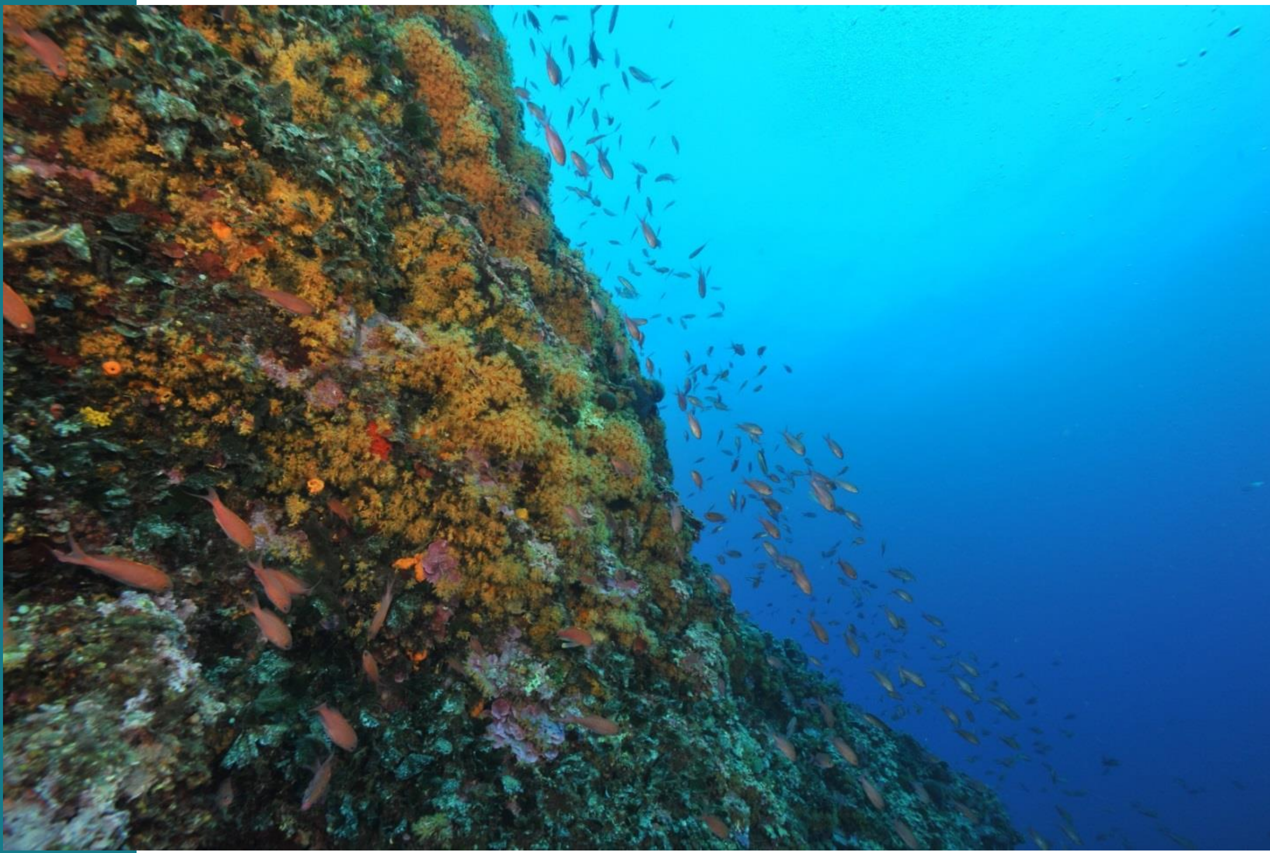
Directorate of Research and Scientific Expertise

Sustainable Development, Nature Conservation and Scientific Expertise Division

MUSÉUM NATIONAL D'HISTOIRE NATURELLE

Natural Heritage Service

Marie La Rivière, Annabelle Aish, Olivier Gauthier, Jacques Grall, Laurent Guérin, Anne-Laure Janson, Céline Labrune, Thierry Thibaut, Eric Thiébaut



Assessing benthic habitats' sensitivity to human pressures: a methodological framework

Summary Report

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

Ministère de l'Environnement, de l'Énergie et de la Mer

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The Natural Heritage Service (SPN)

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The Natural Heritage Service (SPN) of the French Natural History Museum (MNHN) provides scientific advice on biodiversity and geodiversity conservation at a national level. This role includes gathering, analysing and disseminating data via the National Inventory of Natural Heritage (inpn.fr), assessing trends in the state of France's natural heritage and providing scientific support on environmental policy implementation in both mainland France and its overseas territories.

The SPN acts as an intermediary between the scientific research community and decision-makers, and is principally funded by the Ministry of Ecology, as well as other public bodies and a number of private institutions. It works in close partnership with regional, national and international organisations involved in the conservation and management of marine and terrestrial biodiversity.

One overarching goal: to contribute to nature conservation by providing the best available scientific knowledge and expertise.

For more information: http://www.spn.mnhn.fr

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The National Inventory of Natural Heritage (INPN) is an information system developed to centralise, manage and disseminate data on species, habitats, protected areas and the geological heritage of mainland France and its overseas territories. It is the national platform for the French "Information System on Nature and Landscapes" (SINP) and covers both marine and terrestrial environments.

The INPN publishes biodiversity data online according to agreed geographic and taxonomic standards. Data can be accessed at various spatial resolutions: protected areas, 10 x 10 km grids, marine zones, departments and communes. Once validated, this data is used to track and assess biodiversity, as well as to support the development of nature conservation strategies and management plans.

The INPN is the statutory responsibility of the French Natural History Museum (MNHN) (art. L 411.5 of the French Environment Code), and is managed by the Museum's Natural Heritage Service (SPN-MNHN). Data is provided by numerous partner institutions and individuals across France and internationally.

For more information : http://inpn.mnhn.fr

Funded by the French Ministry of Environment, Energy and the Sea (MEEM)

Project Manager: Marie La Rivière (SPN/MNHN) – Contact : mlariviere@mnhn.fr

Marine Team Leader: Annabelle Aish (SPN/MNHN)

Co-authors: O. Gauthier (UBO, LEMAR UMR 6539), J. Grall (UBO, IUEM Observatoire), C. Labrune (UPMC-CNRS, LECOB UMR 8222), T. Thibaut (Univ. Aix Marseille-CNRS, MIO), E. Thiébaut (UPMC, Station Biologique de Roscoff, UMR 7144), A.-L. Janson et L. Guérin (MNHN-Station Marine de Dinard)

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List of abbreviations and acronyms

BRGM: French Geological Survey (Bureau de Recherches Géologiques et Minières)

DEB: Water and Biodiversity Department of the French Ministry of Environment (MEEM)

EUNIS: European Nature Information System

HD: Habitats Directive (92/43/CEE)

ICES: International Council for the Exploration of the Sea

ICG: Intersessional Correspondence Group

ICG-C: ICG on Cumulative Effects

ICG-COBAM: ICG on Biodiversity Assessment and Monitoring

ICG-POSH: ICG on the implementation follow up of measures for the Protection and conservation Of Species and Habitats

IFREMER: French Research Institute for the Exploitation of the Sea

INPN: National Inventory of Natural Heritage

JNCC: Joint Nature Conservation Committee

MarLIN: Marine Life Information Network

MBA: Marine Biological Association of the United Kingdom

MEEM: Ministry of Environment, Energy and the Sea

MNHN: French Natural History Museum

MPA: Marine Protected Area

MSFD: Marine Strategy Framework Directive (2008/56/UE)

NE: Natural England

OSPAR: Convention for the protection of marine environment of the North-East Atlantic

SPN: Natural Heritage Service

1. Introduction

Understanding benthic habitats' sensitivity to anthropogenic pressures is fundamental to the effective management of the marine environment. Sensitivity assessments are required to:

- identify pressures that may compromise the achievement or maintenance of good environmental (or favourable conservation) status,
- assess the risk of impact (vulnerability) related to human activities,
- help prioritise management measures at a local, regional and national scale.

These actions are essential to delivering the objectives set out under European Directives, including the Habitats Directive (HD, 92/43/EEC) and the Marine Strategy Framework Directive (MSFD, 2008/56/CE), as well as those of the Regional Sea Conventions such as OSPAR (Convention for the protection of the marine environment of the North-East Atlantic).

At the request of the French Ministry of Environment (MEEM) the SPN-MNHN, in close collaboration with benthic scientists, developed a methodology to assess the sensitivity of French benthic habitats to anthropogenic pressures[1].

Based on this methodology, a database of benthic habitats' sensitivity will be made publicly available with the goal of supporting marine management decisions. The process of evaluating habitat sensitivity will also highlight those habitats and/or pressures for which information is lacking.

This methodology aims to be (i) pragmatic (ii) applicable to all benthic habitats and relevant human pressures (iii) consistent (insofar as possible) with other equivalent European methodologies, iv) able to produce standardised results at a national level, v) adaptable to both site-scale and regional scale marine management (under the HD, MSFD, OSPAR, etc.), and (vi) based on best available knowledge.

This document presents a breakdown of the methodology, including key terminology and concepts employed, habitat and pressure units, and assessment rules. It is based on a **more detailed report published in French by the MNHN in 2015 (La Rivière *et al.*, 2015).**

2. General approach

As a first step, the SPN-MNHN reviewed existing approaches to assessing marine habitats' sensitivity from other countries (United Kingdom and Australia) (Table 1). This review was presented at a workshop held in Paris in January 2015, which gathered French benthic habitat experts ("Group 1" in charge of methodological development), a representative from the Marine

[1] Sensitivity to natural pressures is not considered within the scope of this project.

Biological Association (MBA) of the United Kingdom, as well as MNHN colleagues involved in MSFD advice and implementation.

Table 1. Summary of approaches used in other countries to assess marine habitat sensitivity

Country	Name	References
United Kingdom	MarLIN	Hiscock *et al.*, 1999, Tyler-Walters *et al.*, 2001
	MB102	Tillin *et al.*, 2010
	MB102 plus	D'avack *et al.*, 2014, Gibb *et al.*, 2014, Mainwaring *et al.*, 2014
	Beaumaris	Hall *et al.*, 2008, Eno *et al.*, 2013
Australia	ERAEF	Hobday *et al.*, 2011, Williams *et al.*, 2011

The draft methodology developed at this workshop was subsequently submitted to a second group of benthic habitat experts ("Group 2") tasked with providing a critical review of the methodology (Figure 1).

It was decided that the evaluation of benthic habitat sensitivity would be based principally on expert judgement (drawing on available scientific literature wherever possible), following recommendations from Mcbride *et al.* (2012) and Barnard and Boyes (2013). Benthic scientists from both the Mediterranean and Atlantic/English Channel/North Sea were asked to contribute to evaluations, with the SPN-MNHN ensuring that their collective expertise covered habitats of both hard and soft substrata.

SPN-MNHN also worked closely with organisations from other countries (JNCC, NE, MBA) and considered the outputs of various international working groups (OSPAR (ICG-COBAM, ICG-POSH, ICG-C), ICES (Benthos Ecology Working Group) and research projects (BenthoVal, Benthis, Index-Cor, etc.) in order to ensure consistency between approaches at a European/North East Atlantic scale.

2.1. Key concepts

All project terminology was defined to avoid confusion in the use of concepts employed (Box 1).

The concept of sensitivity can be divided into two separate parameters: **resistance** and **resilience**. These were first described by Holling (1973) and are used to assess sensitivity under the OSPAR convention (Texel-Faial criteria) and under French MSFD legislation (MEDDE, 2012).

Resistance[2] is defined as the ability of a habitat to tolerate a pressure without a significant change in its biotic and abiotic characteristics.

[2] « Tolerance » is often used as a synonym of « resistance ». "Intolerance" or "fragility" are sometimes used to convey the opposite of resistance.

Resilience[3] is the time needed for a habitat to recover, once the pressure in question has been alleviated (Box 1).

Sensitivity is therefore assessed as a combination of these two parameters, with a final score for each habitat derived from its resistance and resilience scores to each pressure. Resistance and resilience scores are based on a range of criteria including structuring/characteristic/engineer species' sensitivity, substratum type, and biological community characteristics. This approach is similar to the so-called « MB102 » method (Tillin *et al.*, 2010) developed in the United Kingdom. This methodological compatibility will facilitate the joint use of sensitivity data between France and the UK for "shared" habitats (such as in the English Channel).

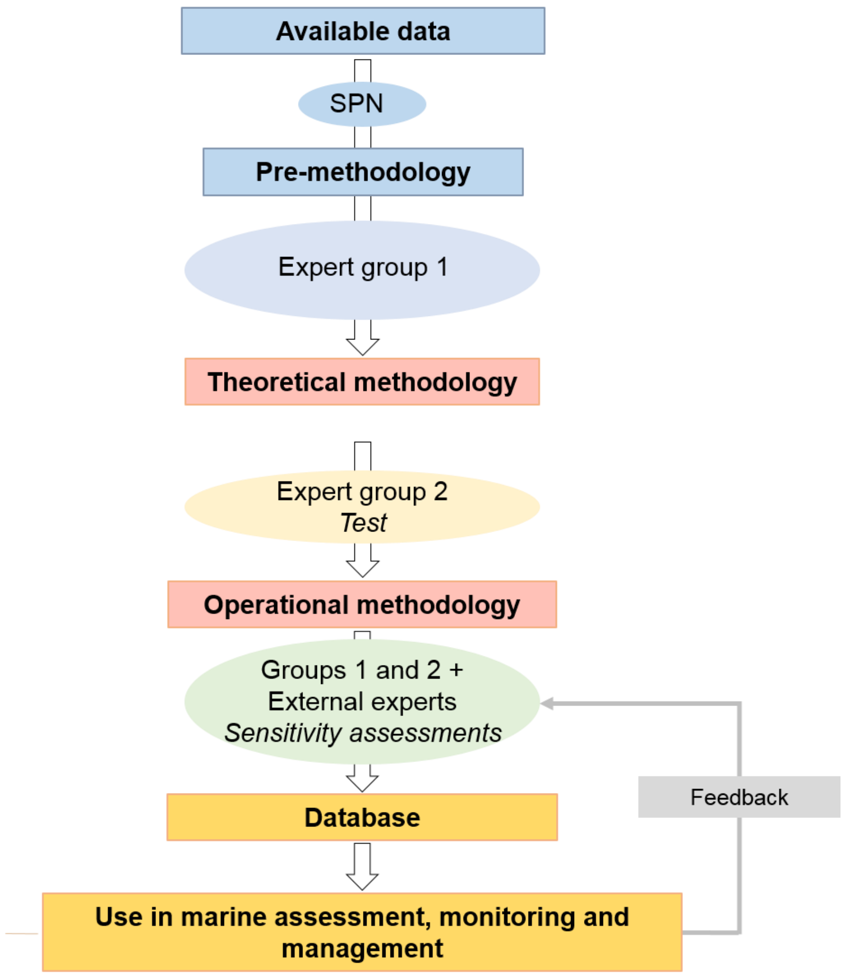

Figure 1. Process of methodological development and habitat sensitivity evaluation

[3] « Recovery » and « recoverability » are often used as synonyms of « resilience ». Resilience and recoverability describe an ability, while recovery describes a process.

Box 1. Terminology[1]

Anthropogenic pressure: The mechanism through which a human activity can have an effect on a habitat. Pressures can be physical[2], chemical or biological. The same pressure can be caused by a number of different activities.

Exposure: The presence of a pressure in/on a habitat. Levels of exposure to a pressure can vary temporally (according the pressure's frequency and duration) and spatially (according to the pressure's distribution).

Habitat: Terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural (Directive 92/43/EEC).

Impact (= Effect): The consequences of a pressure on a habitat where a change in its biotic and/or abiotic characteristics occurs[3].

Intensity: The combination of magnitude, frequency and duration of a pressure[4].

Resilience: The time a habitat needs to recover from the effect of a pressure, once that pressure has been alleviated[5].

Resistance: The ability of a habitat to tolerate a pressure without significantly changing its biotic or abiotic characteristics.

Risk of impact (=Vulnerability): The combination of the likelihood that a feature is exposed to a pressure to which it is sensitive and its sensitivity to that pressure[6].

Sensitivity: The combination of a habitat's capacity to tolerate a pressure (resistance) and the time needed to recover after an impact (resilience).

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[1] Definitions drawn and adapted from Goodsir *et al.* (2015); Hiscock et al. (1999); Holling (1973); Holt *et al.* (1995); Judd *et al.* (2015); La Rivière *et al.* (2015); Laffoley *et al.* (2000); McLeod (1996); Robinson *et al.* (2008); Tillin *et al.* (2010); Tillin and Tyler-Walters (2014); Tyler-Walters *et al.* (2001); Zacharias and Gregr (2005).

[2] Specific definitions of physical pressures are presented in Table 2.

[3] In some scientific/management contexts « effect » and « impact » are not used interchangeably.

[4] Some publications refer to « intensity » to qualify a pressure or an activity, but with a different definition.

[5] Other interpretations of « resilience » can be found in the scientific literature. The definition presented here corresponds to that most frequently used under the MSFD/ OSPAR.

[6] « Vulnerability » is often used as a synonym of « risk of impact ».

2.2. Pressures

Sensitivity assessments are pressure-based. An anthropogenic pressure is defined as the mechanism through which a human activity can have an effect on a habitat (Robinson *et al.*, 2008). Pressures can be physical, chemical or biological. A single activity can generate one or more pressures and the same pressure can result from one or more activities (Figure 2).

An impact is defined as the consequence of a pressure, expressed as changes in a habitat's biotic and/or abiotic characteristics. Different pressures can have similar impacts on a habitat. The degree of impact depends on the duration, frequency and spatial extent of a habitat's exposure to a pressure as well as the pressure's magnitude.

As a first step, habitat sensitivity to 12 physical pressures was evaluated (see Table 2). Other physical, biological and chemical pressures will be defined and assessed in the next phase of this project.

Pressures (and pressures categories) used in this methodology are based on existing lists of pressures under the MSFD (Annex III Table 2) and OSPAR (ICG-C pressures list, OSPAR 2011) to ensure consistency at a European level[4]. Similar pressure definitions ensure that i) habitat sensitivity is assessed with respect to equivalent thresholds or benchmarks and ii) the relative sensitivity of different habitats can be compared[5].

Pressures are defined based on their i) ecological relevance (would the pressure at this magnitude affect benthic habitats?) and ii) technical relevance (do human activities generate the pressure at this magnitude?).

Assumptions and limitations:

- Only single (one-off) pressure events are assessed (e.g. surface abrasion from the pass of one trawl, or habitat removal from one aggregate extraction event).
- Resilience can only be considered if the pressure has been alleviated or reduced to a magnitude that no longer causes an impact (i.e. allowing habitat recovery).
- The spatial extent of a pressure is assumed to allow for habitat recovery via recolonization (from remaining habitat "edges" or from adjacent areas). If the total surface area of a habitat is destroyed and recolonization is unlikely, the assessment of the resilience is not considered relevant.

[4] The 12 physical pressures' relationships with OSPAR/ICG-C and MSFD pressures are presented in Annex 2.

[5] Where sensitivity information is shared internationally, particular attention should be paid to pressure definitions as well as resistance and resilience categories and associated sensitivity scores.

- The pressures listed in Table 2 include both direct and indirect pressures arising from human activities[6].
- Only single pressures are assessed via this methodology. It was not possible to consider the effects of multiple pressures acting on a habitat, despite this being commonplace in the marine environment[7].
- The duration, frequency and spatial scale of pressures and their potential cumulative effects should be considered in the development of appropriate management measures.

[6] A matrix linking pressures with human activities, developed in close collaboration with technical experts (IFREMER, BRGM, etc.) has been published separately.

[7] Pressures can interact in complex ways, and their effects can be additive, synergistic, or antagonistic (Folt *et al.*, 1999; Crain *et al.,* 2008; Stelzenmüller *et al.*, 2010; Halpern and Fujita, 2013; Clarke Murray *et al*., 2014; Aish *et al.*, in press).

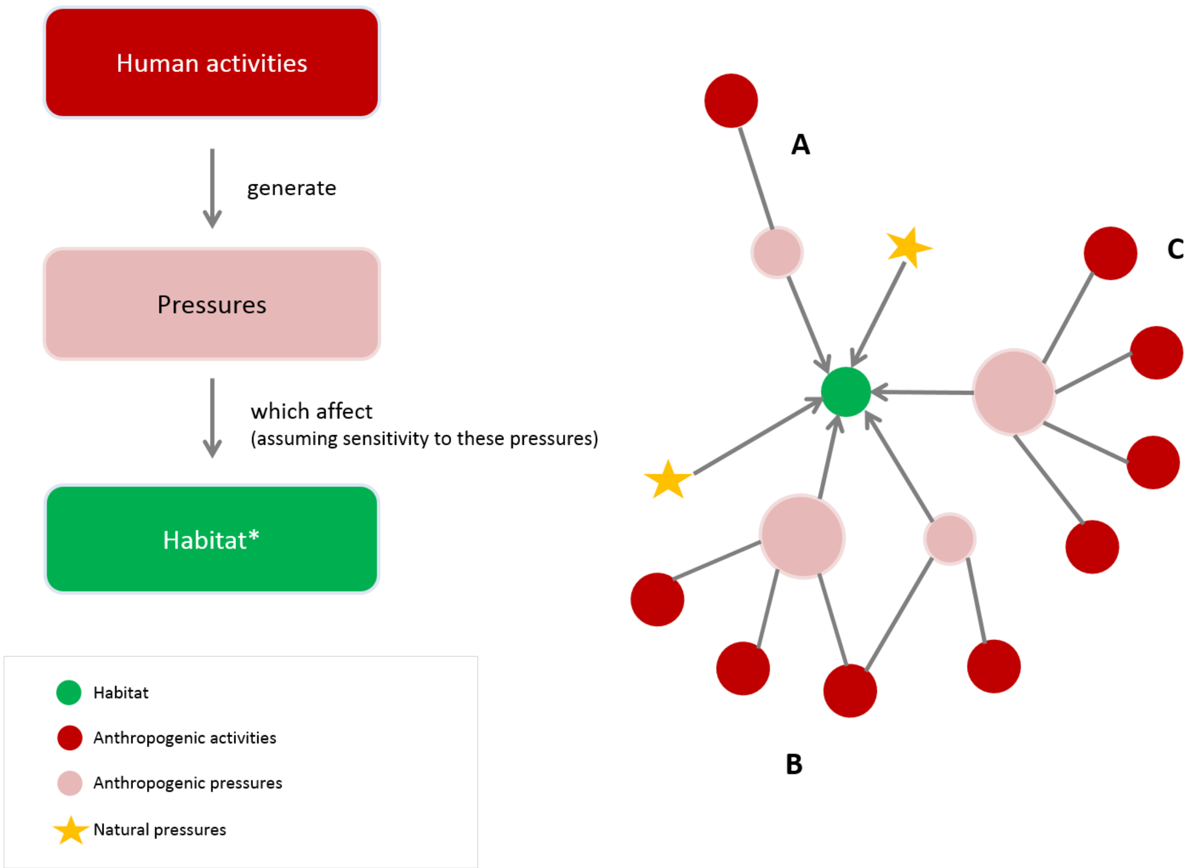

Figure 2. Conceptual relationship between different sources of pressures affecting a habitat in 3 different scenarios (A, B and C)

Different human activities (red circles) create different pressures (pink circles) on a habitat (green circle), with their relative (cumulative) intensity indicated by the size of the circle. The greater the number of activities generating the impacting pressure, the greater likelihood of an impact on the habitat (assuming sensitivity to this pressure). A- A single activity-pressure pathway. B- Multiple activities causing multiple pressures. C- Multiple activities causing a single pressure. The yellow stars indicate « natural » pressures to the habitat (adapted from Knights et al., 2013 ; Clarke Murray et al., *2014 ; Aish* et al., *in press).*

Table 2. Pressure definitions

Pressure category	Pressure	Definition
Physical loss (permanent change)	**Habitat loss**	The permanent loss of an existing marine habitat to land or to a freshwater water habitat. All habitats are considered « very highly sensitive » to this pressure, although deep-sea habitats are considered « not exposed ».
	Habitat change (to another type)	The permanent replacement of one marine habitat by another marine habitat, through a change in substratum and/or a change in biological zone (depth band). This can be caused by i) the addition of a new substratum or ii) the extraction of existing substratum permanently exposing a different seabed type. For soft sediment habitats, a change in substratum is defined here as a change in 1 class of the modified Folk classification (see Annex 1). This includes change to artificial substratum. *NB: This pressure can arise from other physical pressures (physical disturbance or hydrological changes) where the magnitude, frequency or duration of exposure leads to a permanent change in habitat type.*
Physical disturbance or damage (temporary and/or reversible change) (1/2)	**Substratum extraction**	Substratum removal (including of biogenic habitats) which i) exposes substratum of the same type, or ii) temporarily exposes substratum of another type. *NB: This pressure becomes « habitat change » if:* - *The removal exposes substratum of a different type and environmental/hydrodynamic conditions do not allow the newly exposed seabed to return to its original substratum type* - *The depth of extraction leads to a change in bathymetry.*
	Trampling	The vertical compression of the seabed and its associated species.
	Surface abrasion	Mechanical action resulting in disturbance of the seabed surface and associated species (epifauna and epiflora), yet with limited or no loss of substratum.
	Light sub-surface abrasion	Mechanical action resulting in disturbance of the seabed and associated species either i) penetrating the sediment down to 5 cm depth or ii) scouring hard substrata.
	Heavy sub-surface abrasion	Mechanical action resulting in disturbance of the seabed and associated species either i) penetrating the sediment beyond 5 cm depth or ii) scouring hard substrata.
	Reworking of the sediment	The displacement and rearrangement of seabed sediment without any net loss of substratum. This pressure does not apply to hard substrata.

Category of pressures	Pressure	Definition
Physical disturbance or damage (temporary and/or reversible change) (2/2)	**Light deposition**	The addition of up to 5 cm of material on the seabed. This pressure concerns the addition i) of material of the same type as the original substratum, or ii) of a different type but where hydrodynamic conditions allow its rapid removal. *NB: This pressure becomes « habitat change » if the original biological communities are not able to recolonize the deposited substratum.*
	Heavy deposition	The addition of more than 5 cm of material on the seabed. This pressure concerns the addition i) of material of the same type as the original substratum, or ii) of a different type but where hydrodynamic conditions allow its rapid removal. *NB: This pressure becomes « habitat change » if the original biological communities are not able to recolonize the deposited substratum*
Hydrological changes	**Hydrodynamic changes**	Changes in water movement associated with tidal streams, currents, or wave exposure for less than 1 year. *NB: This pressure becomes « habitat change » where new hydrodynamic conditions provoke a change in biological composition by changing the immersion/emersion rate, or by changing the nature of the seabed.*
	Change in suspended solids	An increase in sediment or organic matter (particulate or dissolved) concentrations in the water column that leads to a change in water clarity and/or affects filter-feeding organisms, for less than 1 year. *NB: This pressure becomes « habitat change » if an increase in suspended matter permanently changes biological community composition.*

3. Assessment methodology

Evaluating habitat sensitivity involves the following steps:

- Identifying the key biotic and abiotic elements affecting habitat sensitivity;

- Assessing the habitat's resistance to the pressure in question;

- Assessing the habitat's resilience to the pressure in question

- Combining resistance and resilience scores to generate an overall sensitivity score.

The resistance, resilience and sensitivity categories are defined to be consistent with work undertaken in the United-Kingdom and under the OSPAR Convention (ICG-COBAM). The resulting sensitivity assessments are semi-quantitative (see semi-quantitative scale in 3.4).

Several criteria are used to qualify a habitat's resistance, resilience and sensitivity, including:

- Characteristic, structuring and/or engineer species' life traits[8] (Box 2) ;
- Substratum type;
- Hydrodynamic conditions;
- Bathymetric range;

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[8] These different categories of species are defined as follows:

- Characteristic species: a species that is exclusive or preferential for the biotope considered, whether it is represented widely or not, sporadic or not (PNUE-PAM-CAR/ASP, 2002).
- Structuring species: a species that provides a distinct habitat which supports an associated biological community. Degradation or loss of this species would result in degradation or loss of the associated community but not necessarily the habitat (Tyler-Walters *et al*., 2001) (e.g. gorgonians in a Mediterranean coralligenous habitat).
- Engineer species: a species that creates, modifies or maintains a habitat by causing physical state changes in biotic and abiotic materials, that directly or indirectly, modulate the availability of resources to other species (Jones *et al.*, 1994). Degradation or loss of this species would result in degradation or loss of the habitats it creates (e.g. calcareous algae of the coralligenous habitat). An engineer species is a structuring species, but the inverse is not true.

Box 2. Factors affecting benthic species' sensitivity

The following factors may affect the resistance and/or resilience (and thus sensitivity) of benthic species:

- Size and shape (growth form);
- Substratum position (e.g. epibenthic, infaunal, free-living);
- Depth in substratum (e.g. shallowly or deeply burrowed);
- Mobility/ability to move freely (e.g. permanently/temporarily attached, burrower, crawler, swimmer etc.);
- Flexibility and fragility;
- Dependence on type of substratum;
- Dependence on hydrodynamic conditions;
- Lifespan, growth rate, regeneration rate, age at sexual maturity;
- Reproduction mode and rate, larval dispersion capacity, recruitment rate, vegetative propagation, propagules.

3.1. Habitat units

Habitat sensitivity is assessed at the "biocenosis" level (which takes into account biotic and abiotic characteristics[9]), under the following habitat classification systems:

- **The French Mediterranean benthic habitat classification[10] ;**
- **The French Atlantic-English Channel-North Sea benthic habitat classification[11].**

Relationships between these national classifications and other classifications/habitat lists (EUNIS, OSPAR, HD Annex I, etc.) are available through the INPN (HABREF register)[12].

[9] This term is broadly equivalent to the term "biotope" in English (Dauvin *et al.*, 2008a; 2008b)

[10] Michez *et al.*, 2014 ; https://inpn.mnhn.fr/habitat/cd_typo/32

[11] The current version of this classification (Michez *et al.*, 2015) will be updated shortly, taking into consideration the latest modifications to the EUNIS classification (revision in progress): sensitivity assessments will therefore be based on the latest (updated) version of this classification.

[12] https://inpn.mnhn.fr/telechargement/referentiels/habitats?lg=en

3.2. Resistance

Resistance is defined as the ability of a habitat to tolerate a pressure without significantly changing its biotic or abiotic characteristics.

Four resistance categories are defined (Tableau 3).

Table 3. Resistance scale

None	Low	Medium	High
Habitat destruction, corresponding to a **total loss** of biotic characteristics (e.g. disappearance of characteristic, structuring and/or engineer species) and abiotic characteristics (e.g. loss of the substratum) **potentially causing a change of habitat type.**	**Severe degradation** of a habitat, corresponding to a **major loss** of its biotic characteristics (e.g. major decline in characteristic, structuring and/or engineer species) and abiotic characteristics (e.g. severe degradation of the substratum) **potentially causing a change of habitat type.**	**Some modification** of the habitat's biotic characteristics (e.g. decline in characteristic, structuring and/or engineer species) or abiotic characteristics (e.g. substratum degradation) **without changing the habitat type.**	**No notable modification** of the biotic or abiotic characteristics of the habitat. Some biological processes, like feeding, respiration and reproduction rates may be affected, but **no effect on population viability** of characteristic, structuring and/or engineer species.

3.3. Resilience

Resilience is defined as the time a habitat needs to recover from the effect of a pressure, once that pressure has been alleviated.

Five resilience categories are defined in relation to management timescales (Table 4)[13].

Resilience assumes that the pressure has been alleviated or reduced. Full recovery is a return to the state of the habitat prior to impact, i.e. to a structurally and functionally recognisable habitat and its associated biological community. This does not necessarily mean a return to prior condition, exact community composition, abundance or extent, nor to a hypothetical original ("reference") state. A habitat's recovery is determined by its capacity for regeneration or recolonization (by adults, larvae, spores or propagules of its associated species).

Table 4. Resilience scale

None	Low	Medium	High	Very High
at least 25 years	10-25 years	2-10 years	1-2 years	within 1 year

[13] This resilience scale is consistent with scales used in the United Kingdom for sensitivity assessments.

3.4. Sensitivity

Sensitivity is defined as the **combination of resistance and resilience** (see Table 5 and calculations from numerical scores in Annex 3).

Scores of resilience and resistance are presented along with the derived sensitivity score, because these parameters may have different management implications.

Table 5. Sensitivity scale defined by the combination of resistance and resilience scores

Resilience / Resistance	None > 25 yr	Low 10-25 yr	Medium 2-10 yr	High 1-2 yr	Very High < 1 yr
None	Very High	High	High	Medium	Low
Low	High	High	Medium	Medium	Low
Medium	High	Medium	Medium	Low	Low
High	Medium	Medium	Low	Low	Very Low

A **« not applicable »** category was created for habitats in mainland France that were not exposed to the pressure in question at the time of assessment.

3.5. Confidence index

A confidence index is assigned to each assessment (resistance, resilience, sensitivity) as an indication of the quality of supporting evidence.

Wherever possible, assessments are based on empirical data demonstrating the resistance and/or resilience of benthic habitats. Where such information is lacking, assessments are based on expert judgment (informed by recommendations set out by Mcbride *et al.* (2012) and Barnard and Boyes (2013).

Confidence scores are derived from the combination of three aspects for each resistance and resilience assessment (Tables 6 and 7):

- **Quality of information sources**: expert judgement, peer-reviewed papers, grey literature, etc. ;
- **Applicability of evidence**: the same habitat/area/pressure is evaluated;
- **Degree of concordance** of evidence and quantity of evidence available.

These three aspects are weighted according to their relative importance in order to derive an overall confidence score. *Quality* and *Concordance* are considered the most discriminating factors (weighting scale from 0 to 2), while more flexibility is ascribed to *Applicability* (weighting scale from 1 to 3).

Table 6. Confidence assessment categories

	Quality of information sources	**Applicability of evidence**	**Degree of concordance**
High	Based on peer reviewed papers (experiments and. observational studies) on the habitat	Assessment based on the same pressure acting on the same habitat in the same geographical area (Mediterranean Sea, Atlantic, English Channel-North Sea)	Many studies at multiple sites with high concordance of resistance and resilience assessments
Medium	Based on some peer reviewed papers, mostly on grey literature reports or expert judgment on the habitat or similar habitats	Assessment based on the same pressure acting on the same/equivalent habitat in a different geographical area	Few studies, or studies on a single site, or discrepancies in resistance or resilience assessments
Low	Based on expert judgement in the absence of sufficient or reliable published evidence	Assessment based on proxies for pressures (e.g. natural disturbance events) or on a similar habitat	Discrepancies in resistance and resilience assessments

Table 7. Combining the three confidence assessment category scores to derive a resistance or resilience confidence score

<table>
<tr><th rowspan="2">Quality</th><th rowspan="2">Applicability</th><th colspan="3">Concordance</th></tr>
<tr><td>Low - 0</td><td>Medium - 1</td><td>High - 2</td></tr>
<tr><td rowspan="3">Low
0</td><td>Low - 1</td><td colspan="3" rowspan="3">0
Low</td></tr>
<tr><td>Medium - 2</td></tr>
<tr><td>High - 3</td></tr>
<tr><td rowspan="3">Medium
1</td><td>Low - 1</td><td rowspan="6">0
Low</td><td>1 - Low</td><td>2 - Medium</td></tr>
<tr><td>Medium - 2</td><td>2 - Medium</td><td>4 - Medium</td></tr>
<tr><td>High - 3</td><td>3 - Medium</td><td>6 - High</td></tr>
<tr><td rowspan="3">High
2</td><td>Low - 1</td><td>2 - Medium</td><td>4 - Medium</td></tr>
<tr><td>Medium - 2</td><td>4 - Medium</td><td>8 - High</td></tr>
<tr><td>High - 3</td><td>6 -High</td><td>12 - High</td></tr>
</table>

Three levels confidence are defined by combining these 3 aspects (quality, applicability, concordance) using the combination matrix in Table 7:

Scores 0-1: Low

Scores 2-4: Medium

Scores 6-12: Haut

Resilience and resistance confidence scores are then combined to derive the sensitivity assessment's confidence score (Table 8).

Table 8. Combination of resistance and resilience confidence indices (CI) to derive the sensitivity confidence score

		CI Resilience		
		Low	**Medium**	**High**
CI Résistance	**Low**	Low	Low	Low
	Medium	Low	Medium	Medium
	High	Low	Medium	High

Each assessment is thus transparent, with the evidence base and justification for the assessments recorded in the final assessment matrix[14].

3.6. Assessment matrix

Data derived from the sensitivity assessments are presented in a sensitivity database. Data will be published in two stages (first of all for French Mediterranean habitats, then for French Atlantic-English Channel-North Sea habitats).

The methodological report is available online, as well as assessment matrices by biogeographic region (PDF and Excel files) (Figure 3).

[14] Only the overall confidence indices for each parameter (resistance, resilience, sensitivity) are published.

I.4.1 Supralittoral rock									
Relationship with other classifications									
Category	**Pressure**	**Resist.**	**CI resist.**	**Resil.**	**CI resil.**	**Sensit.**	**CI sensit.**	**Evidence base**	**Evidence type**
Physical loss (permanent change)	**Habitat loss**	N	H	N	H	VH	H	All marine habitats are considered to have no resistance to this pressure and to be unable to recover from a permanent loss of habitat, although no specific evidence is described.	Expert judgement. Confidence index is High due to the permanent nature of impacts arising from this pressure.
	Habitat change (to another type)	N	H	N	H	VH	H	A change in substratum or a change in biological zone (depth band) will lead to a total loss of the habitat's characteristics. By definition, this habitat will not be able to recover on a different substratum or at a different depth.	Expert judgement. Confidence index is High due to the permanent nature of impacts arising from this pressure.
Physical disturbance or damage (temporary and/or reversible change)	**Substratum extraction**	N	H	M	M	H	M	Most of this habitat's characteristic species (lichens, gastropods, crustaceans, etc.) are sessile and will be lost along with the substratum. The time needed for characteristic species to recolonize the newly exposed substratum is estimated at around 5 years, because (i) these species have short life cycles and a strong recruitment and dispersion capacity, and (ii) this habitat is naturally exposed to high wave energy. Resilience depends on the presence of a healthy similar habitat (with mature individuals) in close vicinity. **NB**: If the depth of extracted substratum is too great, there is a risk of changing the habitat to a mediolittoral habitat.	Expert judgment. Directly relevant grey literature; Inference from studies on comparable habitats (Tillin *et al.,* 2010). Resistance's confidence index is High as this pressure affects the habitat's depth.
	Trampling	H	M	M	M	L	M	Most of this habitat's characteristic species are encrusting and/or have a hard exterior, and thus are highly resistant to vertical compression. Nevertheless, if the integrity or functionality of the habitat is compromised, the time needed for recovery is estimated at around 5 years. **NB**: in the case of chronic trampling, resistance and resilience capacities will be altered.	Expert judgement. Inference from directly relevant peer reviewed literature (Brosnan et Crumrine, 1994)
	Surface abrasion	N	H	M	L	H	M	Most of this habitat's characteristic species (lichens, gastropods, crustaceans, etc.) are sessile and will be lost if the habitat is subject to abrasion. The time needed for characteristic species to recolonize the newly exposed substratum is estimated at around 5 years, because (i) these species have short life cycles and a strong recruitment and dispersion capacity, and (ii) this habitat is naturally exposed to high wave energy. Resilience depends on the presence of a healthy similar habitat (with mature individuals) in close vicinity.	Expert judgment. Directly relevant grey literature; Inference from studies on comparable habitats (Tillin *et al.,* 2010).

Figure 3. Example of a sensitivity assessment matrix for supralittoral rock (Mediterranean habitat I.4.1) (from La Rivière* et al.*, 2016)

CI = Confidence index, H = High, L = Low, N = None, M = Medium, VH = Very High

4. User guidance

4.1. Limitations and assumptions

- Sensitivity assessments are based on best available knowledge and may be updated as new data become available.
- The likely effects of a given pressure are assessed at the centre of a habitat's environmental range.
- Habitat sensitivity is affected by local characteristics (natural and/or anthropogenic) and on the health of surrounding habitats. However, where such local data is absent, it is recommended that management decisions be taken based on the "generic" sensitivity evaluations produced via this project.
- Associated confidence assessments should be taken into account when considering possible management options. However, according to the precautionary principle, a lack of scientific certainty should not on its own be sufficient reason for not implementing management measures.
- Sensitivity assessments are not absolute: scores are dependent on pressures defined by their magnitude (see Table 2).
- If an activity generates a pressure below the magnitude described in the pressure definition, this does not mean that it will not have an impact on benthic habitats.
- Assessments are made against single pressures and one-off pressure events. Cumulative pressures are not considered.
- The spatial extent of a pressure is assumed to allow for habitat recovery via recolonization.
- A "pressures-activity" matrix which links pressures to specific marine activities will be published in a separate document.

4.2. Using the habitat sensitivity data

Guidance on the use of the sensitivity data is presented in Figure 4.

When using the "generic" sensitivity assessments at a local level, users should:

- Understand the evidence base on which the assessment was made, including:
    a. which habitat characteristics shaped the sensitivity evaluation, and
    b. whether any of these characteristics were identified as being particularly critical to the final evaluation
- Tailor management measures to local habitat characteristics, where relevant. However, it should be noted that **"generic" sensitivity assessments can be used directly to**

assess risk and that a lack of specific data at the local scale should not hinder management action.

4.2.1. Sensitivity score

- Note that the « **Very Low** » sensitivity score does not mean that exposure to the pressure will not result in impact, only that a limited impact was judged likely at the specified pressure magnitude.
- Note that the « **Not applicable** » sensitivity score means the habitat is not exposed to the pressure (according to best available knowledge).
- Note that a "**Medium**", "**High**" or "**Very high**" sensitivity score indicates that the habitat would be compromised if exposed to the pressure in question, and that management action should be taken where necessary.

4.2.2. Local ecological conditions

- Identify whether local biotic and abiotic characteristics might affect a habitat's sensitivity, for example :
  - The conservation/environmental status of the habitat
  - Specific local environmental characteristics (e.g., naturally fluctuating turbidity)
- Take into account the habitat's (and its characteristic species') geographical isolation. Hydrodynamic conditions and habitat fragmentation influence ecological connectivity, and thus the potential resilience of an impacted habitat.

4.2.3. Pressures at the local scale

- Obtain information on both **the duration and frequency** of local pressures. Extended and/or frequent exposure to a pressure can decrease the habitat's **resilience** (and thus increase its sensitivity). It can also affect its environmental or conservation status. In the long term, extended and/or frequent exposure to pressures can induce a **change to another habitat type**.
- Consider the **spatial scale** of pressures in relation to the scale of potentially exposed habitats. A habitat subject to a very localised pressure is likely to recover more quickly (via the recolonization of the impacted area), compared to a habitat subject to pressure over a larger area.
- Take account of multiple activities operating at a given location. If the habitat is subject to **cumulative pressures**, these pressures may act additively, synergistically or antagonistically.

4.2.4. Resistance and resilience

- **Consider both the final sensitivity score and the underlying resistance and resilience scores.** A "Low" sensitivity score can mean that the habitat has a very low resistance to the pressure but that it recovers quickly (very high resilience), or that it is very resistance to the pressure (high resistance) but that its resilience is low. **These two scenarios may not have the same conservation and management implications.**

- Pay particular attention to the potential resilience of a habitat if the pressure is unlikely to be **adequately reduced/removed** (the latter being a prerequisite for full recovery).

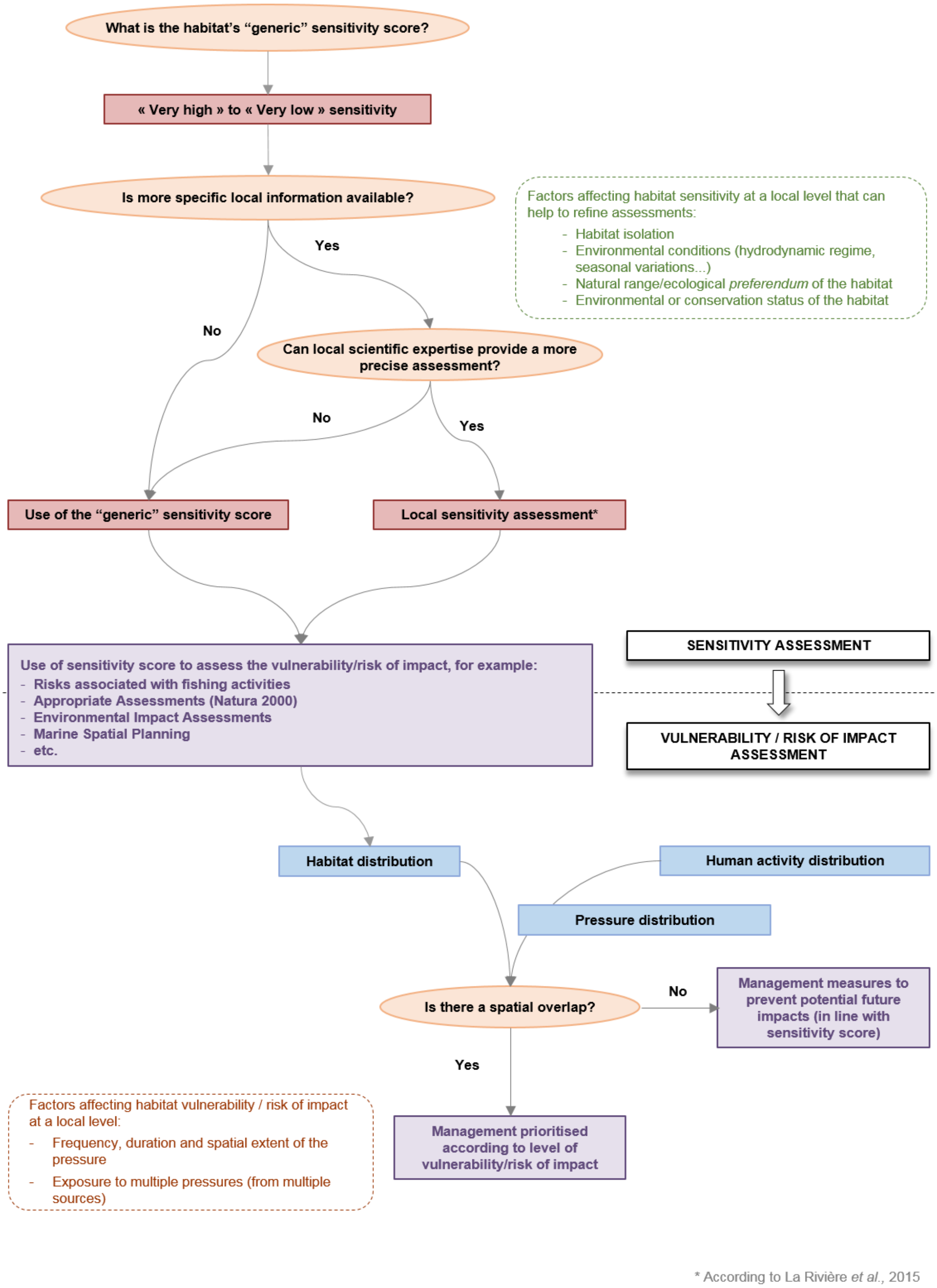

Figure 4. Diagram presenting guidance on the use of sensitivity data in the context of marine habitat management.

The upper part of the diagram concerns benthic habitats' sensitivity assessments (based on the present methodology). The lower part of the diagram concerns the use of sensitivity data in vulnerability analyses or risk assessments.

4.3. Aggregation rules

As explained, sensitivity assessments are undertaken at the "biocenosis" level, given that broader habitat categories may only take abiotic aspects into account (which are not sufficient to determine ecological sensitivity).

However, if need be, sensitivity data can be aggregated to derive the sensitivity score of a "parent" level habitat (habitat n-1). Aggregation can also be used to generate a habitat sensitivity score for an activity causing more than one pressure.

Users need to understand the limits of such aggregated sensitivity scores to avoid presenting misleading results. The following aggregation rules should be observed.

4.3.1. Habitat aggregation rules

Note: The use of habitat "**correlation tables**"[15] is required to derive the sensitivity score of habitats listed in **other habitat classifications**.

Aggregation rules for habitat sensitivity scores are as follows:

- If the habitats included in the parent habitat (n-1) all have the **same sensitivity score**, this score is assigned to the parent habitat.
- If the habitats included in the parent habitat (n-1) have **different sensitivity scores**, the parent habitat is assigned the **modal sensitivity score** (most frequent). The **highest score** (highest sensitivity, lowest resistance, lowest resilience) of one or more of the sub-habitats is indicated in brackets (see example for "Habitat X", Table 9). If the modal score is also the highest score in the aggregation, the presence of **lower scores** for the sub-habitats is specified with an asterisk (see example for "Habitat Y", Table 9).
- If no modal score is identified, the **sensitivity range** of the sub-habitats is indicated (see example for "Habitat Z", Table 9).
- If only one score is retained for habitat management purposes, it should be the **highest sensitivity score** (lowest resistance combined with lowest resilience)**,** in line with the precautionary principle.
- The **lowest confidence index** of the sub-habitats is assigned to the parent habitat (Table 9).

Aggregated sensitivity data can be used as a communication tool in a management context. However, users of aggregated sensitivity scores need to i) be aware of underlying sub-habitat sensitivity assessments and ii) understand the potential for differing habitat sensitivities at a

[15] "Correlation tables" indicate the relationships between habitats in different habitat classification systems. Correlation tables are provided by the MNHN for regional, national and European classifications, through the HABREF register:

https://inpn.mnhn.fr/telechargement/referentiels/habitats/correspondances local scale. It is inadvisable to take management decisions based solely on parent level habitat sensitivity scores as this may lead to measures being either insufficient or overly precautionary.

Table 9. Sensitivity and confidence index aggregation for parent level habitats.
Level "n" is the "biocenosis" level used for sensitivity assessments. Scores are aggregated to the n-1 level habitat (parent level). L= Low, M = Medium, H = High

Habitat level	Habitat code	Habitat sensitivity	Confidence index
n-1	X	L (H)	L
n	X.a	L	M
n	X.b	L	H
n	X.c	M	H
n	X.d	H	L
n-1	Y	H*	L
n	Y.a	M	L
n	Y.b	H	L
n	Y.c	H	H
n-1	Z	L-M	M
n	Z.a	L	M
n	Z.b	M	H

4.3.2. Pressure aggregation rules

When deriving a sensitivity score for a habitat subject to more than one pressure, the precautionary principle should be applied. The worst case scenario is therefore highlighted: the **highest sensitivity score** (lowest resistance and resilience scores) amongst all pressures caused by the given activity is assigned to the habitat.

Similarly, when using sensitivity data to assess the risk of a specific activity, it is advisable to assess the risk posed by each associated pressure individually and then to aggregate the scores by activity.

It is important, in a management context, to retain information on sensitivity to all pressures associated with an activity in case changes in how that activity is practised (e.g. fishing gear modifications) leads to the reduction/elimination of certain pressures.

5. Conclusion

Standardised habitat sensitivity data is an essential support in the management of human activities in the marine environment at a regional, national and international scale. The SPN-MNHN, alongside benthic scientists, developed a methodology for assessing the sensitivity of French marine habitats to human pressures. This report sets out the methodological framework, as well as guidance on how to use the resulting sensitivity evaluations. Twelve physical pressures have been defined and evaluated as part of the first stage of this project; other physical, chemical and biological pressures will be defined and assessed shortly. The resulting data will feed into risk assessments allowing the identification of conservation priorities for Natura 2000 sites, and more globally into marine management/ spatial planning strategies. By ensuring methodological consistency in the generation of sensitivity data with other Member States, the SPN-MNHN hopes to facilitate sharing and collective use of sensitivity information under the MSFD and Regional Sea Conventions (such as OSPAR).

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7. Annex 1: Simplified Folk classification

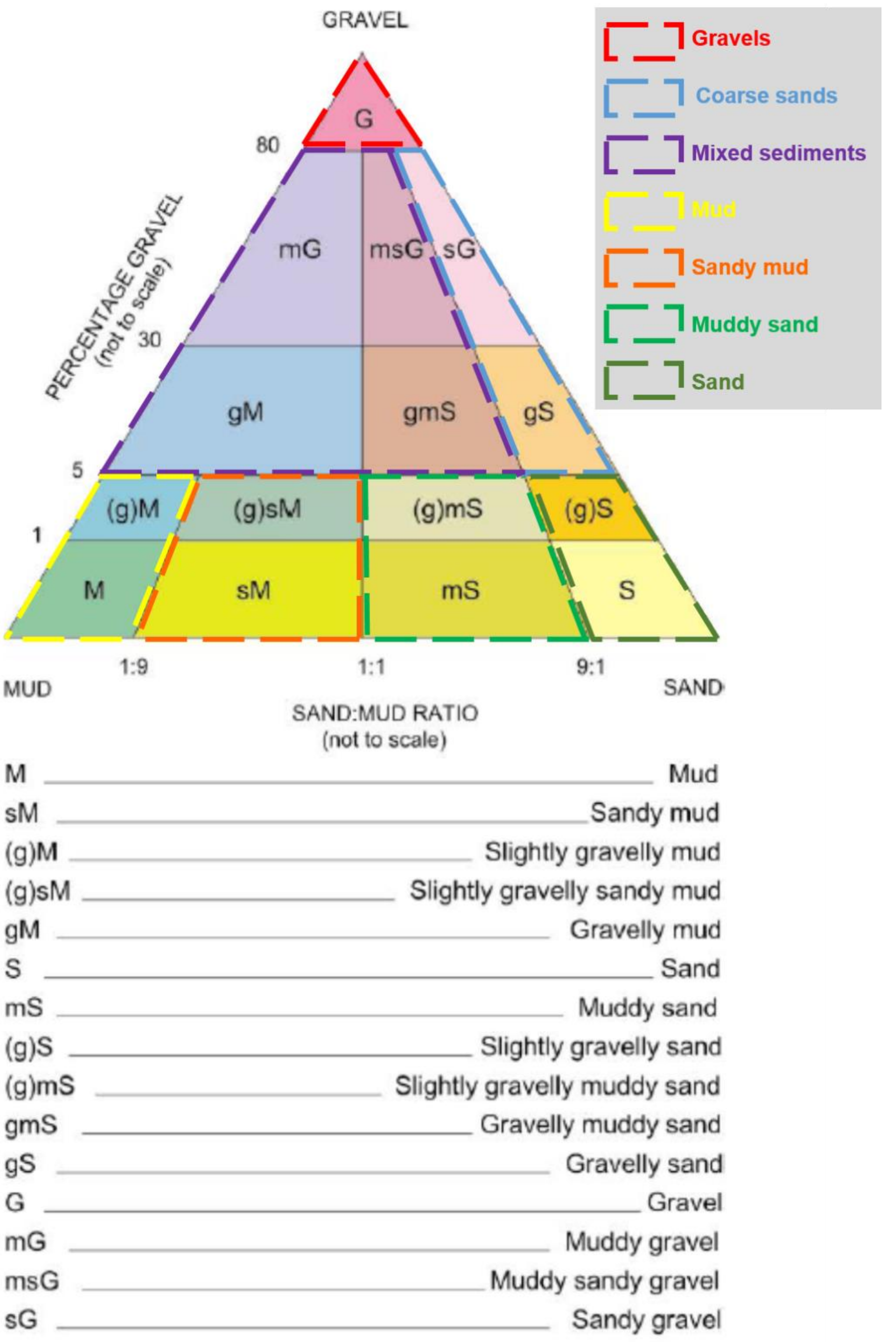

Figure 5. The clustering of original Folk classes (Folk, 1954) for the purposes of habitat sensitivity evaluation

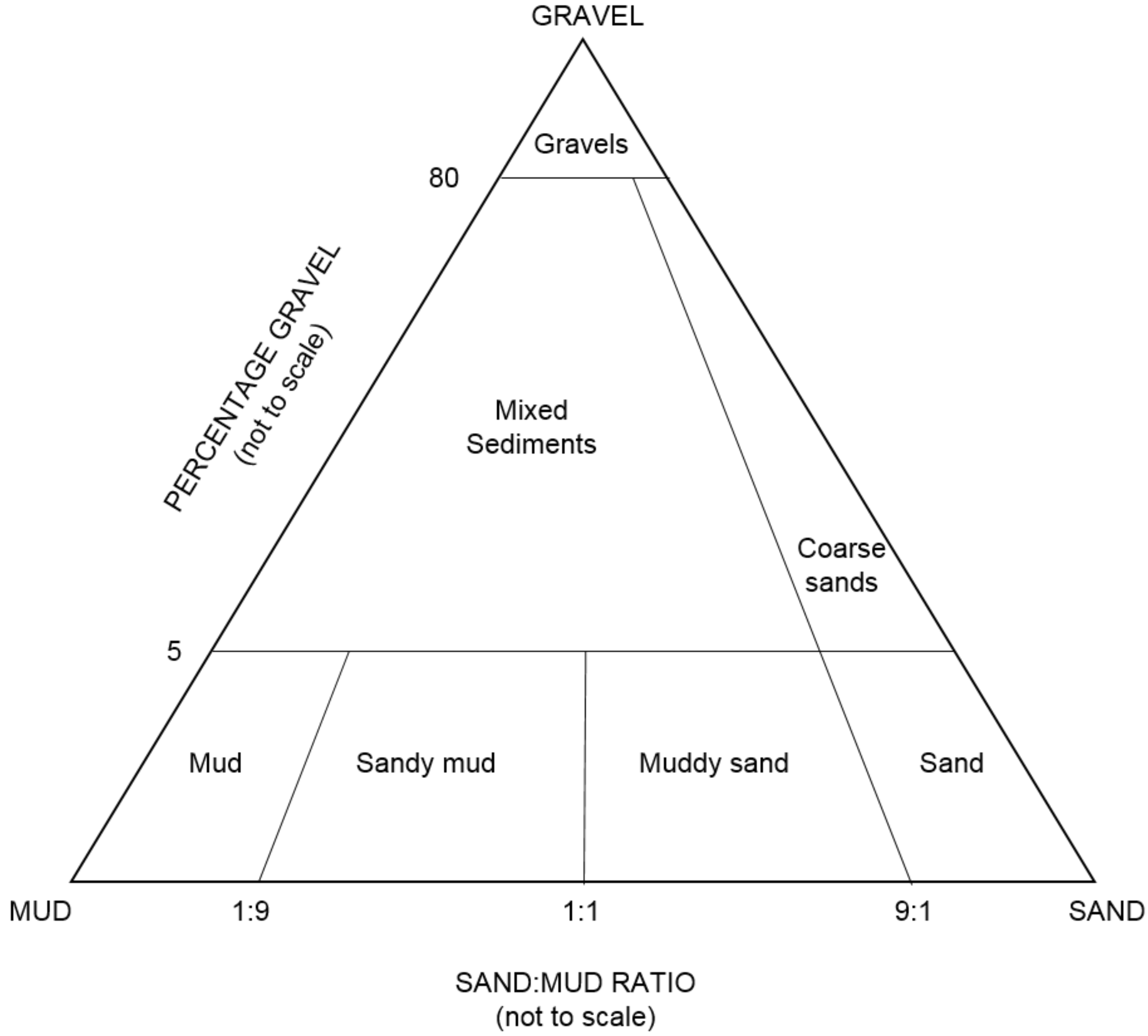

Figure 6. Simplified Folk classification

8. Annex 2: Relationships between the physical pressures and those listed under OSPAR/ICG-C and the MSFD

Relationships between the physical pressures defined under this project and the pressures defined by the OSPAR/ICG-C (EIHA, 11/5/3 Add.2-E) (Table 10) and by the MSFD (Directive 2008/56/UE, Annex III, Table 2) (Table 11) **are indicative only**.

Relationship symbols:

=: MNHN pressure is the same as the OSPAR or MSFD pressure

<: MNHN pressure is contained within the OSPAR or MSFD pressure (i.e. MNHN pressure has a narrower definition than the OSPAR or MSFD pressure)

>: OSPAR or MSFD pressure is contained within the MNHN pressure (i.e. MNHN pressure has a broader definition than the OSPAR or MSFD pressure)

Table 10. OSPAR/ICG-C Pressures: Relationships and definitions

MNHN "sensitivity" project		Relation	OSPAR/ICG-C (EIHA 11/5/3 Add. 2-E), Pressure list and descriptions		
Category of pressure	**Pressure**		**Code**	**Pressure**	**Pressure theme**
Physical loss (permanent change)	Habitat loss	=	L1	Physical loss (to land or freshwater habitat)	**Physical loss (permanent change)**
	Habitat change (to another type)	=	L2	Physical change (to another seabed type)	
Seabed physical disturbance (temporary and/or reversible change)	Substratum extraction	=	D1	Habitat structure changes - removal of substratum (extraction)	**Physical damage (reversible change)**
	Trampling				
	Surface abrasion	<	D2	Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	
	Light sub-surface abrasion	<			
	Heavy sub-surface abrasion	<			
	Reworking of the sediment				
	Light material deposition	<	D4	Siltation rate changes, including smothering (depth of vertical sediment overburden)	
	Heavy material deposition	<			
Hydrological changes	Hydrodynamic conditions change	>	H3	Water flow (tidal current) changes - local, including sediment transport considerations	**Hydrological changes (inshore/local)**
		>	H4	Emergence regime changes - local, including level change considerations	
		>	H5	Wave exposure changes - local	
	Change in suspended solids	=	D3	Changes in suspended solids (water clarity)	**Physical damage (reversible change)**

The complete pressure list (and definitions) of the OSPAR Intersessional correspondence group on cumulative effects (ICG-C) is available here: http://jncc.defra.gov.uk/PDF/20110328_ICG-C_Pressures_list_v4.pdf

Table 11. MSFD Pressures: Relationships and definitions

MNHN "sensitivity" project		Relation	MSFD(2008/56/UE), Annex III, Table 2 « Pressures and impacts »	
Category of pressure	**Pressure**		**Pressure**	**Category of pressure**
Physical loss (permanent change)	Habitat loss	<	Sealing (e.g. by permanent constructions)	Physical loss
	Habitat change (to another type)	=	Smothering (e.g. by man-made structures, disposal of dredge spoil)	
Seabed physical disturbance (temporary and/or reversible change)	Substratum extraction	=	Selective extraction (e.g. exploration and exploitation of living and non-living resources on seabed and subsoil)	Physical damage
	Trampling			
	Surface abrasion	<	Abrasion (e.g. impact on the seabed of commercial fishing, boating, anchoring)	Physical damage
	Light sub-surface abrasion	<		
	Heavy sub-surface abrasion	<		
	Reworking of the sediment			
	Light material deposition	<	Changes in siltation (e.g. by outfalls, increased run-off, dredging/disposal of dredge spoil)	Physical damage
	Heavy material deposition	<		
Hydrological changes	Hydrodynamic conditions change			
	Change in suspended solids			

Table 2

Pressures and impacts

Physical loss	— Smothering (e.g. by man-made structures, disposal of dredge spoil), — sealing (e.g. by permanent constructions).
Physical damage	— Changes in siltation (e.g. by outfalls, increased run-off, dredging/disposal of dredge spoil), — abrasion (e.g. impact on the seabed of commercial fishing, boating, anchoring), — selective extraction (e.g. exploration and exploitation of living and non-living resources on seabed and subsoil).
Other physical disturbance	— Underwater noise (e.g. from shipping, underwater acoustic equipment), — marine litter.
Interference with hydrological processes	— Significant changes in thermal regime (e.g. by outfalls from power stations), — significant changes in salinity regime (e.g. by constructions impeding water movements, water abstraction).
Contamination by hazardous substances	— Introduction of synthetic compounds (e.g. priority substances under Directive 2000/60/EC which are relevant for the marine environment such as pesticides, anti-foulants, pharmaceuticals, resulting, for example, from losses from diffuse sources, pollution by ships, atmospheric deposition and biologically active substances), — introduction of non-synthetic substances and compounds (e.g. heavy metals, hydro-carbons, resulting, for example, from pollution by ships and oil, gas and mineral exploration and exploitation, atmospheric deposition, riverine inputs), — introduction of radio-nuclides.
Systematic and/or intentional release of substances	— Introduction of other substances, whether solid, liquid or gas, in marine waters, resulting from their systematic and/or intentional release into the marine environment, as permitted in accordance with other Community legislation and/or international conventions.
Nutrient and organic matter enrichment	— Inputs of fertilisers and other nitrogen — and phosphorus-rich substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition), — inputs of organic matter (e.g. sewers, mariculture, riverine inputs).
Biological disturbance	— Introduction of microbial pathogens, — introduction of non-indigenous species and translocations, — selective extraction of species, including incidental non-target catches (e.g. by commercial and recreational fishing).

9. Annex 3: Combining resistance and resilience scores

A numerical score is assigned to each category of resistance (2 to 5) and resilience (1 to 5). Numerical scores have been assigned in such a way that the « none » resilience score (5) matches the « none » resistance score (5).

Sensitivity scores are derived by **multiplying** the resistance and resilience scores and assigning a sensitivity category (Table 12).

Table 12. Calculation of the sensitivity score by multiplying the resistance score by the resilience score

Resilience / **Resistance**	**None** ***5***	**Low** ***4***	**Medium** ***3***	**High** ***2***	**Very High** ***1***
None *5*	*25*	*20*	*15*	*10*	*5*
Low *4*	*20*	*16*	*12*	*8*	*4*
Medium *3*	*15*	*12*	*9*	*6*	*3*
High *2*	*10*	*8*	*6*	*4*	*2*

Five sensitivity categories are defined according to the above matrix:

Score 2: Very Low sensitivity

Scores 3-6: Low sensitivity

Scores 8-12: Medium sensitivity

Scores 15-20: High sensitivity

Score 25: Very High sensitivity

Abstract

Understanding benthic habitats' sensitivity to anthropogenic pressures is central to the effective management of the marine environment and to deliver the objectives set out under European Directives (HD, MSFD, WFD). Sensitivity assessments help to:

- identify those pressures that might impede the achievement of good environmental status (or favorable conservation status) for habitats,
- assess habitats vulnerability or risk of being impacted by human activities,
- identify and prioritise appropriate management measures that are consistent at a local, regional and national scale.

The MNHN-SPN, at the request of the French Ministry of Environment, developed a scientific methodology to assess the sensitivity of French (mainland) benthic habitats to anthropogenic pressures, drawing on expertise from the wider scientific community.

This methodology was developed to produce standardised results at a national level and to be consistent (insofar as possible) with other equivalent European methodologies, in order to support risk/vulnerability assessments at a national and international scale (under the HD, MSFD, OSPAR, etc.).

The terminology, habitat and pressure units, methodological framework for marine habitat sensitivity evaluation as well as guidance on how to use the resulting evaluations are presented herein. Twelve physical pressures are defined in the document; other physical, biological and chemical pressures will be defined in the next phase of this project.