

Anthropogenic pressures and Bay of Biscay nurseries: identification, spatial variations and synthetize representation

Solène Mora

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Anthropogenic pressures and Bay of Biscay nurseries: identification, spatial variations and synthetize representation

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Résumé étendu en français

Pressions anthropiques et nourriceries du golfe de Gascogne : identification, variations spatiales et représentation synthétique

Contexte

Les écosystèmes côtiers et estuariens comptent parmi les écosystèmes les plus productifs de la planète ayant une valeur écologique mais aussi économique importante. Ils assurent de multiples rôles, comme celui de nourriceries pour les juvéniles de nombreuses espèces marines. Mais ces écosystèmes subissent également de multiples pressions issues d'activités d'origine anthropique. Ces impacts peuvent être causés de manière directe par les activités de pêche, d'extraction de granulat, de clapage ou dus à des activités terrestres affectant par ruissellement les zones côtières. A cela s'ajoutent des pressions indirectes liées aux changements climatiques. Ces pressions vont modifier à l'échelle des populations, leur recrutement, leur croissance et leur abondance mais également à l'échelle des communautés, la biodiversité, la structure et le fonctionnement trophique.

Dans cette étude nous distinguons l'activité des pressions qu'elle engendre. Une pression est définie comme le mécanisme par lequel l'activité influence le milieu. Il est important de noter qu'une activité peut engendrer plusieurs pressions sur le milieu et qu'une pression peut être causée par plusieurs activités.

La compréhension des effets des pressions anthropiques sur les communautés marines nécessite de bien identifier, voire quantifier, les activités humaines et les pressions qu'elles engendrent. Une méthode pour quantifier ces pressions passe par la construction d'un indicateur global de pression. Cela permet de synthétiser les pressions anthropiques exercées, de les cartographier, de les classer et de comparer les différentes zones étudiées. Cela peut également être une aide à la décision pour la gestion intégrée des zones côtières.

Dans le cadre de la DCE (Directive Cadre sur l'Eau), un indicateur de pressions anthropiques a ainsi été établi en France mais il porte uniquement sur les eaux de transitions (estuaires et lagunes). Il y a donc un réel enjeu à étudier les pressions que subissent les nourriceries côtières. Notre étude vient compléter et continuer le travail commencé par Saulnier et al, (2017) et porte sur les six zones de nourriceries dans le golfe de Gascogne, identifiées lors de précédentes études.

Pour cette étude l'année 2014 a été sélectionnée comme année de référence pour évaluer l'impact des pressions anthropiques sur les nourriceries du golfe de Gascogne.

Objectifs

L'objectif de cette étude est donc d'identifier et quantifier les pressions anthropiques s'appliquant sur ces six zones de nourriceries et d'analyser leurs différences par la construction d'un indicateur de pression permettant d'estimer d'une part le niveau global de pression de chaque nourricerie et d'autre part, d'identifier les zones à forts enjeux anthropiques en cartographiant l'indicateur à l'échelle d'une nourricerie. Deux jeux de données (contamination chimique et pêche) seront notamment travaillés pour pouvoir inclure au mieux ces pressions dans notre étude.

Matériel et Méthode

Cinq pressions ont été retenues pour cette étude : l'extraction de granulat, la présence d'une espèce invasive (*Crepidula Fornicata),* le clapage, la pêche et la contamination chimique. Les trois dernières ont été plus particulièrement travaillées.
Les données de contamination ont été qualifiées, standardisées et normalisées. Deux ACP distincts ont été réalisés sur les métaux et les composés organiques. Les coordonnées sur le 1er axe ont été utilisées comme indicateur de contamination. Une extension spatiale de type buffer leur a ensuite été appliquée afin de représenter la réelle dispersion spatiale de la pression de contamination depuis le centre des estuaires.
Cette extension spatiale a également été appliquée aux points de clapage qui sans cette extension traduisent une pression appliquée aléatoirement en un point de la zone de clapage.
Les données de pêche sont issues de plusieurs jeux de données qui ont été travaillés afin de reconstituer le nombre de sorties des bateaux côtiers dans le golfe de Gascogne en 2014.
Les données des cinq pressions ont été transformées en indices et standardisées avant d'être incluses dans un indicateur global de pression.

Résultat et discussion

Notre étude avait pour but d'identifier, voire de quantifier, et synthétiser les pressions anthropiques s'appliquant sur les six zones de nourriceries du Golfe de Gascogne. Une grande part du travail a été investie pour développer un cadre méthodologique impliquant un travail conséquent concernant la sélection et le traitement des données. Dans le temps imparti nous avons réussi à proposer une approche basée sur des données âprement sélectionnées. Cette démarche a permis de livrer des premiers résultats. Un premier indicateur global de pression a été construit pour chaque nourricerie. Le niveau global de chaque pression a également été étudié dans chaque nourricerie. Les pressions de contamination et de pêche sont prépondérantes en termes de surfaces impactées et dans la contribution à l'indicateur global de pression. La Gironde et la baie de Bourgneuf apparaissent comme les deux zones les plus touchées par les cinq pressions sélectionnées. Le pertuis breton s'illustre quant à lui, en plus d'être la nourricerie la moins touchée comme étant la seule nourricerie où la pression dominante est la pêche.

Ces résultats sont cependant à nuancer au vu des choix effectués concernant les données, et les hypothèses de travail requises. Une étude de sensibilité devra également être conduite concernant la technique de spatialisation des données utilisée ainsi que la pondération des pressions dans l'indicateur. Les résultats de l'indicateur global doivent également être complétés par un indicateur spatialisé qui permettra d'évaluer les différences de répartition des pressions cumulées à l'intérieur d'une nourricerie.

Table of Contents

1. INTRODUCTION 1
2. MATERIEL AND METHODS 3
2.1. Study sites 3
2.2. Pressure selection and detailed information on contamination and fishing pressures 4
2.2.1. Chemical contamination pressure 5
2.2.2 Fishing activity in the Bay of Biscay 8
2.2.3 Aggregate extraction 9
2.2.4 Piling 9
2.2.5 Invasive species 10
2.3. Spatial extension of source and diffuse pressures: the case of chemical contamination and piling 10
2.4. Computation of the multimetric pressure index 12
2.4.1. Building activities index and the contamination pressure index 12
2.4.2. Building the multimetric indicator 13
2.5. Data processing 14
3. RESULTS 15
3.1. Chemical contamination 15
3.2. Fishing activity in the coastal part of the Bay of Biscay 16
3.2.1. General decrease of the fishing fleet in the Bay of Biscay 16
3.2.2. Representativeness of aerial surveys data 17
3.2.3. Investigating work hypothesis 18
3.2.4. Reconstitution of the evolution of the fleets operating in the Bay of Biscay 19
3.2.5. Assessing the temporal evolution of the coastal fleets by region 20
3.3 Spatialization of data points for chemical contamination and piling 22
Buffers on pilling points sources impact 23
3.4 Studying contrasts between nurseries: application of the multimetric pressure indicator to the nurseries sites in the Bay of Biscay 23
3.4.1. Contribution of the different anthropogenic pressures to the multimetric indicator 24
4. DISCUSSION 26
4.1. Limitations of the study and methodological choices 26
4.1.1 Chemical contamination 26
4.2.2 Fishing index 27
4.1.3 Other pressures 28
4.2 Possible improvements to the approach and prospects 28
5. REFERENCES 30
6. APPENDICES 34

List of figures

Figure 1. Location of the studied nurseries of the Bay of Biscay. 3
Figure 2. Location of sampling stations for both biota and sediment matrices for metal (left) and organic (right) compounds 5
Figure 3. Correlation circles for metals (A) and organic compounds (B) 15
Figure 4. Repartition of individuals depending of the nursery for metals (A) and organic (B) compounds 15
Figure 5. Evolution of vessels repartition depending on their length in the Bay of Biscay (A) and mean repartition of the coastal fleet (B) (data extract from SIH syntheses) 16
Figure 6. Comparison of the number of fishing trips between aerial surveys and SIH data for the year 2001 17
Figure 7. Stacked area graph of regional contribution to the coastal fleet between 2003 and 2016 18
Figure 8. Evolution of the Bay of Biscay coastal fleet from 2001 to 2014 using both SIH data sets at the scale of the bay (A) and at the regional scale (B, C, D,E) 19
Figure 9. Linear regressions on SIH data extract from the syntheses 20
Figure 10. Geographic positions of coastal vessels reconstituted for 2014 (A) and pressure index due to fishing activity (B) 21
Figure 11. Result of the spatialization of pressure index for metal contamination (A) and organic contamination (B) 22
Figure 12. Spatialization of the piling index 23
Figure 13. Boxplot of the standardize pressure indices 23
Figure 14. Global Pressure Indices (GPI) and Average Level of Pressure (ALP) for each nursery 25
Figure 15. Distribution of dissolved metals (µg/l) as a function of salinity for the Seine estuary (Chiffoleau et al., 2001) 43

List of Tables

Table 1. Nature, temporal and spatial extension, final data used in the indicator and data sources. 4
Table 2. Buffers parameters 11
Table 4. Percentage of surface impacted by each pressure and for each nursery 24
Table 5. Pivot values for metals 42

List of Appendices

Appendix 1. Review of anthropogenic pressures in the Bay of Biscay (webograpy[1])
Appendix 2. Biota: Timeseries of contamination concentration
Appendix 3. Sediment: Timeseries of raw contamination concentration
Appendix 4. Study of the variation of concentration between oysters (red) and mussels (blue) applying O'Connor correction factor for oyster (green) for Mercury, Cadmuim and Lead.
Appendix 5. Standardization of sediment data and qualification of data
Appendix 6. Diagram of the different steps of data process for metal and organic compounds
Appendix 7. Satellite image showing the plumes of three estuaries selected: Vilaine, Loire and Gironde
Appendix 8. Dispersion of the pressure indices
Appendix 9. Results of the PCAs
Appendix 10. Linear Regression on both access and syntheses data [2001-2014]
Appendix 11. Comparison of slopes and p-values between the two regressions

List of abbreviations and acronyms

CEREMA: Centre d'études et d'Expertise sur les Risques, l'Environnement, la Mobilité et l'Aménagement

ICES: International Council for the Exploitation of the Sea

LD: Limit of Detection

LQ: Limit of Quantitation

MSFD: Marine Strategy Framework Directive

OSPAR : Convention pour la protection du milieu marin de l'Atlantique du Nord-Est ou Convention OSPAR « OsloParis »

PAMM: Action Plan for the Marine environment

REMI : Réseau de contrôle Microbiologique des zones de production conchylicoles

REPAMO: Réseau de surveillance des Pathologies des Mollusques Marins

RNOMV : Réseau National d'Observation de la qualité du milieu marin – Matière Vivante

ROCCH (RNO): Observation Network of Chemical Contamination (previously RNO: National Observation Network)

WFD: Water Framework Directive

List of abbreviations for chemical compounds

Al: Aluminum

Ar: Silver

B(a)P: Benzo(a)pyrene

Cd: Cadmium

Cr: Chromium

Cu: Copper

Hg: Mercury

Ni: Nickel

Pb: Lead

PCBs: PolyChlorinated Biphenyls

PAH: Polycyclic Aromatic Hydrocarbons

TBT: tributyltin

Zn: Zinc.

1. INTRODUCTION

Estuarine and coastal ecosystems are very productive areas with high ecological and economical values (Brown et al., 2018). These ecosystems provide many services for both human and marine species. For example, 44% of Northeast Atlantic species, assessed by the International Council for the Exploration of the Sea (ICES), use coastal habitat during at least one part of their cycle life. Those species also represent 71% of fishery landings in ICES member states (Seitz et al., 2014).

Coastal and estuarine ecosystems fulfill a variety of essential ecological functions, such as nursery grounds for juveniles of several marine species (Elliott and Dewailly 1995). A nursery is defined as a geographical area in which juveniles of a same specie gather together to optimize their growth and survival until their first sexual maturation (Delage and Le Pape, 2015).

However, coastal ecosystems are also submitted to multiple human activities (La Rivière et al., 2015), generating either direct or indirect pressures. Direct anthropogenic pressures are the result of several activities such as fishing, sand extraction, piling, invasive species or even land based activities of the urban, industrial and agricultural sectors. Human pressures can also be indirectly induced by climate change due to ocean acidification, average temperature increase (Brown et al., 2006), habitat modifications... The increase of those activities, together with the increasing use of coastal land, can lead to disturbances and modifications of coastal ecosystems (Courrat et al., 2009; Seitz et al., 2014). Those modifications have consequences at different scales. At the scale of the population, it can affect recruitment, growth and abundance (Courrat et al., 2009; Gibson, 1994), whereas at a larger scale it can affect biodiversity and trophic structure (Pauly et al., 2000).

Throughout this study, we distinguish an activity from its pressure. A pressure is the mechanism by which the activity can have an impact on the environment (La Rivière et al., 2015). An activity can be the source of several pressures as well as a pressure can be the result of several activities. For example, fishing is an activity that can lead to physical pressures such as sediment and turbidity modifications, and to biological pressure like mortality due to the faunal extraction. On the other hand, chemical contamination of marine waters is a pressure resulting from multiple land-based activities such as chemical industries, combustion processes etc.

Assessing the effect of anthropogenic pressures on marine community requires to identify and (most preferably) quantify the human activities and pressures they generate. One way of quantifying human pressures is to build a pressure index based on a pressure-impact approach. That methodological framework was first defined by (Halpern et al., 2008), where they combined into a single estimate (or index) the data from 17 anthropogenic pressures gathered in 20 marine ecosystems worldwide. Based on expert judgment, they weighted the pressures according to their impact in each ecosystem and developed their index. The present study is inspired on Halpern's approach and developed on French coastal nurseries. Since Halpern, this methodology has been used and approved worldwide in different studies at different scales. Ban et al., (2010) and Coll et al., (2012) used it at regional scales, respectively on the pacific Canadian coastal waters and the Mediterranean sea. At larger scales, Teck et al., (2010) applied it to the California Current, using expert judgment to estimate the vulnerability score of an ecosystem to a pressure. This methodology was also tested on terrestrial ecosystems, to map the human footprint (Sanderson et al., 2002).

Generally, the pressure-impact approach is used to describe or illustrate globally the location of hotspots of anthropogenic pressures than really measure the impact on the ecosystems.

Recent integrated approaches, such as the Water Framework Directive (EU, 2000) in Europe, aim to assess and achieve good environmental status. Member States are asked to develop tools in order to assess the ecological quality of the European waters (coastal, transitional...). In that context, Delpech et al. (2010) developed a global multimetric index based on contamination data to assess the ecological status of 13 French estuaries. This index targets transitional waters (estuaries and lagoons) and do not take into account the spatial variability of the different pressures within each estuary. The present work contributes to filling the gaps of the latter estuarine index by integrating spatially multiple pressures located in the coastal nurseries.

To address this issue, a recent study was initiated by (Saulnier et al., 2017). These authors worked on the development of a spatialized indicator focusing on physical pressures affecting coastal habitats. The present study aims at pursuing and improving this preliminary work through two major improvements: 1) Inclusion of organic and heavy metal contamination which data were gathered, normalized, and spatialized to develop contamination indices; 2) Inclusion of spatialized fishing pressure which data, under strong hypotheses, were included by combining different sources of information (aerial counts and fisheries statistics).

For the purpose of this study, the year 2014 was selected as the year of reference to assess the anthropogenic pressures impacting the nurseries of the Bay of Biscay.

Throughout this study, the term spatialized indicator is used for indicator which values vary within the nursery site (i.e. pixelized). The term global indicator refers to an indicator computed at the whole scale of the nursery (not pixelized). Therefore, each nursery is provided with i) a global indicator representing the mean anthropogenic pressure level for the area (GPI), and ii) a spatialized indicator (SPI), showing the spatial variability of the anthropogenic pressure level at the scale of the nursery. Using the two new pressure datasets (chemical contamination and fishing) together with three other pressures (piling, aggregate extraction, invasive species), we initially planned to compute the GPI and SPI for the six coastal nurseries located in the Bay of Biscay. However, in the time allotted only the GPI is presented and discussed among the nurseries.

2. MATERIEL AND METHODS

2.1. Study sites

The Bay of Biscay is located along the French coast in the North Atlantic (ICES area VIIIa and VIIIb). Six sites were identified, by previous studies, to be suitable nursery grounds (Le Pape et al., 2003; Trimoreau et al., 2013). They are located in six estuarine and coastal areas between Brittany and Aquitaine: the Bay of Vilaine, the Loire estuary, the Bay of Bourgneuf, the two Pertuis Charentais (Breton and Antioche) and the Gironde estuary (Figure 1). The spatial extents of the nurseries were defined using the bathymetry (up to 35 meters) and salinity (5 PSS) (Gibson, 1994; Trimoreau et al., 2013).

The six nurseries shelter several species, they are known nurseries for several flatfishes, including the common sole *(Solea solea)* (Le Pape et al., 2003), and also for other species like whiting (*Merlangius merlangus*), European hake *(Merluccius merluccius)*, pouting (*Trisopterus luscus*), and the cuttlefish (*Sepia officinalis*) (Regimbart et al., 2018; Rochette et al., 2010).

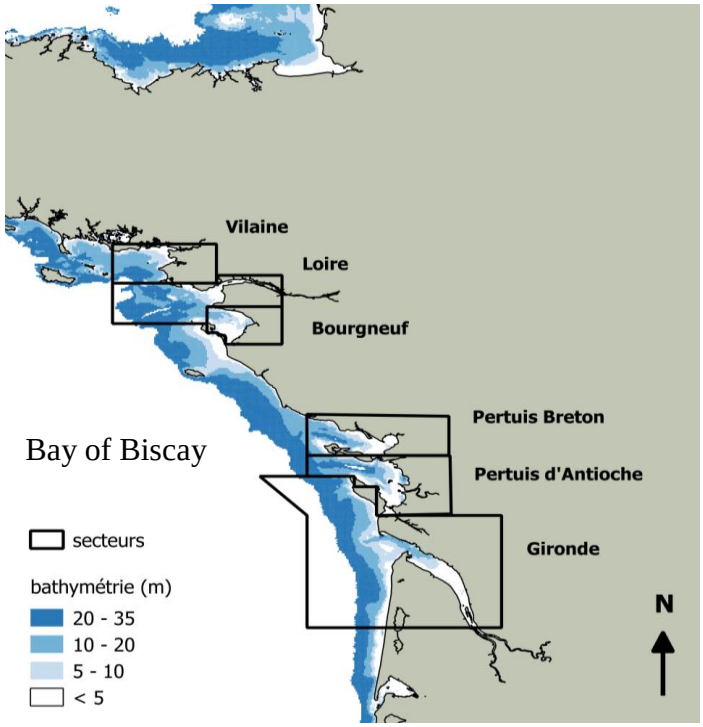


Figure 1. Location of the studied nurseries of the Bay of Biscay.

2.2. Pressure selection and detailed information on contamination and fishing pressures

As part of the Marine Strategy Framework Directive (MSFD), an action plan for the marine environment (PAMM) was implemented. An initial assessment of the impact of anthropogenic activities was carried out in 2012 for each marine sub-region including the Bay of Biscay (https://sextant.ifremer.fr/en/web/dcsmm/pamm/evaluation-initiale). From that work, physical, chemical and biological pressures were individually investigated and summarized. That document was used to develop an exhaustive list of anthropogenic pressures in the Bay of the Biscay (cf. Appendix 1). The choice of pressures to include in the present study was guided by the previous work of Saulnier et al., (2017) and by the review of MSFD syntheses which identified the most relevant and impacting pressures in the Bay of Biscay (La Rivière et al., 2015). Only pressures affecting nurseries and with available datasets were selected (Table 1). This led to the selection of five pressures including chemical (organic and heavy metal) contamination and four pressures linked directly to marine anthropogenic activities namely, fishing, extraction sand aggregates, immersion of dredging spoil and an invasive species (i.e. the slipper limpet - *Crepidula fornicata*). It is worth mentioning that shellfish farming is voluntary excluded from our study as its ultimate effect on juveniles is still under debate (Cugier et al., 2010; Laffargue et al., 2006).

In the present section, a thorough description is done on the two pressures for which analytical improvements were required: chemical contamination and the pressure of fishing activity. These two pressures have been shown to be important anthropogenic drivers(Brown et al., 2018; Gilliers et al., 2006; Smith et al., 2011). The three other pressures are briefly described in table1.

Table 1. Nature, temporal and spatial extension, final data used in the indicator and data sources.

Pressure	Nature	Temporal coverage	Spatial extension of the pressure	Data used in pressure index	Sources
Chemical contamination	Concentration of contaminants measured in sampling stations (data points)	2000-2016 1999, 2004 & 2014	Buffer at the scale of the nursery	Coordinates on the first PCA axis for both metals and organic compounds	ROCCH biota ROCCH sediment
Fishing activity	Access SIH database containing fishing trips Yearly syntheses of fishing activity at different scales (region, ocean) Aerial surveys covering the Bay of Biscay (within the 12 nautical miles)	2001-2005 2006-2016 2001	Data manipulation using different datasets to obtain spatialized point data	Number of fishing trips reconstituted and spatialized for the year 2014	- SIH database -SIH Syntheses - Aerial French custom surveys
Piling	Annual quantity of dredging materials immersed for each piling site (data points)	2005-2016	Buffer at the scale of the piling site	Mean quantity of dredging materials distributed, on a decreasingly basis, over the impacted surface reconstituted	CEREMA
Aggregate extraction	Maximal volume extracted for each site	Period of validity of mining title covering 2014	Geographical shape defined by the area of the extraction site	Maximal Volume uniformly distributed over the surface of the extraction sites	Sextant Ifremer
Invasive Species	Position of slipper limpet beds in the Bay Bourgneuf Cartography of slipper limpet beds (position and surface areas) in Pertuis Charentais	2002 2011	Geographical shape defined by the area of the beds	Geographical positions of slipper limpet beds	Sauriau et al. (2002) Sauriau et al. (2011)

2.2.1. Chemical contamination pressure

The French Research Institute for the Exploitation of the Sea (IFREMER) has been monitoring the chemical contamination of coastal French waters for the French ministry of the Environment since 1974. Mainly through the national observation network for marine environment quality (RNO), a national network which became in 2008, the Observation Network of Chemical Contamination (ROCCH). The survey of coastal waters contamination has been carrying out on the sediments (hereafter sediment) and biota (hereafter MV).. Indeed, this study focuses on the two first matrices because of their integrative properties that allow them to absorb the ambient contamination (sediment) or bio-accumulated them (MV) making them measurable.

Spatialized contamination indices require a spatial dispersion of contaminant data points representing correctly the gradient of chemical contamination within each nursery site. The sampling stations for biota and sediment matrices from the ROCCH are not located at the same place. With certain analyses and standardization (see below), the ROCCH data points for the sediments and the biota were deemed appropriate and used together in this study(data Appendix 2 & 3) (data available at http://dx.doi.org/10.12770/12eadab0-8002-4214-aeff-22c5c2d1d9e9).

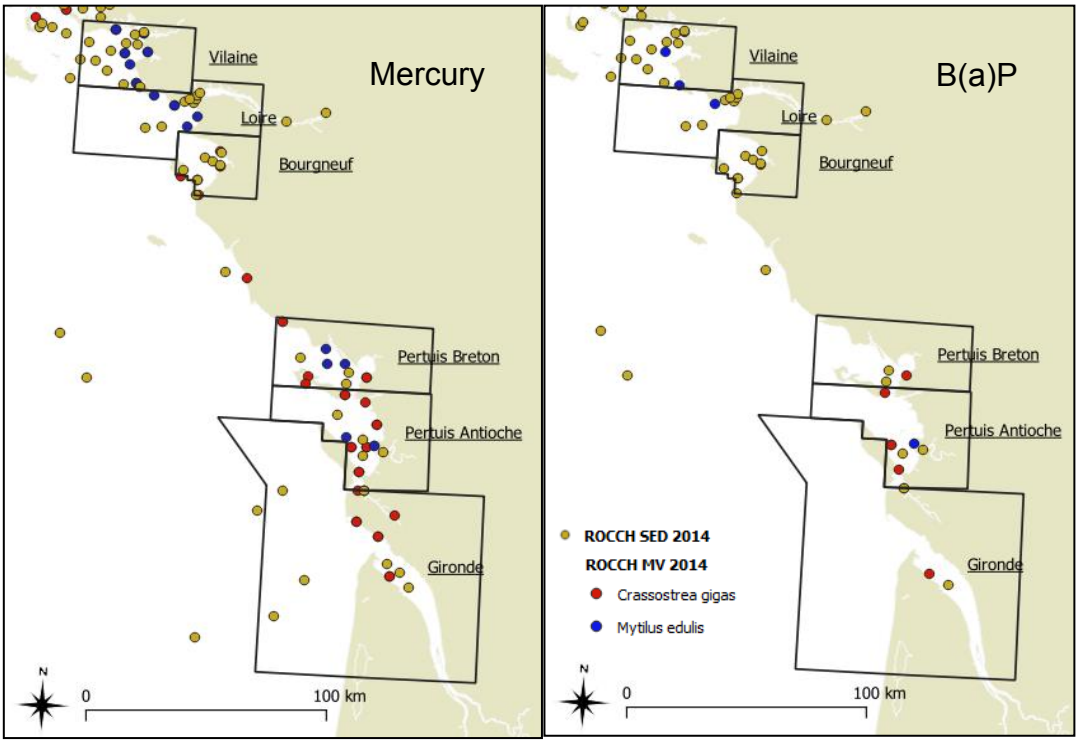


Figure 2. Location of sampling stations for both biota and sediment matrices for metal (left) and organic (right) compounds

a) Biota Matrix(MV)

In the French monitoring program, three species of bivalves are used, following the recommendation of the OSPAR convention: two species of mussels, *Mytilus galloprovincialis* and *Mytilus edulis*, and one species of oyster, *Crassostrea (=Magallana) gigas*. When exposed to pollutants for at least a six month period, bivalves represent the ambient contamination without taking short term variation into account (Chiffoleau, 2017). In the present study, only the M. *edulis* and *C. gigas* are found in the Bay of Biscay. Mussels are the preferred species but when absent from a site, oysters are used instead (Amouroux and Claisse, 2015). A sampling protocol is also defined to insure the homogeneity of measures from one year and one station to another. For a given station, the same species within the same size or age range are always collected *(35-65 mm for mussels; between 2 and 3 years for oysters).* The level of contamination is determined on a sufficient number of bivalves (more than 60 for mussels and more than 10 for oysters) in order to minimize the effect of individual variations (Amouroux and Claisse, 2015). The period of sampling is also important in order to have comparable data. Indeed, the content of contaminant in bivalves varies over a year. It is due to biological parameters like their reproduction cycle (Chiffoleau et al., 2001). This phenomenon of yearly fluctuation was study by the ROCCH network and their conclusion showed that contamination is higher in the beginning of the year. Therefore, this study only includes contamination measures taken from January to march for metals. For the organic contaminant however, all the data were kept as they were sampled only once a year.

The biota dataset covered 16 years (2000 and 2016), including 36 sampling stations repetitively sampled in the Bay of Biscay. Substantial work was done to control the quality of the data and only the qualified data for the year 2014 were used. In the following lines we resume the data manipulation that was done as this essential task was time-consuming and required a chemistry expert. The first step is the qualification of the data. Two limits exist to qualify the quality of the values. The detection limit (LD) is the value below which one a laboratory cannot distinguish the contamination from analytical background noise. The limit of quantitation (LQ) is the value below which a laboratory cannot, with certainty, determine a concentration. The LQ can vary between laboratories, depending on the technique use and its precision. To avoid overestimating the contamination, concentrations equals to the LQ values were kept if they were minimums. The second step concerned the standardization of the two species monitored. It is commonly known that bivalves have different abilities to bioaccumulate contaminants (Kimbrough et al., 2008) and several studies compared the contamination levels of mussels and oysters (O'Connor, 1992; Rojas de Astudillo et al., 2005). However, the above-mentioned authors, as well as Michel & Marchand (1988) showed no difference in the ability to bioccumulate the organic compounds for the different species of oysters and mussels. For the metals, the difference of bioaccumulation between oysters and mussels varies depending on the metal (O'Connor, 1992; Cantillo, 1998). It is worth mentioning that O'Connor deemed that for metals with small differences concentrations can be used regardless of the species. Only five metals (Silver, Copper, Chromium, Lead and Zinc) were excluded for spatial comparison of metal concentrations, because large differences were found (O'Connor, 1992). Several tests were conducted on our data set (Appendix 4). But the oysters and mussels were on the same order of magnitude, for the three metals selected (see below). Applying O'Connor correction factors, as seen in the study of Gilliers *et al*, (2006) induced more differences. Based on those observations, we concluded that it was more relevant not to correct the bivalve datasets.

b) Sediments matrix (Sediment)

Sediment contamination monitoring relies on hypothesis that surface sediments are in balance with their surrounding water. They are used to study temporal variation at a large/long temporal scale. The first layer of sediment can record several years of contamination, depending on the sedimentation rate, resuspension dynamics…. In those conditions, experts assume that a multiannual monitoring is relevant. The sampling frequency of the French monitoring program was of each 10 years and since 2007 it became every six years following the recommendations of Water Framework Directive. For the present work only the data from the first sediment horizon were selected in order to have the most recent year of contamination. In the Bay of Biscay, three years are available: 1999, 2008 and 2014. Therefore, the most recent data (e.g. 2014) were used in the study.

Raw sediment concentration cannot be directly used as an index of contamination. Concentration of contaminants in sediment depends on the type of sediment such as the particle size and organic carbon content. For instance, metals have an affinity to clay and organic contaminant to organic matter. Therefore; a large body of work was done to normalize the data to a standard sediment composition and then qualify the data. This was done following the OSPAR recommendation, e.g. using a correction procedure with a chemical parameter (see Appendix 5).

c) Selection and combination of contaminants

With the help of Mauffret's expertise, investigations were made to select contaminants, common to the sediment and biota matrices. In the Bay of Biscay in 2014, 44 chemicals compounds were monitored in sediments and 122 in bivalves. From those, eight metals were monitored in both matrices: Mercury (Hg), Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Silver (Ar), Nickel (Ni) and Chromium (Cr). The first three metals were selected for this study because of their toxicity (Hg, Pb, Cd), their properties to be bioaccumulated (Hg) and the number of sampling stations available. Moreover, they are used by OSPAR as metal contamination indicator (Mauffret et al., 2018). The three metals selected respect the quality criteria having concentrations higher than the two thresholds for both matrices (Appendices 1& 2).

Two types of organic compounds monitored in both matrices and validated for quality criteria were selected: Polychlorinated Biphenyls (PCBs) and Polycyclic Aromatic Hydrocarbons (PAH). Most of pesticide concentrations measured in sediment did not pass the quality control criteria. Among the PCBs, only four congeners (PCB118, 138,153 and 80) are common to both matrices. The congener 153 was selected because it is most likely to be found in marine environment it is the most abundant CB congener. Several PAHs were common to both matrices but we kept the benzo(a)pyrene(BAP) which is the most studied compound with a well-known toxicity that can have consequences on human health (Abarnou et al., 2000; Tronczynski and Moisan, 1999). For these two organic compounds, qualifications of data were investigated and were globally respected (90% of the data)[1].

Once contamination data were homogenized, qualified and standardized for sediment and biota datasets, concentrations were then retrieved for the year 2014. Only sampling stations located within nursery areas were kept. Concentrations were log transformed and standardized.

[1] For the sediment matrix, in 2014, all BAP concentrations respect that condition, and only three points for the PCB153 are below the threshold. In biota matrix it's the opposite, PCB153 concentrations are above the LQ and four concentrations are below the threshold for the BAP.

$X_i = \frac{x_i - \bar{x_i}}{\sigma(x_i)}$ with: Xi the standardized variable x_i the data point

$\bar{x_i}$ the mean of xi

$\sigma(x_i)$ the standard deviation of xi variables

Then, a Principal Component Analyses (PCA) conducted on the standardized values observed at each sampling stations was used to synthesize the contamination pressure and create two contamination indices, one for metals and one for organic compounds. Using coordinates of the first PCA component we recreate a contamination gradient. The two PCAs were conducted with the FactomineR library of the software R (see the recap diagram in Appendix 6).

2.2.2 Fishing activity in the Bay of Biscay

Building an indicator at the nurseries scale requires spatialized fishing data for the year 2014. Although such data exist (Valpena project), its access was refused for the present study. Instead, we combined two sources of available fishing information to develop a spatialized index of fishing activity in the six study sites. The following section describes the working hypotheses and methodology applied to develop the index.

a) Description of the different datasets

Aerial survey dataset – From November 2000 to November 2001, the French Custom Air Service realized monthly diurnal aerial surveys of the fishing fleet in the Bay of Biscay (Leaute, 2006). These surveys provided the geographic positions of the French fishing vessels that were active within the 12 nautical miles of the bay. For each active vessel, the month, the gear and the geographic coordinates were taken. We acknowledge the fact that diurnal surveys may underestimate the fishing activity, although we assume that these data still provide relevant high spatial resolution data for vessel locations.

SIH datasets – The second source of information came from the Fisheries Information System (SIH) of Ifremer. The SIH forms a network of observations of the French fishing resources and activities. Among its missions, it acquires fishing data and produces syntheses which are in open access (http://sih.ifremer.fr/). Comparing to the aerial counts, the SIH data are more accurate in term of fishing effort by fleet and the type of gear used in each fishing trip. However, the syntheses are not spatialized and cover a very broad spatial scale, namely the region.

Two types of data were retrieved from the SIH: an extraction of an ACCESS database (2001-2005) and a set of yearly national syntheses from 2003 and 2016 (excluding 2013). The common examination of those two sources of data gave us a detailed description of the fleet temporal variability. Prior to the analysis of the two datasets, several manipulations on the ACCESS SIH database were required to standardize its format with those of the annual syntheses. Hence, the regional filters were applied and a common typology of the fleet was assessed. The SIH typology of(Berthou et al., 2003) was used. Assignment of vessels using several gears to a fleet was done as follow. All the vessels using trawling nets, for at least one month, are classified in the trawler fleet. For vessels using other gears, the predominant towed gear defines the fleet in which the vessel is affected with a priority given to the dredgers and sievers. Then, the remaining vessels using multiple passive gears were processed. They included vessels using one of the three following combinations: trap-net or trap-hook or net-

hook. Remaining vessel assignments were spread out among fleets according to the remaining gear: trap, hook or net (respectively trap, troller and gillnetter).

b) Combining the different datasets: from regression to spatialization

Prior to the combination of the aerial counts and SIH datasets, we simplified the above mentioned typology into two classes of fishing gears: the *towed gears*, including trawlers, draggers and sievers, and the *passive gears* corresponding to gillnets, trollers, longliners, and mixed passive gears. We also selected coastal vessels in the two datasets which corresponded to vessels observed within the 12 nautical miles for the aerial surveys and vessels conducting more than 75% of its activity in the 12 nautical miles (Berthou et al., 2003), vessels smaller than 20m. in the SIH data set . In the latter dataset, the vessels are then attributed to one of the four regions depending on their associated marine region in the SIH dataset. It has been shown that the most of the vessels worked near their landing ports and that fishing areas of neighbours fleets mainly don't overlap. For the aerial surveys, the geographical position associated with the ICES statistical sub-rectangle enabled the regional assignment of the observed vessels in one of the four regions.

c) Working hypotheses

The approach chosen was to assess globally and regionally the temporal trends of the fishing fleet of the Bay of Biscay using the combined SIH datasets. Then we predict the fishing activity (i.e. number of fishing trip) in 2014. Using the spatial resolution of aerial surveys we translated that situation in 2014 spatially. That methodology relies on several strong hypotheses. The most important hypothesis implies that the visual surveys in 2001 are representative of the spatial distribution of the fisherman during that year, and that the spatial distribution of the vessels still holds true in 2014. Indeed, no new fishing locations that would have been visited following that year is considered. It is also important to state that our index is only concerned by the impact of bottom gears, excluding any effect of pelagic or non-vessels fisheries.

2.2.3 Aggregate extraction

There are three types of extraction. Granular materials can be exploited for the construction industries, used to recharged beaches or, in the case of harbours and waterways, they are dredged to maintain the maritime access. Here we focus on the extraction of siliceous and limestone materials that are exploited for the construction industry. This activity can alter habitats and induce changes in the benthic communities (Desprez et al., 2010). In the Bay of Biscay, mainly siliceous materials (sand and gravel) are exploited. It represents 4 678 000 m^3 of siliceous materials extracted from a 29.5 km^2 surface. Ifremer have available data concerning the perimeter of extraction sites authorized or ongoing (see webography[2]).

2.2.4 Piling

Piling activity is directly linked to the dredging of harbourd and waterways. It is the immersion of dredging materials. In the Bay of Biscay, 90% of dredging sediments are immersed. Piling can alter ecosystem by smothering and clogging it. It is also an source of chemical compounds. In this study, we focus on the physical pressure of this activity (cf Appendix 1). Fifty seven sites exist in the Bay of Biscay, but about 27 of them are yearly used. Principal immersion sites correspond to the two largest estuaries: the Gironde and the Loire matching the two major harbours Nantes-Saint-Nazaire and Bordeaux. For the Bay of Biscay, the quantity of dry matter yearly immersed between 2005 and 2016 varies between 10

and 17 million tones, reaching a peak in 2014. Data used came from yearly surveys carried out by the CEREMA under the OSPAR Convention. For each disposal site, geographical coordinates and the quantity of dry matter immersed, in tones, were provided. As mentioned previously, the year 2014 was used to estimate the pressure index. It is important to precise that the geographical position, provided by CEREMA surveys for each site, is a point taken from any part of the dumping zone. Therefore, in here we spatialized the piling data by building at each piling site a concentric buffer with a decreasing effect using three levels of decreasing intensity. The buffer was developed in R using several libraries (KernSmooth, ks, sm, raster, dismo, maptools, rgdal, PBSmapping, shape, geosphere).

2.2.5 Invasive species

The slipper limpet is one of the main non native benthic species introduced in the Bay of Biscay. Originating from the North coast of America, it was detected for the first time in 1949 in the Bay of Brest from where it spread from Brittany to Bay of Arcachon mostly because of oyster farming and fishing activity (i.e. towed gears). It has been developed especially in the Bay of Bourgneuf, the Pertuis Charentais (Pertuis d'Antioche and PertuisBreton) (Le Pape et al., 2004; Sauriau et al., 1998). The slipper limpet colonizes the substratum, thereby modifying benthic communities, inducing trophic competition with other filter feeding species, and precluding the settlement of flatfish juveniles (Kostecki et al., 2011). The data used in our study came from two previous studies of Sauriau et al. (in 2002 and 2011) on slipper limpet in the Bay of Bourgneuf and the Pertuis Charentais (Sauriau et al., 2004; Sauriau, and Curti, 2011). Positions and extents of slipper limpet beds were provided as geometric objects (i.e. shape file). No weighting by the density of slipper limpets within the bed is done as such data was not available.

2.3. Spatial extension of source and diffuse pressures: the case of chemical contamination and piling

Two of the datasets described previously, namely contamination data and piling, contain localized point data, although the effect of each pressure extents spatially. Contamination data points traduce the contamination level present in the surrounding habitat (water, sediment) and the sampling sites are supposed to be representative of the surrounding contamination (see webography[3]). It is a diffuse pressure. Whereas piling data points represent a localized pressure that is added in the marine environment. This pressure, due to the immersion of dredging materials, spreads around its immersion site. Moreover, only one geographical position within the immersion site is given. It was therefore necessary to apply a spatial extension on both datasets. Different statistical methodologies for developing specific spatial distributions can be used (Ban and Alder 2008, Murray et al., 2015) but for the purpose of the present work within the given time framework, one approach was investigated: the buffer type approach. That approach creates a uniform pressure around the data point and then incrementally add rings of around the data point. By multiplying the pressures impact by a decreasing weight, the pressure impact is progressively reduced. The number of rings, their diameter and decreasing weight need to be set but can easily be adapt. That approach was used by Ban and Alder (2008) to map the human marine impact, applying buffers for each activity. The overlapping buffers allowed them to identify their intensity and pattern.

In the present study, we used the buffer approach for both the piling and contamination pressures but at different spatial scales. Stating that the piling activities

generated localized impact, multiple buffers localized at each data point were developed to define the extent of the impacted zone. Buffers values depend of the quantity of dry matter immersed in each sites. Buffers were constructed by decrementing the average value of piling material by m^2 in each ring, using the same reduction weights and the same diameters for all piling sites. The buffer parameters are defined in Table 2. Overlaying buffer rings where added as they were considered as supplementary sources of pressures.

A similar approach was used for the contamination data with a close difference: the location of the source of the contamination was delocalized from the survey points. Indeed, as contamination is a diffuse pressure, we used the mouth of the estuary as an arbitrary point source to develop the buffer, given that marine contamination results mainly from land uses. We decided to define three starting point for the Bay of Biscay contamination, those points corresponding to the three mains estuaries (Gironde estuary, Loire, and Vilaine). The extension of the plume estuary for Loire covers the bay of Bourgneuf, and the plume of Gironde estuary extends to the Pertuis (Appendix 7). The data used in the contamination datasets were those standardized across the different matrices, i.e. the principal coordinates of the first PCA axis. As mentioned earlier, the two types of contamination (metal or organic) were processed separately. The largest values observed near the mouth of each selected estuary were used as the contamination values in the first buffer ring. Given that the three estuaries differ in their contamination level, the starting values of each buffer also varied. The diameters and the decreasing weights were defined using the information in the localized (and standardized) data measured at each sampling points. No overlap was found for contamination buffers.

For the two buffer applications, the resulting data was a raster built at the scale of the Bay of Biscay and pixelized with the associated buffer values. Buffers were constructed using R software and libraries (KernSmooth, ks, sm, raster, dismo, maptools, rgdal, PBSmapping, shape, geosphere).

Table 2. Buffers parameters

	Methodology	Number of rings(r) values of diameters (d) (in km)	Sources
Piling	One buffer by dumping site	d1=1; d2=1.5 d3=2 ; r=3	(Alzieu et al., 2003; Bougis and Farnole, 2002; Silva Jacinto and Burel, 2002)
Chemical contamination	3 buffers with a diffusion from the mouth of three main estuaries(Gironde, Loire and Vilaine)	R=4; Metals: Dvilaine(7,14,21,31) Dloire(10,20,30,43) Dgironde(20,40,60,100) Organic compounds: Dvilaine(4,8,16,24) Dloire(17,22,25,43) Dgironde(30,50,70,100)	Cf Appendix 7

2.4. Computation of the multimetric pressure index

To implement the five pressures selected in a global indicator, a square mesh grid of 1.5 nautical miles, covering the studied sites, was created. It delimits pixels where pressures are calculated and added into a multimeric indicator. The size of the mesh is based on a compromise guided by the different spatial resolutions and precisions of our five data sets.

2.4.1. Building activities index and the contamination pressure index

An index was built for each of the five selected activity or pressure selected.

Chemical Contamination

The two indices of contamination consisted in the scores of the first PCA component computed for the metals and the organic compounds separately. That data were spatialized as mentioned above and rasters of the two contamination indices were created.

Fishing activity

The index was built with the spatially reconstructed data for the year 2014. The spatial repartition of vessels observed in 2001 during aerial surveys was extrapolated for the year 2014. For each region, linear regressions were used to recreate the evolution, from 2001 to 2014, of the number of vessel for the two types of gears.

The pressure due to fishing activity, $P_{fishing}$, is defined as the number of fishing trip in each pixel of the grid for the year 2014.

Aggregate extraction

The pressure index due to the extraction of granular materials, $P_{extraction}$, is determined for each pixel by the maximum amount of granular materials extracted allowed in 2014 (V_{max}).

$$P_{extraction,i} = V_{max,j} * \frac{Sextraction_{i,j}}{Sextraction_{j}}$$

with: $Sextraction_{j}$ total surface of extraction site j
$Sextraction_{i,j}$ surface of extraction j in pixel i

Piling

The pressure index of piling activity, P_{piling}, was built using the quantity of dry matter immersed in 2014. The index values were retrieved from the buffers constructed.

Invasive Species

The pressure index of invasive species, P_{limpet}, is the percentage occupied by slipper limpet beds in each pixel of the grid.

2.4.2. Building the multimetric indicator

a) Standardization of pressures indices

Important dispersion between the fives pressures index built were observed (Appendix 8).

Given that each pressure has different unity and range, each pressure was log transform and standardize to reach values between 0 and 1 according the formula:

$$Z_j = \frac{\log(P_j + 1)}{\mathrm{Max}(\log(P_j + 1)}$$

with: Pj the index of pressure j and
Z_j the new log transform-standardized pressure index used from now on

For contamination data only the data were first set to positive values before being transformed in order to keep the contamination gradient along the first axis of the PCA.

$$Z_j = \frac{\log(P_j + |\min(Pj)| + 1)}{\mathrm{Max}(\log(P_j + |\min(Pj)| + 1)}$$

with: $|\min(Pj)|$ the absolute value of the minimum for contamination index

b) Compiling pressures indices in a spatialized anthropogenic pressure indicator

The spatialized pressure indicator (SPI) was then calculated using the indices built previously for the five pressures. By drawing on the work of Halpern et al. (2008), the indicator was calculated in each pixel of the grid, for each nursery sites, using the formula:

$$SPI_i = \sum_{j=1}^{5} w_j * Z_{i,j}$$

with: w_j the impact weight of pressure j
$Z_{i,j}$ Pressure index j in pixel i

For this study, the same weight was applied to the five anthropogenic indices built. As a first approach, impact weights were all set equally to 1, pending further investigations.

c) Determination of the global level of anthropogenic pressure for each nursery site

To compare anthropogenic pressures level between nurseries sites, a global pressure indicator (GPI) was determined.
First, a global index was calculated for each pressure j in the n nurseries sites by summing the pressure index values. To avoid confusions it was named Average Level of the Pressure j in the nursery n ($ALP_{j,n}$). To avoid a bias due to the size of the nursery, $ALP_{j,n}$ was divided by the ratio of the nursery surface on the maximal nursery surface.

$$\mathrm{ALP_{j,n}} = \frac{\sum_i Z_{i,j,n}}{S_n/\max(S_n)}$$

with: S_n surface of the nursery n
$\max(S_n)$ the largest nursery surface

Then the six ALP of a nursery were sum in the GPI.

$$\mathrm{GPI_n} = \sum_j ALP_{j,n}$$

with j=1 to 6 and n=1 to 6

2.5. Data processing

A postgreSQL database, named « Nourpress », was created in 2009 and used in a previous study (Saulnier et al., 2017). The work was carried out on the Nourpress database hosted by the sirs.agrocampus-ouest.fr server using the platform pgAdmin 4 (version 3). For this study, an update of the database was needed. Old data needed to be sorted and updated, new data were added. A new scheme, named nourpress2018, was created in order to have a full new database containing only the set used in this study while keeping the previous version in case of further use.

The postgreSQL database contains all the raw data, as table, used in this study. They were loaded in the database with the help of R(foreign, DBI, odbc and rpostgis libraries). Materialized view were created to construct a grid to calculate pressures indices and the indicator.

In addition to the pgAdmin platform, others software were used. As described throughout the previous parts of the report, the sofware R (version 3.3.1) was used in different steps of the study with various libraries. Qgis software (version 3.2.1) was also used to produce the map of anthropogenic pressures indicator in the Bay of Biscay and maps showing the ROCCH sampling stations.

3. RESULTS

3.1. Chemical contamination

Results of the PCA

For metals, the first axis explains 56 % of the total variance (Figure 3A). The three metals are significantly correlated with the first axis and with each other even if the lead is less correlated than the two others.

For organic compounds, 67.78% of the total variance is explained by the first axis (Figure 3B). BaP and PCB153 are significantly correlated with the first component and with each other. Representative of the contamination gradient, the coordinates on the first factor of both PCA were used for each sampling site as indicator of metals and organic contamination.

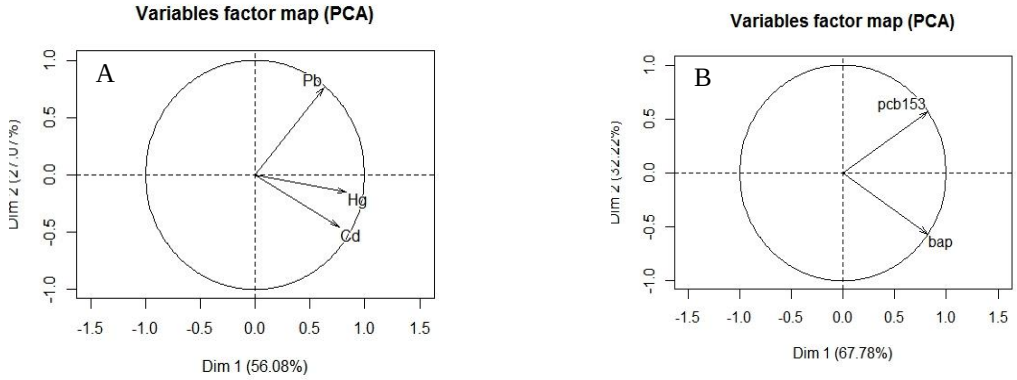


Figure 3. Correlation circles for metals (A) and organic compounds (B)

The standardization of the sediments and biota data sets allowing the joined analysis of the two matrices. Hence, for the metals and the organic compounds, no gradient, due to the type of matrices, could be detected (see Appendix 9).

The analysis of the repartition of the sites according to the nursery (Figure 4) suggests that the Loire nursery has higher levels of organic contamination, whereas the Vilaine nursery seemed to have the lower indices of contamination, for both metals and organic compounds, among the six nurseries.

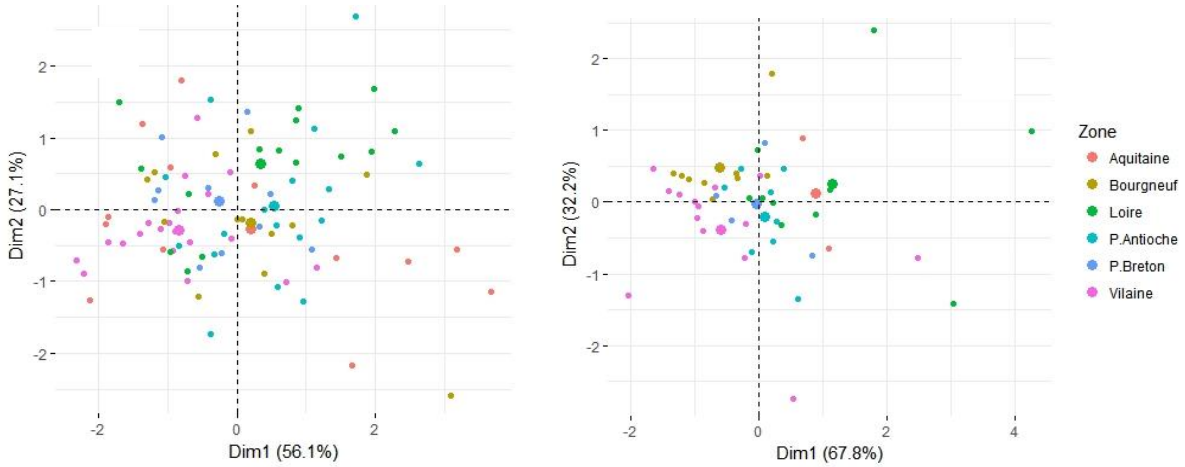


Figure 4. Repartition of individuals depending of the nursery for metals (A) and organic (B) compounds

3.2. Fishing activity in the coastal part of the Bay of Biscay

3.2.1. General decrease of the fishing fleet in the Bay of Biscay

SIH syntheses data (Figure 5.A), show a general decrease of the Bay of Biscay fleet, from 2003 to 2016, that is mainly driven by the diminution of the coastal fleet. This is not surprising given the proportion of coastal vessels in the total French fleet. The coastal vessels were divided into three size classes : less than twelve meters, vessels between twelve and sixteen meters and last class vessels between sixteen and twenty meters. Most of the vessels are less than twelve meters. On average, less than twelve meters vessels represent 94% of coastal vessel (Figure 5B). This proportion is globaly stable between 2006 and 2016. In 2014, the French fleet operating in the coastal area of the Bay of Biscay consists of 1043 vessels, for a total number of 1589 vessels in the bay, mostly less than twelve meters vessels (96% in 2014).

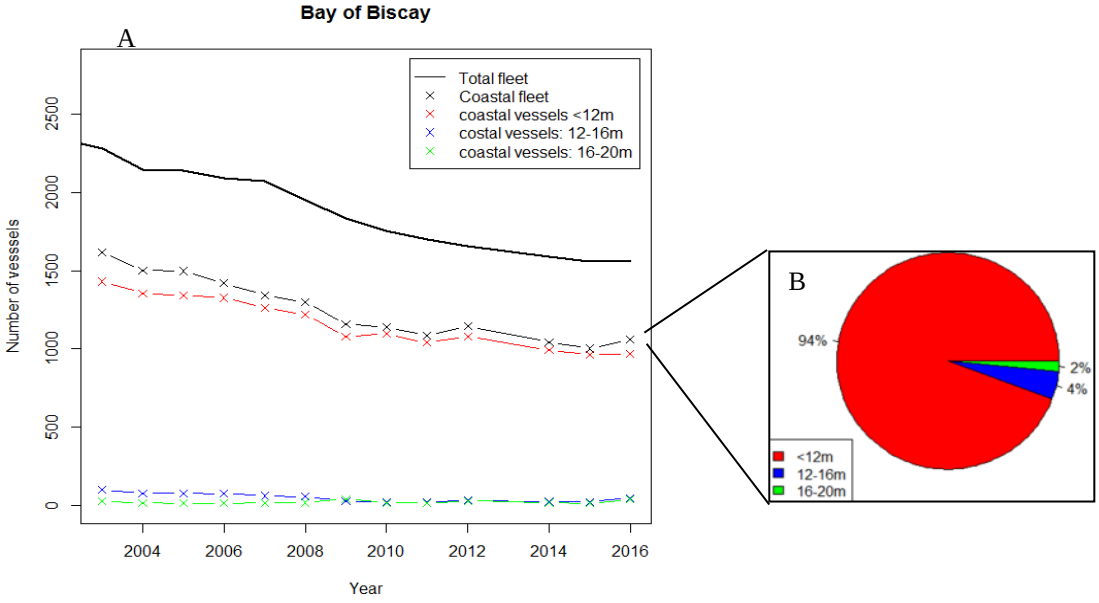


Figure 5. Evolution of vessels repartition depending on their length in the Bay of Biscay (A) and mean repartition of the coastal fleet (B) (data extract from SIH syntheses)

3.2.2. Representativeness of aerial surveys data

The spatialisation of the fishing pressure is notably based on the aerial surveys data, realized during day time. For the pupose of the sudy we assessed the representativeness of those data. Graphs were produced in order to see what is really observed by those aerial surveys. The number of fishing trips in 2001 was compared between aerial surveys and SIH data.

Generally, there is a higher percentage of towed gears observed. For both passives and towed gears, less than 10% of fishing trips occuring in the Bay of Biscay are recorded. At a smaller scale, disparities are observed at the regional scale, depending on the type of gear and the region. The percentage of fishing trips identifyed in each region is low, varying from 3%, in Brittany for passives gears to 25% for towed gears in Aquitaine.

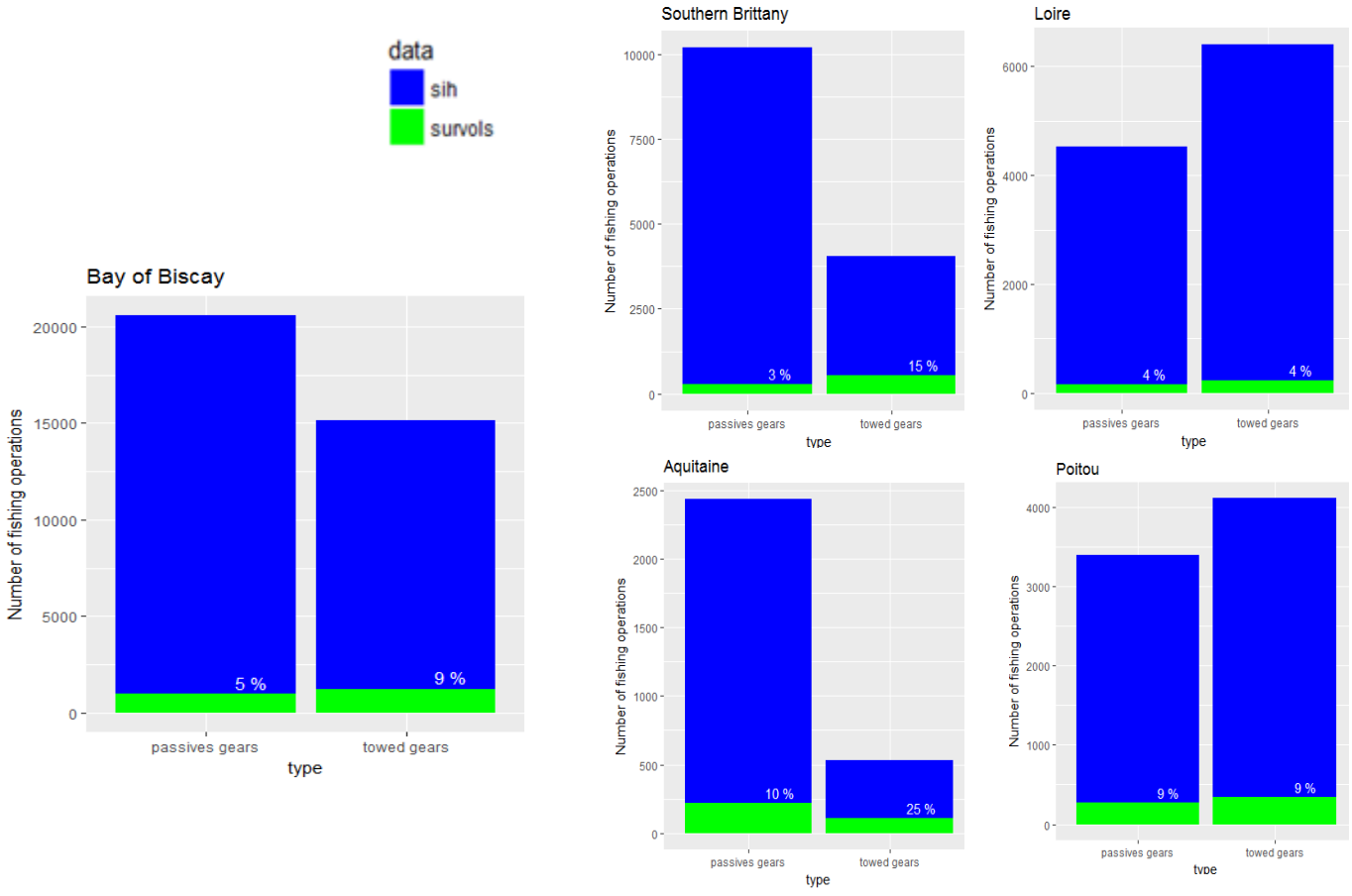


Figure 6. Comparison of the number of fishing trips between aerial surveys and SIH data for the year 2001

3.2.3. Investigating work hypothesis

One of our work hypotheses was that the spatial occupancy of the fishing vessels, at the scale of the nursery, remained the same between 2001, year of the aerial survey, and in more recent year. This means that the reduction of the fleet observed needed to be equally divided among every fishing zone, e.g. between each region.

The stacked area graph (Figure 7) shows that each region is affected by the decrease of vessels. It also seems that the distribution among regions remained the same on the studied period. Indeed, the contribution of each region to the Bay of Biscay coastal fleet is stable between 2003 and 2016. South of Brittany contributes the most, with 41%, to the coastal fleet, followed by Loire (26%) and Aquitaine (19%) regions. The region Poitou contributes the less with 14% of Bay of Biscay coastal vessels.

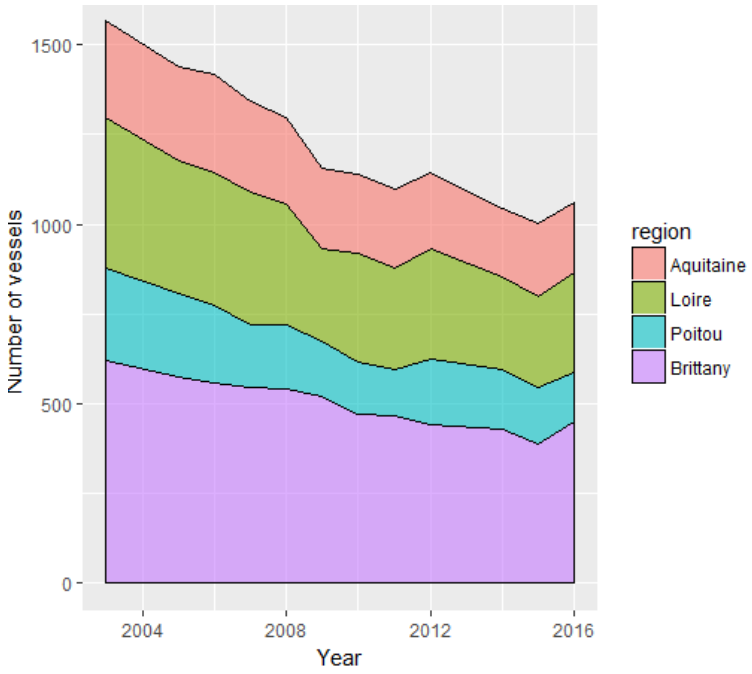


Figure 7. Stacked area graph of regional contribution to the coastal fleet between 2003 and 2016

3.2.4. Reconstitution of the evolution of the fleets operating in the Bay of Biscay

Using a common gear typology to data extract from SIH syntheses and the access SIH database, the evolution of the fleets operating in the Bay of Biscay was reconstituted from 2001 to 2014. Both general and regional scales were investigated

At the scale of the Bay of Biscay (Figure 8.A), we can note that the number of vessels of each gear class for common years are similar for the two datasets. The graph (Figure 8.A) shows a general decline of the number of vessels, for the coastal fleet. It is mostly repercuted on towed gears whereas passive gears are globaly stable over the period. A shift of the type of gear prevailing is observed in 2010. Towed gears used to be predominant before 2010, after what they dropped below passive gears. The same pattern is observed at the regional scale. Globally, the number of towed gears is decreasing whereas passive gears are stable. The reconstruction of fleets evolution seems also corrected at the regionale scale (Figure 8.B, 8.C, 8.D) except for Aquitaine (Figure 8.E) where a general underestimation is underlined. Nevertheless, Poitou-Charentes region shows a slight tendency to increase for the last few years. Finally, the green point (Figure 8.A) that represents the 900 french vessels observed in the Bay of Biscay by the aerial surveys shows that globaly half of the French vessel operating in the coastal zone of the bay of biscay were not observed.

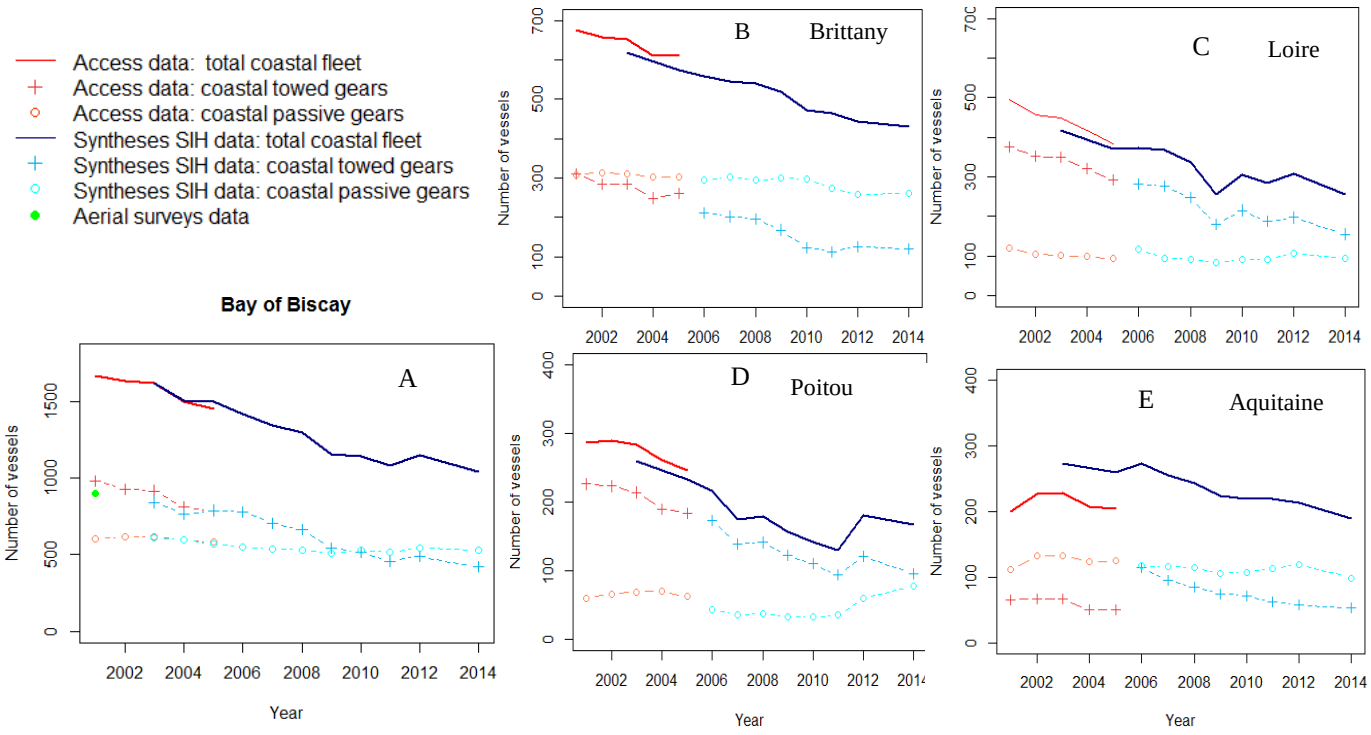


Figure 8. Evolution of the Bay of Biscay coastal fleet from 2001 to 2014 using both SIH data sets at the scale of the bay (A) and at the regional scale (B, C, D,E)

3.2.5. Assessing the temporal evolution of the coastal fleets by region

The prediction of the fishing situation in 2014 was assessed using linear regressions were on the data from the SIH syntheses data (e.g. on the time period 2006-2014).

For each region, the evolution of the two types of gears were extracted from the linear regressions. Between 2001 and 2014, towed gears fleet lost 181 vessels in Britanny, 202 in Loire, 111 vessels in Poitou and 96 in Aquitaine. For passive gears, only the regression for the Brittany region was stastically significant, it is the only passive gears fleet affected by a reduction of 75 vessels in 13 years. The percentage of decrease and the number of fishing operations in 2001were retrieved for the 5 significant regressions. The situation in 2014 was then created, for each region and each type of gear.

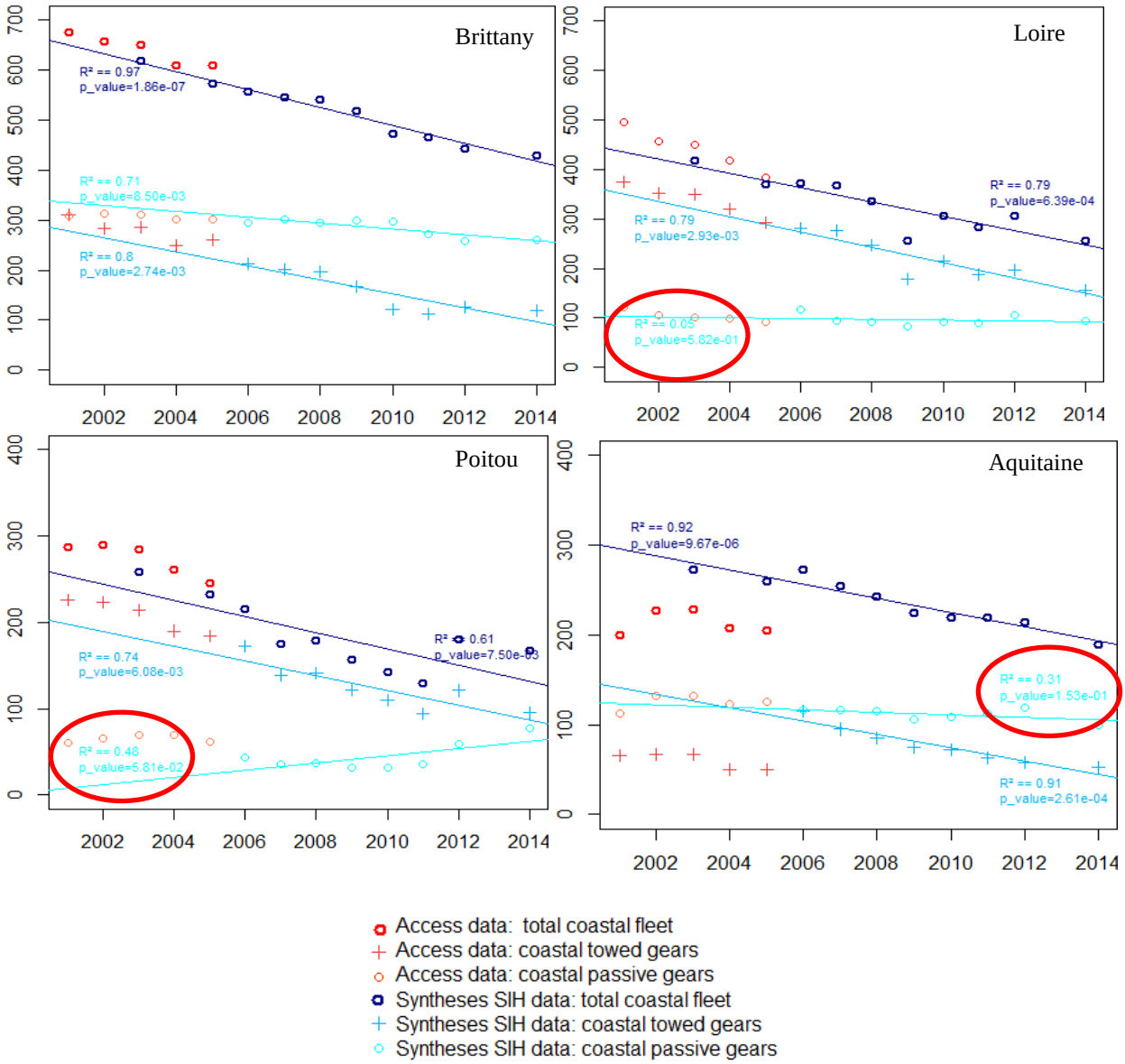


Figure 9. Linear regressions on SIH data extract from the syntheses

Then, by combining those results to the geographical positions retrieved from aerial surveys we were able to reconstitute a spatial repartition for the fishing trips that occurred in 2014 (Figure 10.A). Finally, the fishing index was calculated (Figure 10.B)

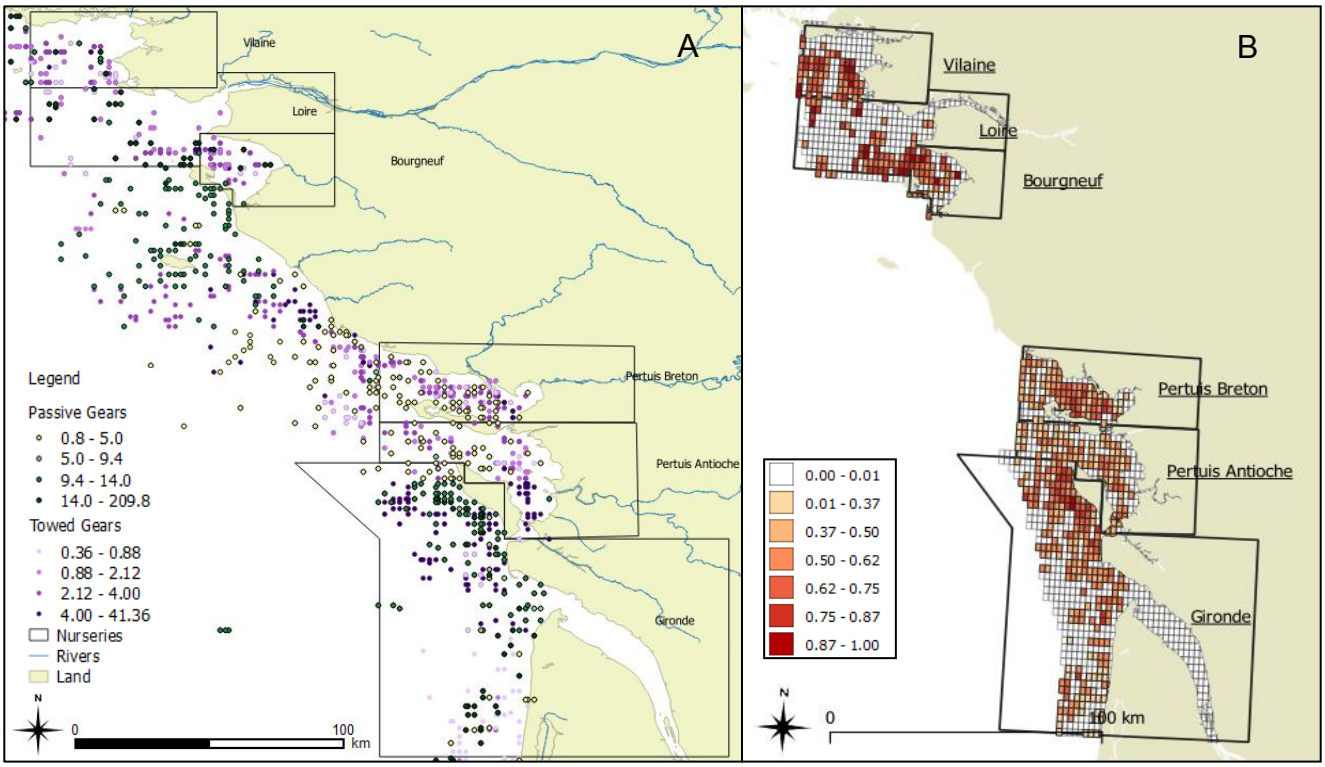


Figure 10. Geographic positions of coastal vessels reconstituted for 2014 (A) and pressure index due to fishing activity (B)

3.3 Spatialization of data points for chemical contamination and piling

Chemical contamination spatialized according to buffer method considering the three main estuaries as main sources. Results of the spatial extension of the chemical contamination reflect the gradient of nursery sites according to the level of metal or organic contamination. In particular, for organic contamination, the Loire shows the highest scores and the Vilaine the smallest compared to the other nurseries.

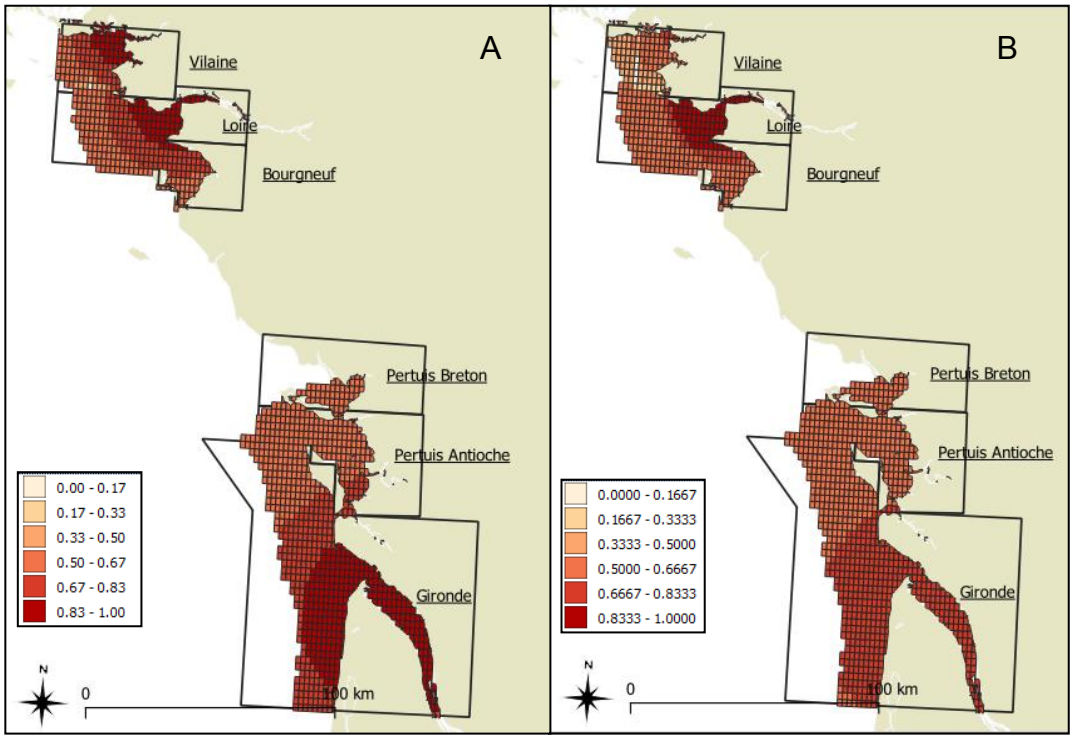


Figure 11. Result of the spatialization of pressure index for metal contamination (A) and organic contamination (B)

Buffers on pilling points sources impact

For the buffers on piling data, the nursery in the Loire estuary stand out with a higher index of pressure. Both the Vilaine and Pertuis Breton are not affected by this pressure.

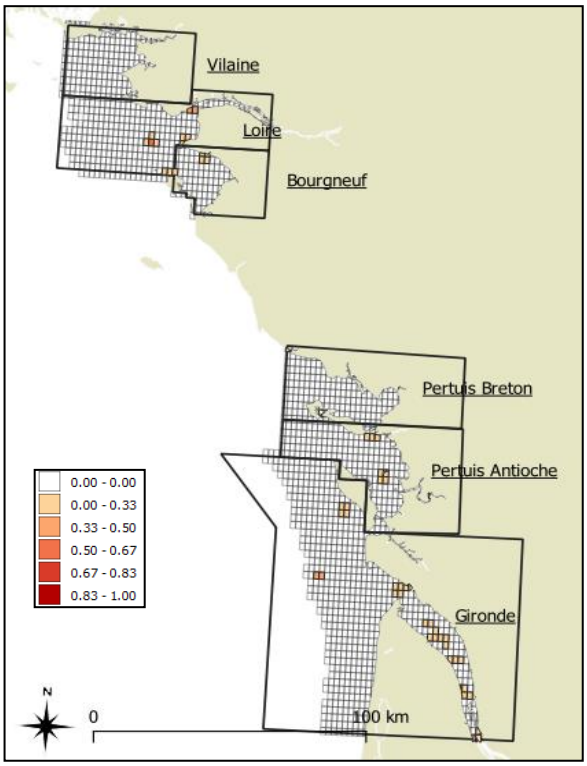


Figure 12. Spatialization of the piling index

3.4 Studying contrasts between nurseries: application of the multimetric pressure indicator to the nurseries sites in the Bay of Biscay

To compare and build the indicator, pressure indices were log- transformed and standardized.

Metal contamination and the presence of invasive species seem to be the most variable pressures regardless of the nursery (Figure 13).

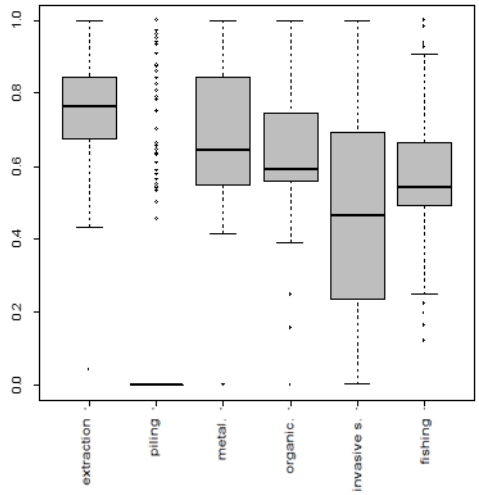


Figure 13. Boxplot of the standardize pressure indices

3.4.1. Contribution of the different anthropogenic pressures to the multimetric indicator

The six nurseries sites face different level of anthropogenic pressures in term of surfaces impacted as well as number of pressure present in each site. The Bay of Vilaine stands out being exempt of three of the five pressures (piling, aggregate extraction and presence of the slipper limpet) (Table 4).

In term of surface impacted, metal and organic contamination are the most important ones as it diffuses in the water. However, that result is likely due to the spatial extension approach used to diffuse the contamination data. Other approaches as those mentioned earlier should be studied in a sensitivity analysis. Comparing the four other pressures, fishing is the predominant pressure in term of surface impacted.

Table 3. Percentage of surface impacted by each pressure and for each nursery

Nursery	Vilaine	Loire	Gironde	P.Antioche	Bourgneuf	P.Breton
Fishing	34	24	36	44	45	51
Metal contamination	100	100	100	100	100	100
Organic contamination	100	100	100	100	100	100
Piling	0	4	5	3	7	1
Aggregate extraction	0	4	2	2	0	0
Invasive species	0	0	0	17	25	11

Global Pressure Indicator (GPI) & Average Level of Pressure j (ALP_j)

The GPI was used to compare nurseries sites on their global level of pressure (in black on Figure 15). It is important to note that GPI values don't reflect the actual values of pressures impacts applied on a nursery. This indicator allows to compare and class nurseries according to their global level of anthropogenic pressure and to identify the nursery with higher exposure. When comparing GPI, the Bay of Bourgneuf, the Gironde and the Pertuis Breton stand out but for opposites reasons. The Gironde and the Bay of Bourgneuf being the most impacted nurseries (respectively with a GPI value of 1038 and 1035) whereas the pertuis Breton has a two time lower GPI (482). The Pertuis Breton is also the only nursery site where fishing pressure contributes the most to the global pressure indicator.

The Average level of a pressure j (ALP_j) was used to compare the variation of a pressure between nurseries. The ALP shows the difference of the average level of a pressure from one site to another. But it can reflect the pressure variation intranurseries.

The ALP Contamination has high values for both metal and organic compounds. Contamination is a diffuse pressure that extends to all the surface of the nurceries. That's why $ALP_{contamination}$ is higher than the other punctual pressures. Fishing was also found to be the second factor, after metal and organic contaminations, affecting nurseries. It represents an average of 18% of the global pressures affecting nurseries, 75% being already taken by the two contamination indices. The pressure of invasive species, when present in a nursery, contributes more to the GPI of a nursery than both piling and aggregate extraction, two pressures more localized. Those observations are coherent with the previous ones regarding the percentage of surface impacted.

If we compare organic and metal contamination in nurseries, it can be noticed that both Pertuis are more impacted by the organic than metal. Whereas Vilaine nursery presents a higher global level of metal contamination, compare to the organic one. It can be noticed that the decreasing contamiant gradient, imposed by the buffer, appears between the gironde the pertuis Antioche and the pertuis breton. This is not the case for the Loire estuary and the Bay of bourgneuf. The average level of both contaminants is higher in the Bay of Bourgneuf.

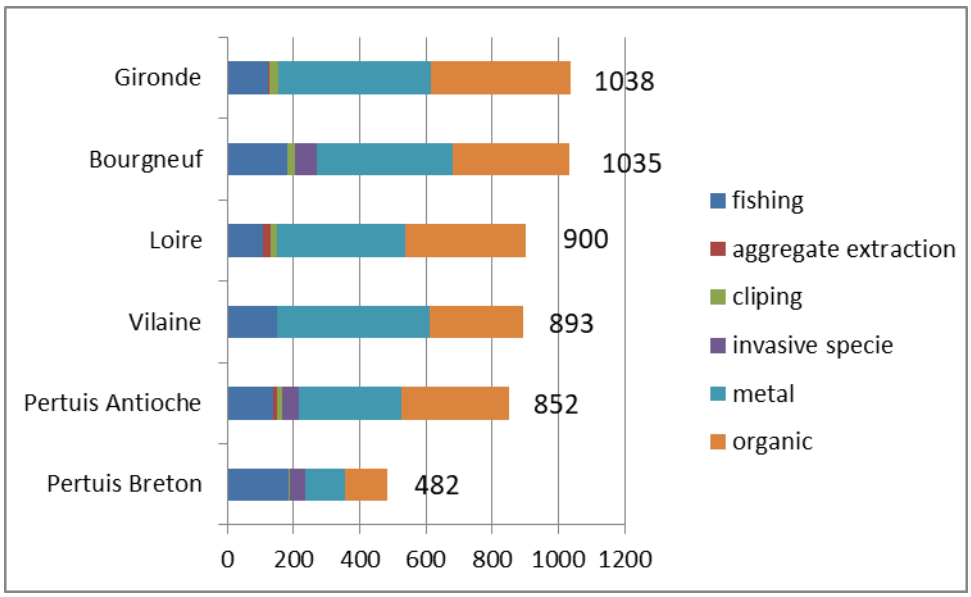


Figure 14. Global Pressure Indices (GPI) and Average Level of Pressure (ALP) for each nursery

4. DISCUSSION

The present study aimed to identify and quantify human activities and the pressures they create on six nurseries of the Bay of Biscay. Lots of efforts were invested to develop a framework to synthesize them in a global indicator. An important part of the work was dedicated to select, gather and process proper data. As a consequence, we propose here to discuss on this methodology by reviewing its limits, the choices made and possible improvements. In the allocated time, first results of this approach were obtained. However, both GPI and ALP need to be complete by the spatial pressure indicator allowing the study of contrasts within a nursery. It could be interested to study the differences observed between Bourgneuf and Loire contamination. Others studies used indicator to study cumulative anthropogenic impacts. They were either realized at higher scales,(Halpern et al., 2008) studied 20 ecosystems, or with a higher number of pressures as seen for the 38 activities included in Ban et al, (2010) study. This make comparisons across studies difficult.

4.1. Limitations of the study and methodological choices

4.1.1 Chemical contamination

The phase of data qualification has allowed the selection of several compounds and the exclusion of others. Some of them are well known for their ecological impact. Such as Tributyltin (TBT), a powerful endocrine disrupter (Alzieu and Michel, 1998) used in antifouling paintings and also in several industries. TBT showed concentrations mostly below the LQ (63% of the data set) for both matrices (Appendices 1 & 2). This compound was therefore not used in the study because it wasn't able to discriminated areas depending on their TBT concentration. However it could be used as a source point impact with important pressure on ecosystems.

Initially, an additional data set for contamination data was included during the first part of the study. The national monitoring network of water and sediment quality in harbour (REPOM) was created in 1997. Constituted by departmental networks, the analyses are carried out by several laboratories. The data set used in the study would have had a twofold benefit. First, it would have increased the number of sampling stations for the spatial extension of marine chemical contamination. Second, it would have provided information regarding harbour pressure on marine ecosystems that are otherwise not included in this study. Lots of efforts were then put into the investigation of this data set and its qualification. But we faced many problems: multiples inconsistent units, high number of concentrations below the LQ varying according to the laboratory. Based on those observations, this data set was deemed not reliable enough to be safely included in the study.

Taking into account the contaminant punctual concentrations and their temporal trends could be interesting for a better insight of growing or decreasing pressure on the ecosystem. Moreover, an upward tendency could cause more stress to an ecosystem than a constant concentration. Using only the value of contaminant concentration at a given year doesn't include the additional impact on the ecosystem. Trends are actually used in DSCMM 2018 evaluation of the descriptor 8 (e.g. contaminants in the environment in metropolitan France) as a metric defined as the slope parameter of the time-series contaminants (Mauffret et al., 2018). For the Bay of Biscay, when a trend could be calculated, metals and benzo(a)pyrene were found to have an upward trend in some stations whereas a decreasing tendency was

observed in half of the stations for PCB153. Based on these information it could be interesting to take those trends into account when evaluating the impact of the contaminant pressure.

Regarding the spatial extension of contaminants, the location of the source of the buffer are delocalized from the survey points. The buffer was constructed by building on the contamination values of the stations. Another study used mouth estuaries to diffuse land based pressure but with another spatial extension technic (Clarke Murray et al., 2015). The diffusion of the pressure, however, was calibrated using a watershed activity index. This index was only calculated for watershed with large stream rivers. Indeed in our approach we limit the inputs of chemical contaminants to the tree main estuaries. Which means that punctual additional inflows of other rivers were not taken into account. This can particularly concern the two nurseries in the Pertuis because the Charente River and the Sevre River can be additional sources of chemical contamination coming from the watershed. Nevertheless they might be negligible as their flows are tiny compared to those of other rivers.

(Ban et al., 2010) also used the buffer technique to map the intensity of anthropogenic activities. Buffer were also calibrated using a qualitative ranking determine for each activity and the magnitude of its impact extension. But three scenarios were built by increasing the radius of the successive rings to test the effect on the results. It could be interesting to test different scenario of contaminant spatial diffusion by changing the radius and weighting of the buffer.

4.2.2 Fishing index

The reconstitution of the time series for the regional fishing data using SIH data has shown discrepancies between database and synthesis for towed gears of the Aquitaine region (Figure 8). This consequently affected the coastal fleet for this region. It concerns the period 2001-2005 less vessels were observed in the SIH database than expected given the data provided by SIH syntheses for 2006-2016. This is also supported by coastal fleet data that showed for 2003 and 2005 a higher number of vessels in Aquitaine. These differences are due to a different typology applied by the SIH to create the data base.

The linear regressions were supposed to be conducted on the 13 years retrieved. But due to the gap between the two data sets, the regression for towed gears in Aquitaine wasn't significant. The differences induced by this choice were investigated (Appendix 10). As a precaution, linear regressions were only carried out on SIH data extracted from the syntheses that is for the years 2006 to 2014. This approach introduces several problems regarding the evolution scenario. As well as reducing the number of points and time coverage of the statistical sample, it also affects fleet evolutions trends. For the three other regions, the reduction of towed gears fleet seems underestimated. For passive gears it is less obvious because this fleet has been more stable for the past years, for Poitou and Loire they are not significant. For Brittany however, it tends to amplify the small decrease observed (Appendix 11).

Nevertheless, it was possible to overcome the gap found in the access SIH database by using regression only on the 2006-2014 period.

It seems also important to keep in mind the unusual nature of the fishing data used to build the fishing pressure index. Data were reconstructed for 2014 using relatively old data (2001) to extract the cartography of fishing trips, and large scale data for the SIH ones.

The reliability level of the mapping of fishing activities can also be questioning. Aerial surveys were carried out during day time, whereas a part of coastal fishing occurred by night (Leaute, 2006). They only took place once a month and aimed at the 12 miles zone, without a special focus on coastal fishing. Due to the nature of the observations, the gear distinction wasn't always possible or accurate especially for gillnetters, potters and longliners, among others, where fishing gear are not visible during fishing time (Leaute, 2006).

In the absence of other available data the choice was made to use them rather than to not consider this important source of anthropogenic pressure. This study has provided a methodology that could be used and adapted when more recent and precise data will be available.

Other data could be used to study other area such as Vessels Monitoring System (VMS) data. They have a high temporal and spatial resolution providing hourly geographical position of vessels. But they are only available for more than twelve meters for French coastal vessels which makes them not suitable for our study. But they could be used in other area where VMS are more develop such as in Marine Park.

4.1.3 Other pressures

It is also important to underline the limits concerning the others pressures. Regarding granular material extraction data, maximal extraction volumes are used instead of real volumes extracted. This means that the impact of this pressure may be overestimated. But the real volumes extracted being confidential data, only available data were used instead. Slipper limpet data are a combination of two sources both of them being out of date data and covering different time period (2002 and 2012). Few data concerning invasive species in the Bay of Biscay exists, those two data sets were the best found.

4.2 Possible improvements to the approach and prospects

Only five of the pressures occurring in the bay (Appendix 1) were used in the present study. The number of selected pressures is relatively low compared to the 17 pressures included in the study of Halpern et al (2008). Our choice was made within the limits of available data and an emphasis was made on data quality rather than quantity. It represents a compromise between time and spatial precision.

This study could be improved by adding others pressures. Data concerning harbours, marinas and other coastal facilities and development of the waterfront zone should be included in further studies. Data search of such data were initiated at the beginning of the study. A shape file of coastal developments and coastal infrastructures is available from the CEREMA. It is a non-exhaustive list that was last updated in 2017. The spatial dispersion of the associated pressure could be modelised using the same methodology applied for piling.

Another pressure that needs special attention is the shellfish farming. Saulnier et al (2017) showed that farming area are the second most important anthropogenic pressure in term of surface impacted and relative weight in the global level of pressure. But its real impact on coastal area was found to be low (Dumbauld et al., 2009; Forrest et al., 2009). In the Bay of Mont Saint Michel, its impact was even found to be lower than the impact of the invasive species slipper limpet (Cugier et al., 2010). Other studies even show that it can have a positive impact by increasing, at the beginning, the level of nutriments, improving water quality through bivalve's filtering activity (see webography[1]) and even providing a shelter for juvenile flatfish (Laffargue et al., 2006). But in excess the increase of nutriment can also

cause severe damage to ecosystem such as clogging and smothering them see webography[1]).

As a first approach, pressure weights were set equal to 1 when summed in the indicator. The next step of this study will be to conduct a sensitivity analysis of the effect of pressures weighting scenario on the indicator. Weighting scenarios are often based on literature review or on surveys collecting experts' advices on the subject. Using classification technics, weights of the selected anthropogenic pressures are defined (Aubry and Elliott, 2006; Halpern et al., 2008; Teck et al., 2010). For our study, pressure weights were to be assessed by crossing two sources of references. First, using the literature review of DSCMM technical guides on bay of Biscay pressures and impacts (Appendix 1) (see webography[1]). Together with activities-pressures and pressures-impacts matrices, establish by experts for the Bay of Biscay.

As said previously, different statistical methodologies exist to develop spatial distributions (Ban and Alder 2008, Murray et al., 2015). A similar technics as the one used in this study is the Kernel density decay. It relies on the same principle except that a smoothing function is used to reduce progressively the pressure of the activity from its application point. Murray et al., (2015) used it in their study and applied it at two different scales. First, with point sources coastal activities to map their extent impact. Then, at the mouth of estuaries to recreate the spatial diffusion of land based activities in marine waters. This technic allows a smoother extension of the data points. Another methodology which may be considered was the co-kriging because it has the particularity to use the spatial correlation of a co-variable to estimate the other variable. It seemed interesting for contamination data, using salinity or bathymetry as co-variable. But even with both matrices, there were not enough points in some nurseries, especially in Gironde (Figure 1), the reason why this method was excluded.

Our indicator was constructed following an additive effect scenario of pressure indices. That hypothesis assumes that there is no interaction between the pressures selected. It has been shown that cumulative effect can be greater (synergism) or smaller (antagonism) than the additive sum of the effect of each pressure taken separately (Crain et al., 2008; Piggott et al., 2015). This concept can also be applied to chemical contamination. The presence of other substances can positively affect its effectiveness (Piggott et al., 2015) or change its bioavailability. Salinity or even turbidity can affect metals mobility and availability (Chiffoleau et al., 2001; Du Laing et al., 2008; Turner, 1996).But until now none of the study using cumulative anthropogenic impact has taken that parameter into account, impacts are always assume to be additive (Ban et al., 2010; Clarke Murray et al., 2015; Halpern et al., 2008) due to the uncertainties regarding the non-additive responses of cumulative impacts.

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Webography :

[1] Directive Cadre Stratégie pour le milieu marin https://sextant.ifremer.fr/fr/web/dcsmm/pressions-et-impacts).

[2] Ifremer https://wwz.ifremer.fr/gm/Comprendre/Soutien-a-la-puissance-publique/Les-granulats-marins/Granulats-marins

[3] Le ROCCH à travers les âges - Stratégie et évolution d'un observatoire de l'environnement, présentation par Jean-François Chiffoleau le 5 décembre 2017, SEM'BE, Nantes

6. APPENDICES

- Appendix 1. Review of anthropogenic pressures in the Bay of Biscay (webograpy[1])

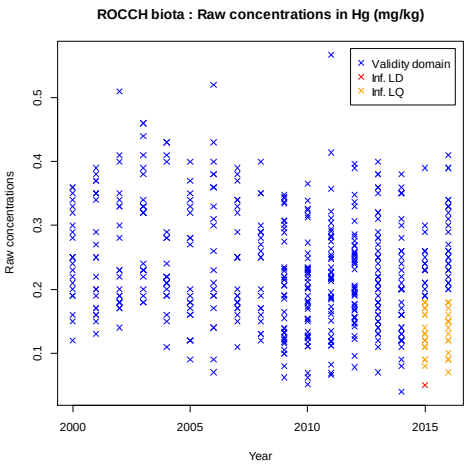
Catégorie pression		Libellé pression	ACTIVITES = Sources de la pression	Impacts	Spécificité du GG	Pris en compte	Justification	Données
Pressions physiques	Pertes & Dommages Physiques	Etouffement & Colmatage	Construction H permanentes : poldérisation ouvrages côtiers (ports, ouvrages protection)	Destruction totale faune/flore localement		Non		
				obstruction, étouffement habitat & biocénoses (f° hydrodynamique)		Non		
			Conchyliculture	Sur site : étouffement, privation de lumière, d'O2 & tassement		Non	Effet sur milieu discuté	
			Immersion & rejet matériaux de dragage	Etouffement biocénose & habitat		Oui		CEREMA
			Autres : câbles sous-marins récifs artificiels & épaves			Non	Négligeable	
				surface locale imp mais rapidement recolonisée				
		Abrasion	Pêche (dépend type engins & sol)	modification fond et turbidité, impact sur diversité & production communauté B		Oui		
			Navigation & mouillages					
			Câbles sous-marins			Non	Négligeable	
		Extraction sélective de matériaux	Exploitation de granulats marins par aspiration	Changement habitat & communautés benthiques		Oui		
			Dragages portuaires & chenaux navigation	Dégradation et destruction habitat & biocénoses		Oui		
			Prélèvements pour la recharge des plages	*Impact Jamais étudié*		?	#	
	Autres Pressions Physiques	Bruit	Traffic maritime (marchand, passagers, pêche, plaisance)	pp cétacés (corrélation échouages) + complexe à quantifier pr poissons : impact bruits impulsifs fort sur vessie natatoire & impact possible p° acoustiques sur céphalopodes	P° forte & stable. Dominé par tr. marchandise dans rail navigation Ouessant-> La Corogne	Non	*Hors cadre étude*	
			Activités SONAR : focus sur prospection pétrolière & gazière + expérimenta° recherche spé		émissions sonores<10kHz => modérées voire en recul	Non		
			Travaux en mer		peu : pp granulats & sécurité maritime			
		Déchets littoral (i.e. macro déchets)	Pollution due à l'homme	hab & com B : diminu° échanges gazeux, asphyxie, modif° param physique, micro-courant fond… Engin pêche perdus : abras° habitats, écrasement & enchevêtrement organismes esp non B : pêche fantôme, ingestion	données hétérogènes, ponctuelles et locales =>complexe à extrapoler	Non		
		Déchets en mer sur le fond	déchets fond					EVHOE
			munitions					OTAN
			conteneurs perdus		~5-150 /an pp long voie navigation	*Non*	*Hors cadre étude*	
		Microparticules	source diffuse : dégradation plastique en mer, polymère plastique de synthèse	concentre contaminants à surface microparticules=>favorise diffusion, ingestion	données trop limitées	Non	Manque de données	
		Dérangement faune	mammifères et oiseaux marins : collision ac tr maritime	échouages	impact difficile à quantifier	Non		

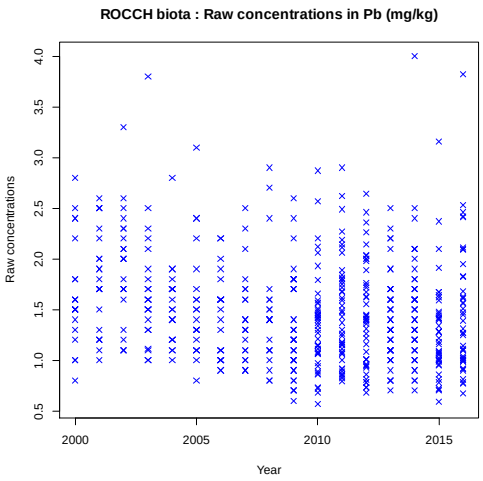
	Interférences avec des processus hydrologiques	Modification régime thermiques	centrales électriques	réchauffement dû rejet eau refroidissement	2 centrales ds estuaire Loire & Gironde (p° indirect). Bilan étude : réchauffemt négligeable	Non	pas d'effet observé	
		Modification régime salinité	modification débit cours d'eau par apport eau douce (irrigation, barrage…)		complexe avoir série données correctes	Non	Manque de données	
		Modification régime courants	installation conchylicole	diminution courant dans les installations	reste local i.e. dans les parcs	Non	pas d'effet observé	
			aménagements côtiers	modif courant à proximité, créa° tourbillon stationnaire	vite dissipé			
			prises & rejets d'eaux	taille installation pas suffisante pour avoir une influence				
Pressions Chimiques	Contamination par des substances dangereuses	Apports fluviaux substances chimiques (micropolluant)	rejets agricoles	contamination par des substances chimiques du milieu et des espèces => toxicité reconnu. Ex : imposex et gastéropodes	BV Loire-Bret : p° fortes dû glyphosate, désherbant, fongicide. BV Adour-Garonne : p° fortes (Charente, vallée Garonne, affluents gersois Garonne) dû: glyphosate	Oui		ROCCH
			rejets collectivités		majo métaux + retrouvé			
			rejets des industries		BV L-B : métaux pp. BV A-G : métaux en aval, Cd Zn vallée lot(métallurgie, mines)			
		Apports atmosphériques substances chimiques	Combustion (principalement) ex : centrales électriques		retombé svt accompagné réémission. HG & PCB 153 : réémis°>retombées. CD : réémission + imp. Gradient cote/large	Non		
		Pollutions accidentelles rejets illicites (hors pollution hydrocarbure)	composés synthétiques : artificiels & produit par l'homme	impact écologique : létaux et sub-letaux, forte mortalité mais recolonisation rpde	1970-2008 : 12 pollutions pp métaux en Bret S & 512 rapports de pollution	Non		
			compo non synthétiques : métaux lourds					
			Epaves		43 épaves connues dans 30 miles nautiques + navires coulés pdt GM			
		Apports substances dangereuses dragage/clapage	dragage portuaire et déversement des boues (clapage)	apport de substances chimiques supplémentaires venant des ports => contamination du milieu et des espèces		Oui		point clapage : CEREMA
	Introduction de radionucléides dans le milieu marin		secteur nucléaire : industries nucléaires	dispersés courant, fixent sur particules en suspension dans l'eau, sont stockés dans les sédiments & s'accumulent dans les espèces		Non		
			secteur non nucléaire : industries pétrolières & gazières offshore, usages médicaux					

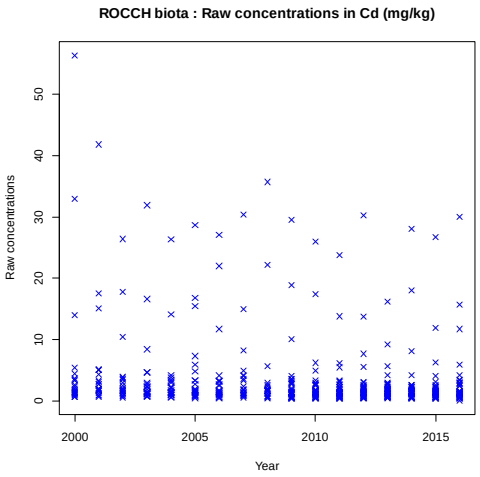
	Enrichissement en nutriments et en matière organique	Apports fluviaux nutriments MO	sources diffuses : interaction directe eau pluie-sol sources ponctuelles : rejets (collectivités, industrie), mariculture	NB : pisciculture pleine mer + impact que conchyliculture. Apport nutriment (N, P) : déséquilibre=>eutrophisation. 68 sites touché en 2009 Audierne->Charente). zone + sensible : plupart zones côtières de Bret Sud et Loire jusqu'à ile Noirmoutier. zones sous influence des fleuves très sensibles, baie vilaine sensible à hypoxie. Apport mo. : surconso O2 pour autoépuration	Bilan modèle : B. L-B pp contributeur apports N & P. B A-G : contribue majo aux flux C			
		Apports atmosphériques nutriments (Focus uniquement sur N)			Bilan modèle estimation retombées atm N : ~24% apport N total => non négligeable MAIS : dilué dans GG (VS apport fluviaux c° lg cote) & variation retombées en fonction météo		complexe	

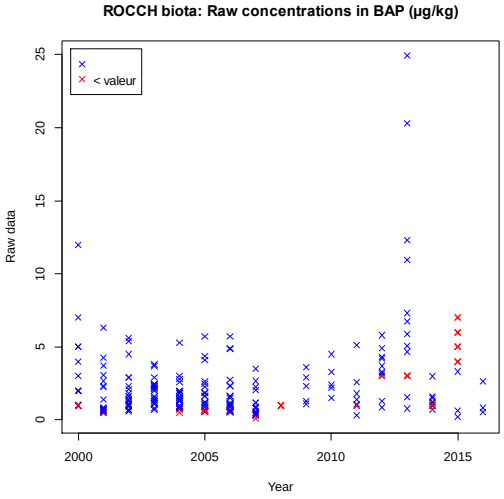
Pressions Biologiques	Introduction d'organismes pathogènes	Contamination coquillages : E. coli	<u>Origine urbaine</u> : station épuration, eaux usées… <u>Origine animal :</u> exploitation agricole (épandage, écoulement diffus& pâturage) <u>Origine humaine</u> : rejet en masse lors épidémies hivernales	contamination espèces => risque sanitaire lors consommation de coquillages & mortalité espèces		Non		REMI
		Contamination coquillages : bactéries pathogènes			peu études récentes=>données insuffisantes	Non	Manque de données	#
		Contamination coquillages : virus			pas info dispo => pas dispositif de surveillance, données rares	Non	Manque de données	#
		Introduction pathogènes espèces exploitées	aquaculture : concentration individus=> facilite propagation, transmission	mauvaise santé de l'élevage : maladie, mort individus	concerne principalement les fermes conchylicoles	Non		REPAMO
	Espèces non indigènes	Espèces non indigènes	culture marine (introduction délibérées, esp évadées, clandestines)	remplacement esp indigènes, chgmt communautés, modification niche écologique et des habitats voire création, compétition pour ressources, modification des conditions environnementales	125 esp introduites pp par cultures marines 37%. <u>Pp esp</u> : crassostrea gigas, crepidula fornicata, ruditapes philippinarum(palourde japonaise), ocenebra inornata(bigorneau perceur), sargassum mutium(sargasse japonaise), 2 esp de spartina, Bonamia ostrae (parasite huitre plate)	Oui	crépidules	
			Transport maritime : eaux de ballast et caisson de prise d'eau de mer					
			Transport maritime : biosalissures (aujourd'hui limité par les peintures antifouling)					
	Extraction sélective d'espèces	Extraction espèces : pêche	GG : capture pp côtier. Répartition métiers (débarquements) : Nord <u>GG</u> : 60% chalut, 25% bolinche. <u>Sud GG :</u> 1/3 chalut, 1/4 filet, reste : casier ou palangre	Impact sur l'état des ressources et des écosystèmes. P° direct sur les populations et indirects via réseau trophique. Diminution taille des espèces. Rejet contribue à la mortalité par pêche et dc incertitude sur l'évaluation des stocks concernés.	Pp espèces débarquées <u>N GG :</u> sardine, merlu, baudroies, maquereau, chinchard. <u>S GG</u> sole & merlu ~1/4	Oui		
		Rejets pêche	Pêche (cf. PI 32). Pp chaluts dont langoustiniers (rejets= 60% captures), trémail(27%) et filets(13%)		Rejet : pp langoustiniers(vasières) et merlus => rejet merlu petites taille. Rejets imp petits ind : raie cardines sole perdrix.	Non	Manque de données	
		Captures accidentelles	Pêche (cf. PI 32)	mort d'espèces emblématiques, protégées (mammifères marins oiseaux & tortues)	manque de données pour certaines espèces et pour la pêche récréative	Non	Manque de données	

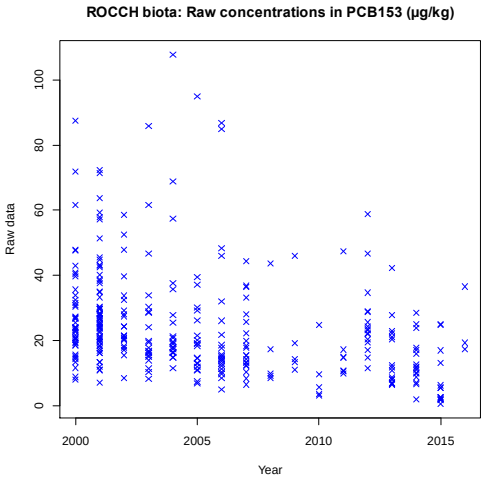
- Appendix 2. Biota: Timeseries of contamination concentration

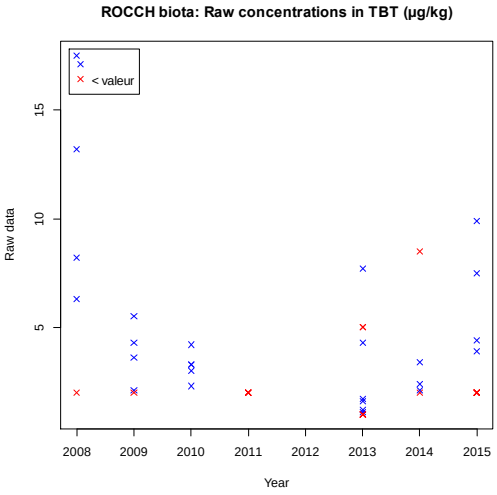




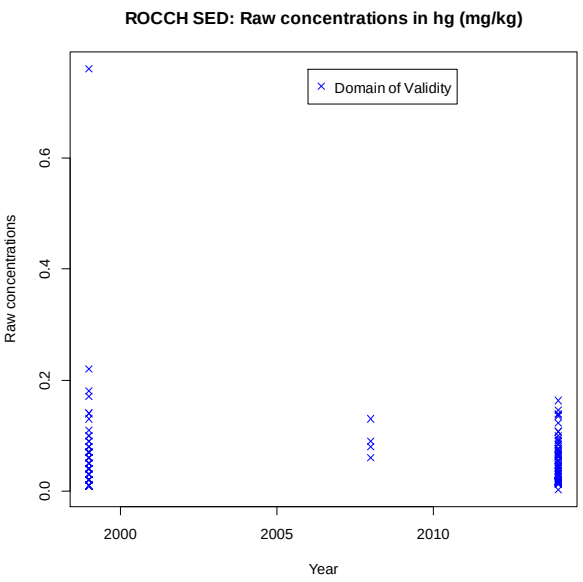


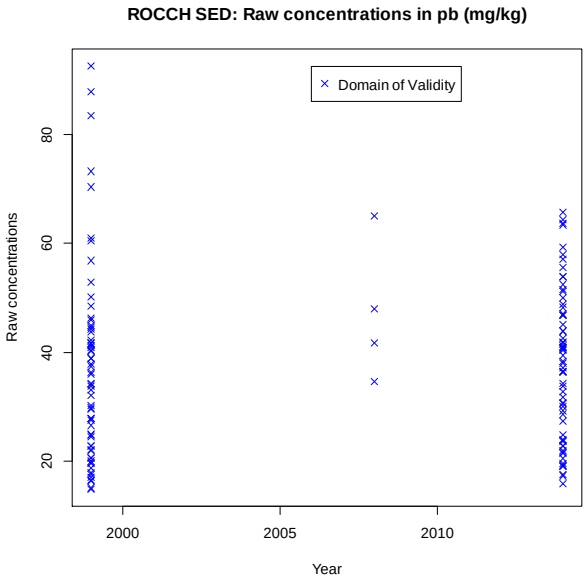


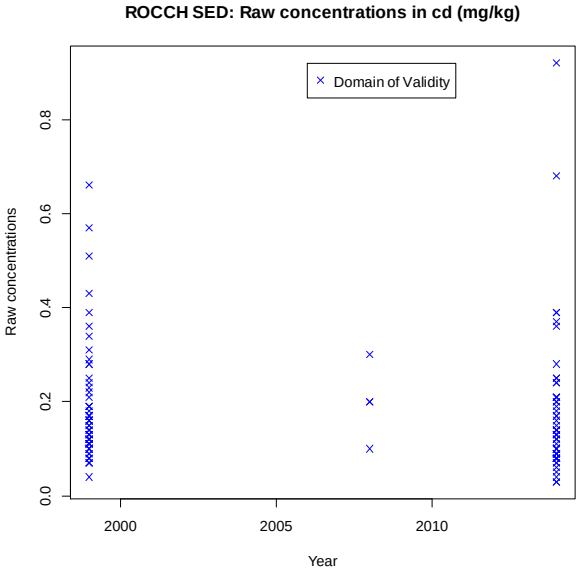


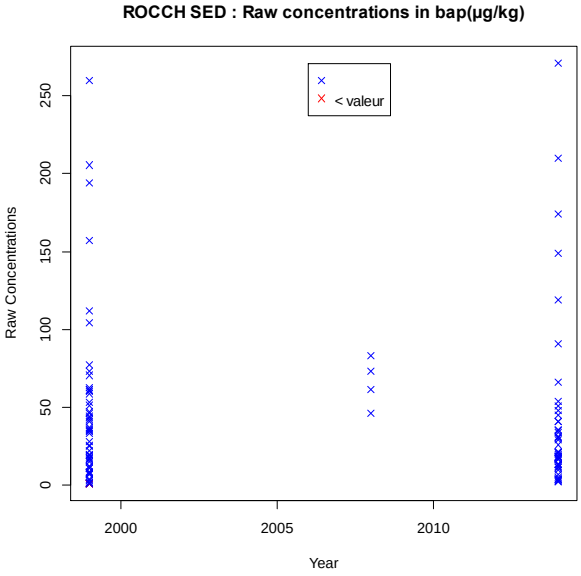


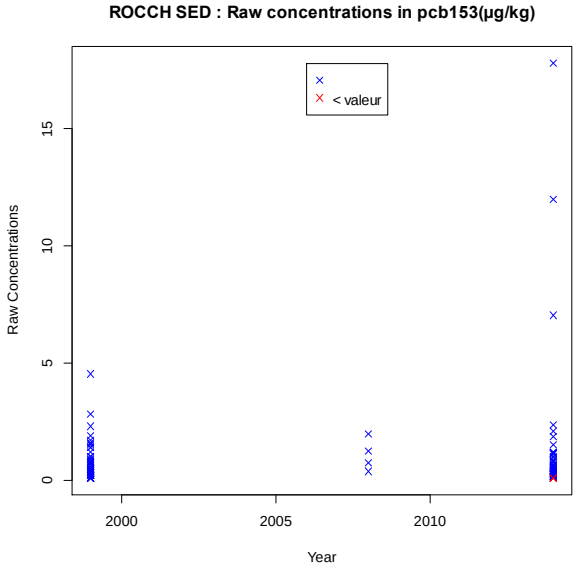
- Appendix 3. Sediment: Timeseries of raw contamination concentration

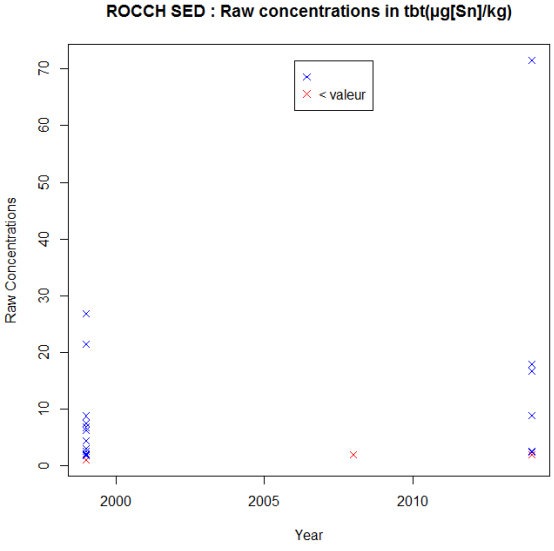




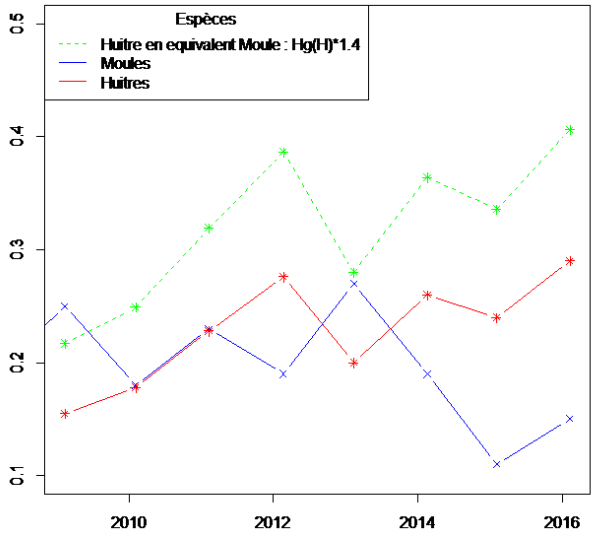


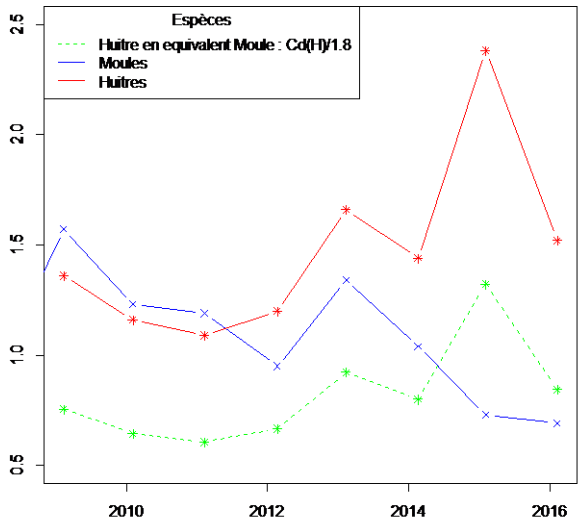


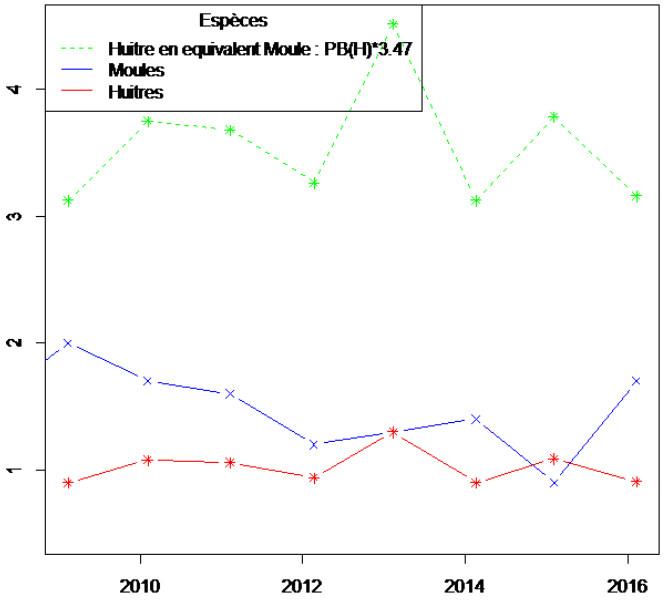




- Appendix 4. Study of the variation of concentration between oysters (red) and mussels (blue) applying O'Connor correction factor for oyster (green) for Mercury, Cadmium and Lead.







- Appendix 5. Standardization of sediment data and qualification of data

Sediment standardization

Metals concentrations were normalized to a standard granulometry. Aluminum is often used as a proxy of grain-size because it is naturally present at high concentration in marine environment being one of the main elements of clay (Covelli and Fontolan, 1997). Whereas organic compound concentrations were normalized to a standard composition in particulate organic matter. Organic carbon content is usually used as a proxy.

We normalized all metal concentrations to a 5% of Aluminum and organic concentrations to a 2.5% of organic carbon using the following formula:

$$C_{ss} = C_x + \frac{(C_m - C_x) * (N_{ss} - N_x)}{N_m - N_x}$$

With: C_{ss} normalized concentration

C_m measured concentration of the contaminant

C_x pivot value for the contaminant

N_x pivot value for the normalizer

N_m measured value of the normalizer

N_{ss} standard reference of normalizer concentration

N_{ss}(Al)= 50 000 mg/kg & N_{ss}(C)= 2500 mg/kg

The pivot value C_x and N_x are the concentration in a pure sand fraction (sediment without the silt and clay fractions). We used the values defined by the ROCCH network for the bay of Biscay (RNO 2005, 2005).

Table 4. Pivot values for metals

	Element	Pivot value (mg/kg)
Nx	Al	10 200
Cx	Cd	0.05
	Hg	0.002
	Pb	8.5

But for organic matter and carbon, which are not present in pure sand, pivot values are null. Thus, the formula simplifies to

$$C_{ss} = \frac{C_m * N_{ss}}{N_m}$$

Data qualification

Metals need further investigations concerning the aluminum concentration. Aluminum concentration needs to be higher than the normalizer pivot value otherwise the relation metal/aluminum is no longer linear. Moreover, if the relation is no longer valid, the formula cannot be used to normalize metal concentration. As a precaution, the threshold for the linear relation was set to 13 000 mg/kg as recommended by Ifremer for the DCSMM evaluation (Mauffret et al., 2018). This condition was respected for all the station. Such filter is not needed for organic carbon because there is no pivot.

Another problem to assess the concentration of metal contaminant can be the salinity. Studies (Chiffoleau et al., 2001; Du Laing et al., 2008) have showed that salinity can affect availability of heavy metal. As salinity increases in an estuary Lead will be less bioavailable and Cadmium will be more soluble (Figure 15)

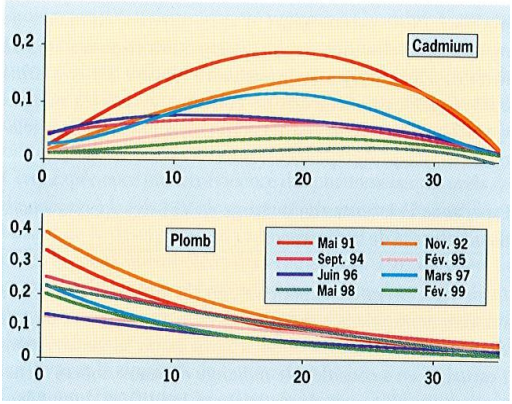
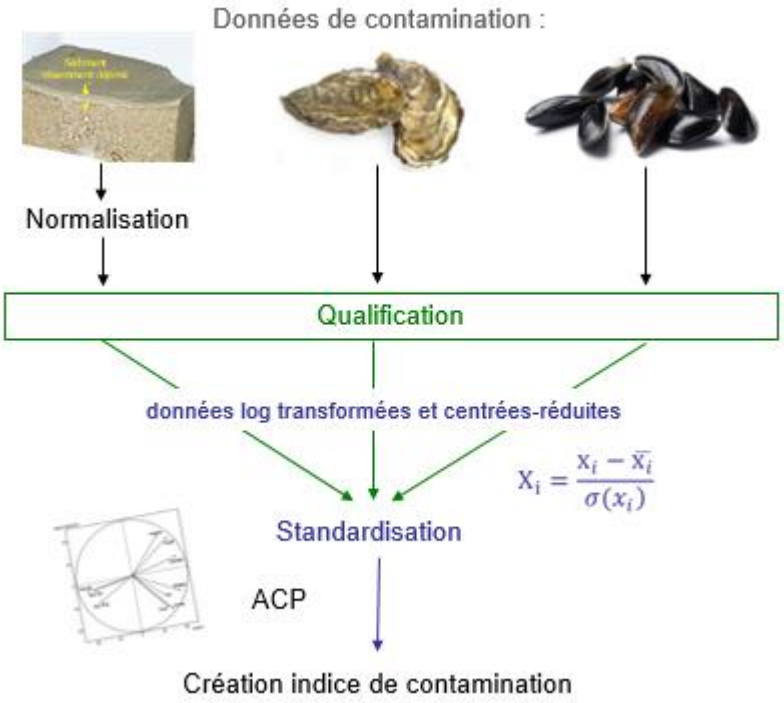


Figure 15. Distribution of dissolved metals (µg/l) as a function of salinity for the Seine estuary (Chiffoleau et al., 2001)

The range of salinity was checked for the area studied. For all nurseries grounds, the salinity varies between 31 ppm and 36 ppm. According to the figure 16, in this range of salinity the impact of salinity variation on Lead and Cadmium bioavailability is negligeable.

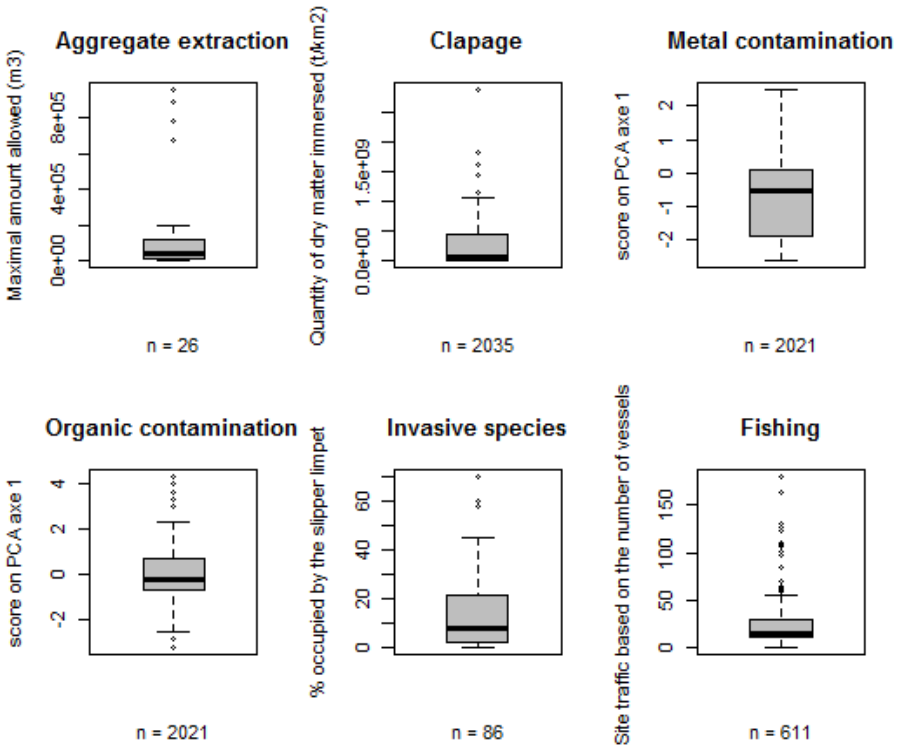
-Appendix 6. Diagram of the different steps of data process for metal and organic compounds



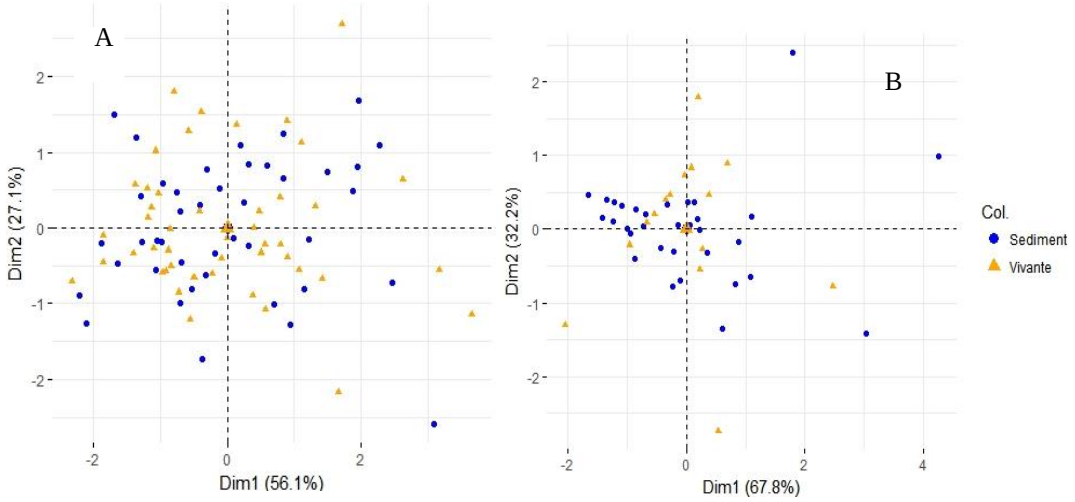
-Appendix 7. Satellite image showing the plumes of three estuaries selected: Vilaine, Loire and Gironde (image from http://regard-sur-la-terre.over-blog.com/tag/oceanographie)



-Appendix 8. Dispersion of the pressure indices

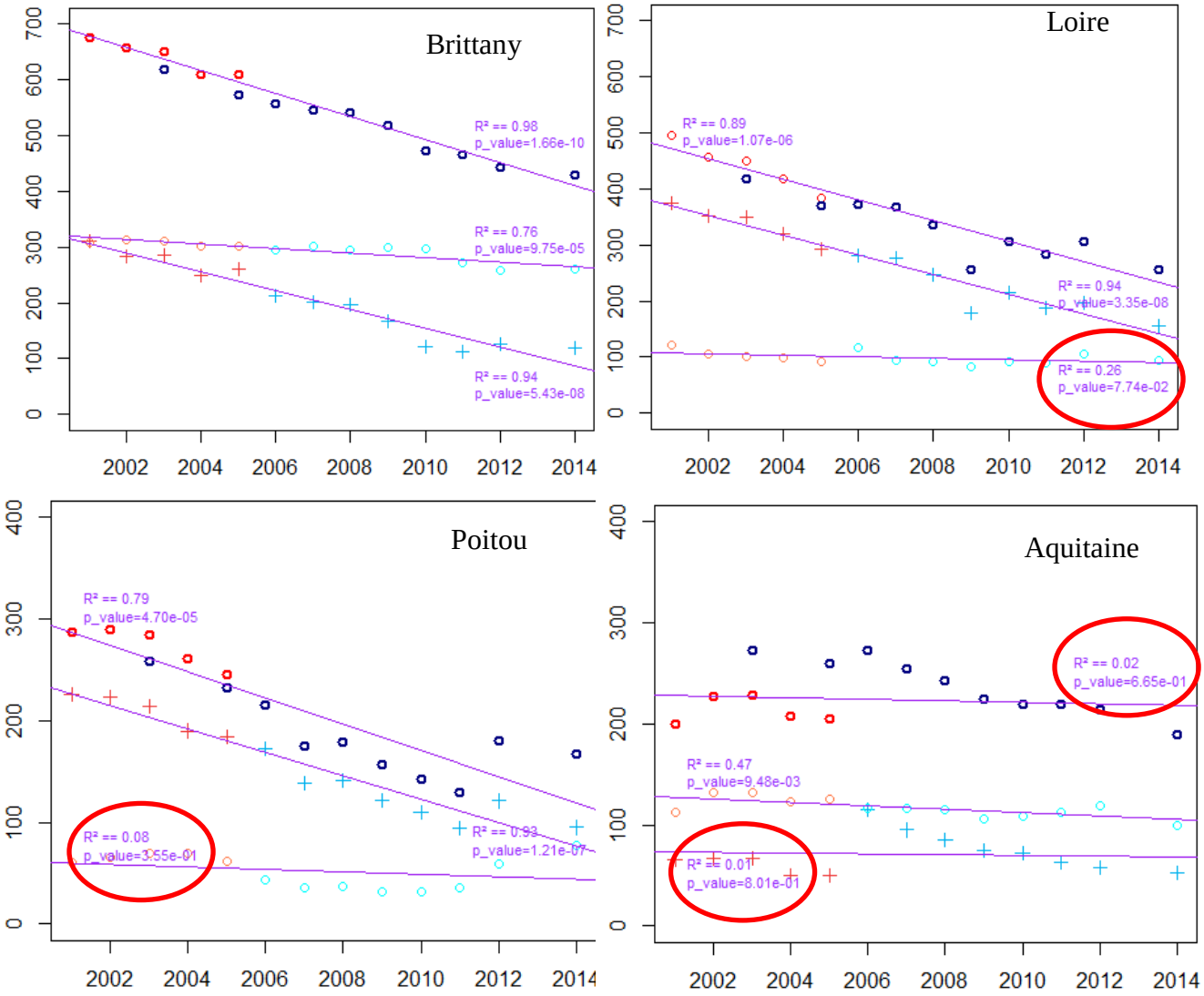


- Appendix 9. Results of the PCAs



Repartition of individuals (stations) depending on the matrix for metals (A) and organic (B) compounds

- Appendix 10. Linear Regression on both access and syntheses data [2001-2014]



- Appendix 11. Comparison of slopes and p-values between the two regressions

Region	Towed Gears		Passive Gears		Coastal fleet	
	Regression 1 Slope (p-value)	Regression 2 Slope (p-value)	Regression 1 Slope (p-value)	Regression 2 Slope (p-value)	Regression 1 Slope (p-value)	Regression 2 Slope (p-value)
Aquitaine	-0.36 (8 e-01)	-7.38 (2.6 e-04)	-1.65 (9.5 e-03)	-1.4 (1.5 e-01)	-0.75 (6.7 e-01)	-7.9 (9.7 e-06)
Poitou Charente	-11.5 (1.2 e-07)	-8.5 (6.1 e-03)	-1.15 (3.6 e-01)	+4.1 (5.8 e-02)	-12.8 (4.7 e-05)	-9.4 (7.5 e-03)
Loire	-17.6 (3.4 e-08)	-15.6 (2.9 e-03)	-1.4 (7.7 e-02)	-0.9 (5.8 e-01)	-18.4 (1.1 e-06)	-14.3 (6.4 e-04)
Bretagne	-16.9 (5.4 e-08)	-14 (2.7e-03)	-3.95 (9.8 e-05)	-5.75 (8.5 e-03)	-20.65 (1.7 e-10)	-18 (1.8e-07)

With :
- Regression 1: Regression on both access and syntheses data [2001-2014]
- Regression 2: Regression only on the syntheses data [2006-2014]

Legend:

Statistically significant

Statistically insignificant

Significantly underestimated

Significantly overestimated

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Titre français : Pressions anthropiques et nourriceries du golfe de Gascogne : identification, variations spatiales et représentation synthétique

Titre anglais : Anthropogenic pressures and Bay of Biscay nurseries: identification, spatial variations and synthetize representation.

Résumé :

Les écosystèmes côtiers et estuariens assurent de multiples rôles, comme celui de nourriceries pour les juvéniles de nombreuses espèces marines. Mais ces écosystèmes subissent également de multiples pressions issues d'activités d'origine anthropique. La compréhension des effets de ces pressions engendrés sur les communautés marines nécessite de bien identifier, voire quantifier, les activités humaines et les pressions qu'elles engendrent. Cette étude se concentre sur une sélection de cinq pressions anthropiques s'appliquant sur six zones de nourriceries du golfe de Gascogne. L'objectif de ce stage est d'identifier et quantifier ces pressions afin de développer un indice global permettant de comparer l'empreinte spatiale de ces dernières sur les nourriceries côtières et d'identifier les zones à forts enjeux anthropiques. Deux de ces pressions, la contamination chimique et la pêche, ont fait l'objet d'une analyse plus poussée afin de comprendre en compte leur dynamique, d'assurer leur qualité et de pallier à un manque de résolution spatiale suffisante pour ce travail. Les données de pressions "ponctuelles" ont également été spatialisées en utilisant la méthode dite "des buffers" pour apprécier la dispersion spatiale de ces pressions. Un premier indicateur global de pression a été construit pour chaque nourricerie. Le niveau global de chaque pression a également été étudié dans chaque nourricerie.

Abstract:

Estuarine and coastal ecosystems fulfill a variety of essential ecological functions, such as nursery grounds for juveniles of several marine species. However, those ecosystems are also subject to multiples pressures from human activities. Assessing the effect of anthropogenic pressure on marine communities requires to identify and quantify anthropogenic pressures. This study focus on five selected anthropogenic pressures applying on six nurseries in the Bay of Biscay. The aim is to identify and quantify those pressures to develop a global pressure indicator that will allow us to compare and identify area with high levels of anthropogenic disturbance. Pressures linked to fishing activity and chemical contamination were further investigated to apprehend their dynamic, ensure data quality and to overcome a lack of spatial resolution. Punctual data were also spatialized using a buffer type approach to assess their spatial distribution. A first global pressure indicator was built for each nursery. Average levels of each pressure were also studied in each nursery.

Mots-clés : indicateur spatialisé, spatialisation de données ponctuelles, contamination chimique, scenario de pêche, nourriceries côtières

Key Words: spatialized indicator, data source point spatialization, chemical contamination, fishing scenario, coastal nursery