.

b. Methods

First, we will perform an implementation of a land-sea physical-biogeochemical model for the BoB and its two main watersheds (Aulne and Elorn), based on the coupling of river (RIVERSTRHALER) and marine (ECO-MARS3D, C-GEM) models. The historical run will be based on historical data (e.g. morphology, geology, land use, anthropogenic point sources, river flow, temperature, salinity, concentrations in nitrate, phosphate, silicate, oxygen, suspended matter, phytoplankton biomass...) and intercomparisons between model outputs and sediment paleoreconstructions. The choice of the models is related to recent advances in land-sea modelling [15]. Based on these developments, the river model pyNuts-Riverstrahler [12,13,29] will be coupled to the estuarine model C-GEM [14,15], both forced and validated by local datasets.

- **Before WWII:** For the pre-WWII scenario, the external constraints will be based on hydrometeorological reconstructions [31] or natural streamflow [32], forest land use, no fertilizer inputs. In the absence of data, the estuarine morphology will be considered as similar, while accounting for sea level rise. As a perspective, applying a model of morphological evolution could help accounting for morphological modifications, as recently performed for the Seine estuary [15,29].
- **After WWII:** The external constraints (e.g. meteorology, morphology, land use, geology, point sources, and diffuse sources) will be extracted from data gathering of historical archives, literature and instrumental data to characterize spatial and temporal dynamics. The estuarine morphology will be constrained by in situ measurements: i) campaign to be asked to the CNFC to define the geometry of the estuaries and ii) Litto3D (Shom). Aquatic variables (streamflow and water quality) will be used for validation.

2.2 Team involved in PACTE

Name	First name	Position	Role & responsibilities in PACTE	Existing collaboration or new one. If PACTE PI collaborates with the team, projects led by the team members are mentioned
PENAUD	Aurélie	Lecturer	<i>PI Coordinator of PACTE - Marine palynologist - Co-supervision of PACTE PhD</i>	
GOSLIN	Jérôme	Researcher	Resp. of WP2. Will co-supervise the bathymetric, seismic, and coring campaign with A. Ehrhold	Ifremer project « Historical human occupation of watersheds and terrigenous inputs to the environment » (2020-2021)
EHRHOLD	Axel	Researcher	WP2. Will co-supervise the bathymetric, seismic, and coring campaign with J. Goslin.	Ifremer project « Paléo-Écologie et Paléo-environnement du maërl en Bretagne à l'holocène » (2019-2021)
VIDAL	Muriel	Lecturer	WP2. Palynologist (pollen grains), Co-supervision of PACTE PhD.	ISblue-Emergence « Dynamics of anthropisation of coastal environments in North Brittany: Pollen and ancient DNA from the end of the Mesolithic to the present day » (2021-2022)
LAMBERT	Clément	Lecturer	Resp. of WP2. Palynologist (dinocysts and pollen grains)	UBS project « Potential of dinoflagellate cysts to trace the dynamics of toxic microalgal blooms » (2020-2021)
REVILLON	Sidonie	Researcher	WP2. Geochemist. Head of SEDISOR company.	New collaboration
XXXXXXXXXX	XXXXXX	Assistant Engineer	Development of the palynological-micropaleontological technical platform. Banking of PACTE data in local databases.	To be recruited in 2022 by Univ. Brest (UBO)
SCHMIDT	Sabine	Researcher	WP2. Specialist of radionuclides and sediment dynamics in the water column and sediments	Regular radionuclide determination (²¹⁰ Pb, ¹³⁷ Cs) for dating purpose with PACTE PI
SIANO	Raffaele	Researcher	Resp. of WP3. Specialist in paleogenetics	Ifremer project « Paléocéologie de Alexandrium Mnutum en RAd de Brest » (2017-2018)
MERTENS	Kenneth	Researcher	WP3. Expert on dinoflagellates	New collaboration
SUTTON	Jill	Lecturer	Resp. of WP3. Non-traditional stable isotope biogeochemist - Co-supervision of PACTE PhD.	New collaboration
LEYNAERT	Aude	Researcher	WP3. Specialist on the marine silicon cycle.	New collaboration
DELEBECQ	Gaspard	Engineer	WP3. Phytoplankton taxonomy and physiology, in charge of diatom taxonomy for PACTE	New collaboration
PONDAVEN	Philippe	Lecturer	WP3. Specialist in marine ecology and biogeochemistry, coordinator of the participative science programme "Objectif Plancton".	New collaboration
GOUBERT	Evelyne	Lecturer	WP3. Micropaleontologist (benthic foraminifera)	UBO-UBS project CLINE "Holocene Climate changes and anthropic dynamics since the Neolithic period in Southern Brittany" (2020-2023)
PAULET	Yves-Marie	Lecturer	Resp. of WP4. Ecophysiological - Co-supervision of the IUEM-CRBC PhD in History with P. Jarnoux.	UBO project Histo-Rade "Trajectory of a Socio-Ecological system at the land-sea interface: Case of the Rade de Brest from the 18th century to the present day" (2021-2024)
RAGUENEAU	Olivier	Researcher	WP4. Specialist of inter- and trans-disciplinary works along the land-sea continuum.	HDR for Clément Lambert PhD co-supervised with A. Penaud and M. Vidal (2014-2017)
RAIMONET	Mélanie	Researcher	Resp. of WP4. Specialist of the land-sea continuum through modelling approaches	New collaboration
JARNOUX	Philippe	Lecturer	WP4. History Professor at UBO, specialist of the Bay of Brest recent history. Co-supervision of the IUEM-CRBC PhD with Y-M. Paulet.	New collaboration
AILLIOT	Pierre	Lecturer	WP3. mathematical statistics	New collaboration started in 2021 in the framework of a M1 internship co-supervision
DERRIEN	Jean-Marc	Lecturer	WP3. mathematical statistics	New collaboration started in 2021 in the framework of a M1 internship co-supervision
ROUAN	Mathias	Research engineer	Head of « Indigéo » research infrastructure database at IUEM	New collaboration
PRESSAC	Jean-Baptiste	Researcher	Structuring, processing and analysis of databases at Brest University	New collaboration

3 - Expected outcomes

3.1 Expected follow-up of the project

PACTE is in line with societal expectations - The BoB is rich in diversified economic activities (e.g. shellfish farming, fishing, and recreational activities), and the established partnership with local managers (SBE, EPAGA, PNRA, *Océanopolis*) will ensure scientific discussion and export of main results to a wide audience. The stakeholder committee ([Appendix 1](#)), including non-academic members, will meet annually with the PACTE research team, to co-construct an integrated understanding of the BoB socio-ecosystem, useful for risk assessments and the development of remediation strategies. In this framework, PACTE results will directly enrich the **program “Contrat de Rade de Brest” (pre-diagnostic done in November 2021) carried out by Brest Metropole, SBE-Elorn and EPAGA-Aulne, in particular the theme related to the long-term perspective of the BoB socio-ecosystem (coord. A. Penaud).**

Scientific valorisation of PACTE - Scientific manuscripts will be submitted to **high impact international and open-access peer-reviewed journals** and subsequently posted on the **HAL platform** and **professional networks**. We also plan to **create a Peer-Community In ([Appendix 3](#))** journal dedicated to land-sea interdisciplinary approaches that we would untitled **“Anthropocene socio-ecosystems”**.

Dissemination of the scientific knowledge - PACTE PI is co-coordinator of the **“communication and scientific mediation”** working group for ZABrI (2021-2025), dedicated to "internal" and "external" communication for the ZABrI. In this framework, PACTE will contribute to: i) the **strengthening of the ZABrI website with PACTE results**, ii) **scientific culture events and exhibitions** (*Fête de la Science, Nuit Européenne des Chercheurs, 70.8* described in [Appendix 4](#)), iii) **innovative tools in scientific outreach**. As an example for point ii), a filmed conference of R. Siano and A. Penaud will take place in the *Océanopolis* auditorium in 2022 to present results from [7], [8] and [9]. Regarding point iii), the project "Evol'Iroise", currently underway at IUEM, is a 55" digital and interactive scientific poster that can present multi-format information, constituting a stimulating educational experience for scientific culture events and student training. This innovative tool will be enriched with PACTE results. The retrospective perspective of PACTE could also be disseminated to high school students within the participatory project ECOFLUX-Bretagne that studies water quality at Aulne and Elorn river outlets.

Data Management Plan - All compiled-acquired data of WPs 2-3 (Fig. 2) will be stored in the **IUEM “Indigéo” database** [33]. Also, in order to meet the challenges of Open Science, the digitized historical data of WP 4 (Fig. 2) will be deposited in the **Nakala research data repository of the TGIR “Huma-Num”** and published according to the FAIR (Findable, Accessible, Interoperable, Reusable) data principles.

3.2 Impact of the project on ISblue training

International events are planned to establish collaborations with teams working on socio-ecosystemic trajectories worldwide, and to take advantage of this opportunity to bring undergraduate and PhD students as well as young and senior researchers willing to share knowledge and to experiment new interdisciplinary practices. We plan to invite professors for teaching sessions and student-doctors to a **thematic school on coastal socio-ecosystem trajectories** at the IUEM (July or August 2024). PACTE PI and WP coordinators will promote PACTE results by proposing sessions at national and international conferences about **“transdisciplinary approaches to discuss the land-sea continuum with a socio-ecosystemic long-term perspective” ([Appendix 5](#))**. In addition, we plan an **international conference** at the IUEM on coastal socio-ecosystem trajectories at the IUEM (July or August 2025) at the end of the project, with a large diffusion taking advantage of the well-identified disciplinary networks including associations, diffusion lists ([Appendix 5](#)), in addition to the information that will be transmitted through the eLTER-ILTER networks. In addition, scenarios of PACTE results will be proposed for IUEM undergraduate students to enrich the project "Evol'Iroise" but also to enrich audiovisual clips related to ZABrI studies in the framework of the ISblue training module “CAMERA” (coord. I. Peuziat) that will be proposed during the inter-semester period dedicated to transverse formations between Master students at the IUEM.

4 - Resources and budget

If PACTE is funded, the project will start by **recruiting a PhD student in October 2022**. PACTE will last from 2022 to 2025 and will end with an international conference at the IUEM. The PACTE PI and her collaborators will also apply for other research-based funds during the duration of the project (e.g. CNFC for the bathymetry-coring mission, ANR, IUEM for M2 internship funding, ISblue, *Région Bretagne*, UBO...). Furthermore, we are expecting the recruitment of an UBO engineer dedicated to physical and chemical separation from the sediment of foraminifera, diatoms and palynomorphs in 2022. For this reason, we do not mention this need in the following budget. The engineer will also be in charge of the storage of data in the Geographic Data Infrastructures. This will permit to connect local databases (IUEM, CRBC) with other open access platforms in interaction with the RI Data Terra, following the INSPIRE European norm to ensure that all the data produced in the project will be Findable, Accessible, Interoperable and Reusable (FAIR), and identified with a doi under appropriate licence.

Start: February 2022; End: December 2025	2022				2023				2024				2025											
Months (1 column = 2 months)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
Kick-off meeting with SC																								
Proposal to be submitted to the CNFC																								
Bathymetric-seismic-coring campaign																								
PhD : Historical archives (ongoing, 2021-2024)																								
PhD: Fossilized bio-indicators (2022-2025)																								
M2 - Benthic foraminiferal analysis																								
M2 - Mathematical statistics																								
PostDoc Paleogenetics																								
PostDoc River and estuarine models																								
End PACTE's first year with SC																								
International thematic school at IUEM																								
End PACTE's second year with SC																								
International conference at IUEM																								
End of PACTE's project with SC																								

SC: Stakeholder Committee ; CNFC: *Commission Nationale Flotte Côtière* ; thematic school and conference on coastal socio-ecosystems

Funded

PhD 1 (WP4). *“Trajectory of a Socio-Ecological system at the land-sea interface: Case of the Bay of Brest from the 18th century to the present day”*. EDSML-UBO; **2021- 2024**; co-supervised by Y-M. Paulet and P. Jarnoux. **120 k€**

Co-funding to be sought alongside ISblue funds

Master 2 (WP3): 2 X Master 2 internships SML-IUEM (**2023 and 2024**) for benthic foraminiferal determinations co-supervised by E. Goubert and PACTE PhD (2022-2025). Internship gratification will be asked to LGO and IUEM resources (e.g. transverse axis *“Historical dynamics”*). **8 k€**

International thematic school + International conference: these are planned in the following budget. However, in order to encourage the participation of junior researchers, without any fees, complementary funding will be asked to different calls (ISblue, CG29, UBO, laboratories) in order to organize these international meetings at IUEM. **5 k€**

ANR Project MOQQA: *“Modelling land-sea ecosystem trajectories through qualitative and quantitative approaches for eutrophication issues”*. Submitted to ANR JCJC in October 2021, 48 months. **340 k€**

Funding sought from the ISblue Flagship program: 408.22 k€

1. Staff expenses: 308 k€

PACTE PhD (2022-2025, WP2-WP3). With an expertise in sedimentology and micropaleontology-palynology that will be co-supervised by A. Penaud, J. Sutton and M. Vidal, with the help of C. Lambert and E. Goubert (both from UBS) = **120 k€** for the acquisition of (paleo)reconstructions from sediment cores (sedimentological and geochemical data, palynological tools: pollen and dinocysts, diatoms).

Post-Doc (2023-2025, WP3): 24 months for paleogenetics (**Aulne sediments**) = **90 k€**

Post-Doc (2023-2025, WP4): 24 months for the validation of the river and estuarine models on Aulne and Elorn systems for a reference period (2000-2010) and application to the historical period (before and after WWII) = **90 k€**

Master 2 (2023 and 2024, WP3): 2 X Master 2 internship LMBA-IUEM for mathematical statistics with P. Alliot and J-M. Derrien = **8 k€**

2. Instruments and material costs, including scientific consumables: 48.82 k€

LEICA (WP3): Acquisition of two X40 oil immersion objectives for Leica microscopes = **11.39 k€** ; Maintenance contract with LEICA for the microscopes: 2 maintenance phases over the 3 years of PACTE (in 2023 and 2025) = **2.93 k€**

Computer (WP4): High performance computer for numerical models = **3.5 k€**

Computer (WP2-WP3): for PACTE PhD = **1.5 k€**

Microfossil analysis (WP3): palynology 15 €/sample X 100 = **1.5 k€** // benthic foraminifera 5 €/sample X 100 = **0.5 k€** // silica analyses 5 €/sample X 100 = **0.5 k€**

Paleogenetics (WP3): x 100 samples (sedDNA extractions **10 k€** (100€ per sample), V4 rDNA region amplification and qPCR (**2 k€**), metabarcoding (1 run Illumina MiSeq subcontracting at GenoToul Toulouse, **4 k€**), metagenomics (1 shotgun sequencing at the University of Copenhagen **5 k€**) = **21 k€**

Database (WP1): Contribution to development/maintenance of the database infrastructure “*Indigéo*” = **6 k€**

3. Outsourcing and subcontracting: 51.4k€

EPOC (WP2): Radionuclide dating: 44 €/sample X 100 = **4.4 k€**

AMS-¹⁴C (WP2): 275 €/sample X 20 at Poznań = **5.5 k€** (or via ARTEMIS)

SEDISOR (WP2): Trace metal concentrations and Pb isotope ratios: 160€/sample X 100 = **16 k€**

BTU (WP2-WP3-WP4): University Translation Office at UBO for article correction: 5 X 500 = **2.5 k€**

Conferences (WP2-WP3-WP4): National conferences 2023–2024–2025: 6 X 500 = **3 k€**; International conferences 2023–2024–2025: 6 X 2000 = **12 k€**

Meeting (WP1): Kick-off meeting with PACTE SC (25 people) – October 2022 = **0.5 k€**

End of first year (WP1) with PACTE SC (25 people) – October 2023 = **0.5 k€**

International thematic school at IUEM (WP1) (50 people) – July or august 2024 = **2 k€**

End of second year (WP1) with PACTE SC (25 people) – October 2024 = **0.5 k€**

International conference "Coastal and estuarine socio-ecosystem trajectories" at IUEM (WP1) (200 pers.) - July or august 2025 = **4 k€**

Project ending (WP1) with PACTE SC (25 people) – October 2025 = **0.5 k€**

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Appendix 1

Name	First name	Position and Professional affiliation
LIRET	Céline	<i>In charge of Scientific and Cultural Mediation at the Océanopolis Museum, Brest, the third-most visited ocean discovery park in France</i>
NICOL	Pascale	<i>In charge of Scientific and Cultural Mediation at 70.8, gallery of maritime innovations museum, located at The Ateliers des Capucins, Brest</i>
LEGAC	Nolwenn	<i>Agricultural Affairs Officer (CA) at the Public territorial development and management board of the Elorn river (SBE-Elorn)</i>
REY	Nathalie	<i>Director (NR) and Environmental Studies Officer (XB) at the Public territorial establishment of the Aulne watershed (EPAGA-Aulne)</i>
BADE	Xavier	
LARZILLIERE	Agathe	<i>Biodiversity Officer at "Parc Naturel Régional d'Armorique" (PNRA) encompassing all of the upstream watersheds of the Bay of Brest</i>
FLOC'H	France	<i>Lecturer at UBO and coordinator of UBO-IUEM's ISblue graduate school's training and research programme (Theme 3) "Sustainable coastal systems"</i>

Stakeholder committee planned to participate in PACTE over the 2022-2025 project.

Appendix 2

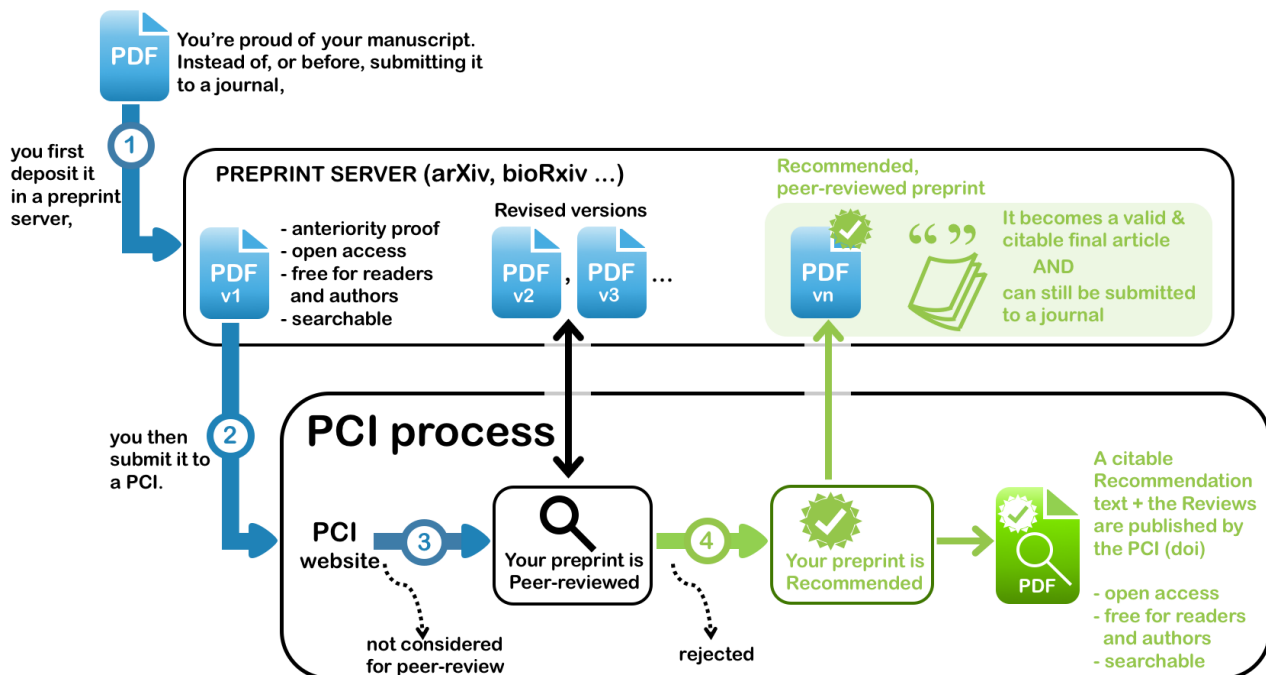


The illustration displays a part of the front page, accessible at the following address: historade.fr.

Appendix 3

Peer Community In: A free alternative to evaluate, validate (and publish?) preprints

The Peer Community in (PCI, [<https://peercommunityin.org/> | <https://peercommunityin.org>]) project offers an alternative to the current system of publication - which is particularly expensive and not transparent. PCI is a non-profit scientific organization building communities of researchers handling the evaluation of (through peer review) and recommending preprints in their scientific field. Each PCI is a group of several hundred recommenders playing the role of editors who recommend such preprints based on peer-reviews to make them complete, reliable and citable articles, without the need for publication in 'traditional' journals (although the authors can submit their recommended preprints afterwards). Evaluations and recommendations by a PCI are free of charge. When a recommender decides to recommend a preprint, they write a recommendation text that is published along with all the editorial correspondence (reviews, recommender's decisions, authors' replies) by PCI. The preprint itself is not published by PCI: it remains in the preprint server where it has been posted by the authors and can therefore be submitted to a journal and publish in Peer Community Journal, an open access diamond journal that PCI will launch, this fall. The first Peer Community in has been launched in 2017: Peer Community in Evolutionary Biology (PCI Evol Biol). PCI genomics was created two years ago. More than 1200 recommenders have already joined PCI Evol Biol, PCI Genomics, PCI Paleontology, PCI Ecology, PCI Animal Science, PCI Zoology, PCI Mathematical and Computational Biology, PCI Archaeology, etc. PCI won the 2020 LIBER award for library innovation of the European League of Research Libraries.



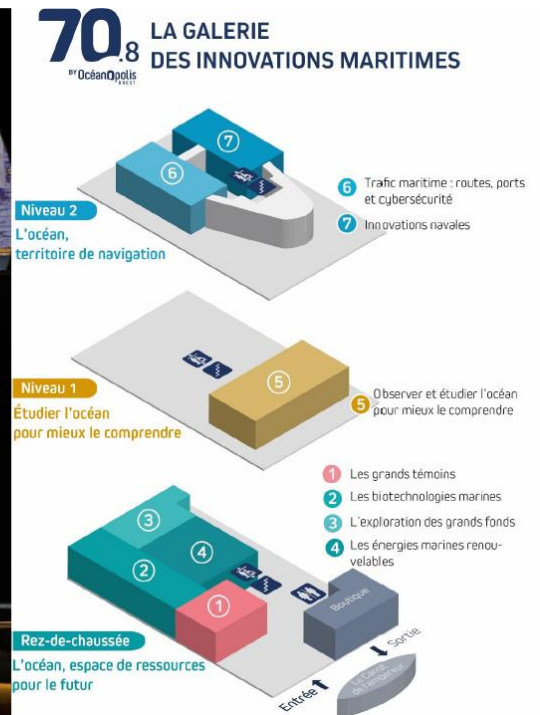
Appendix 4

“70.8”, gallery of maritime innovations, addresses three major themes around the Ocean: a resource space for the future, a navigation area, studying the ocean to better understand it.

Showcase of the World Campus of the Sea, it illustrates the maritime excellence of the territory in terms of research, technological development and innovation in certain fields. A space for science and innovation.

From marine biotechnologies to deep-sea exploration, maritime routes to the development of renewable marine energies, the means of transport of tomorrow to knowledge of the ocean through satellites, each major theme is illustrated by projects carried by partners including scientists and industrialists.

The Ateliers des Capucins are undoubtedly one of the finest examples of urban reconversion. Not so long ago, these buildings shook with the incessant din of machinery as they housed the shipbuilding workshops that have played such a large role in shaping the history of Brest.



Appendix 5

(Paleo)climate-Quaternary sciences

National: AFEQ list: afeq-cnf_inqua@groupes.renater.fr. AFEQ: *Association Française pour l'Étude du Quaternaire*.

International: CNF INQUA (via Johan Etourneau, in charge of international relationships for AFEQ). INQUA: International Union for Quaternary Research, next conference will be held in Roma in 2023.

Sedimentology

National: ASF conference is planned in Brest in September 2022. ASF : *Association des Sédimentologues Français*.

International: IAS Meeting of Sedimentology, next conference will be held in June 2023 in Dubrovnik, Croatia.

Palynology

National: L'APLF: laplf@listes.univ-brest.fr. L'APLF: *L'association des Palynologues de Langue Française*. PACTE PI is secretary of the association and holds the mailing list diffusion. Next conference MedPalynoS will be held September 2022, Paestum, Italy.

International: IFPS: International Federation of Palynological Societies. The international contact identified to transfer information between L'APLF and IFPS is Marie-Pierre Ledru.

Ancient sedimentary DNA

National: GDR GE "Génomique Environnementale" (<https://gdr3692.wixsite.com/gdrge>). Webseminar "DNA et al in paleoenvironments" April 2021 (<https://gdr3692.wixsite.com/gdrge/copie-de-webinars-unknowomics>).

International: The sedDNA scientific society: <https://sedadna.github.io/>: international network of sedDNA research.

Land-sea continuum modelling

National: RZA network: Réseau National des Zones Ateliers (CNRS-INEE)

International: ASLO : American Society of Limnology and Oceanography (scheduled meetings: Aquatic Sciences Meeting Palma de Mallorca, Spain, 2023 ; Ocean Sciences Meeting, New Orleans, Louisiana, USA, 2024; Aquatic Sciences Meeting, Charlotte, North Carolina, USA); iEMSs : International Environmental Modelling and Software Systems Society