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Assessment of marine and coastal ecosystems and ecosystem services

Contribution to the EFESE programme

Synthesis of the study performed by Ifremer, UBO and AFB

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Although the idea that nature renders indispensable services to humans is very old, the approach of ecosystem services gained universal recognition with the publication of the *Millenium Ecosystem Assessment* at the beginning of the 2000s. In the contemporary meaning of this notion, assessments of ecosystem services must above all serve to implement ambitious policies to protect ecosystems and biodiversity. Thus, the objectives of Aïchi for 2020 set out by the Convention on Biological Diversity foresee that the values of biodiversity can be incorporated in the decision-making process. The French Ecosystem and Ecosystemic Assessment (EFESE) is a programme initiated in 2012 by the Ministry of Ecology that aims to produce a series of assessments intended to provide better knowledge of, and make known, the state of French biodiversity. The first phase of EFESE produced assessments according to major types of ecosystem: forest ecosystems; agricultural ecosystems; urban ecosystems; wetlands; marine and coastal habitats; rocky and high mountain areas. The assessment of marine and coastal ecosystems and ecosystem services (EFESE-Mer) was performed by a workgroup (Marine WG) driven by the IFREMER and the University of Brest (UBO), with the support of the French Agency for Biodiversity (AFB), based on an exhaustive review of currently available knowledge[1].

1. The assessment procedure

Scientific foundations

Operationally, the ecosystem service approach corresponds to an **approach to support ecosystem and biodiversity conservation policies**: it entails producing knowledge focused on the indispensable benefits of the living component of nature, seen as a heritage to be preserved for present and future generations. Its rationale consists in ensuring the recognition that there are limits that should never be broken regarding damage to nature and biodiversity, limits beyond which there is a tipping point in critical situations, characterised by irreversible losses of ecosystem components, ecological functions and ecosystem services, many of which are irreplaceable. The internal consistency of the approach therefore demands that **the flows of services are considered as dependent on the ecological functions that underpin them** and thus as intrinsically linked to the resilience of ecosystems.

Ecosystem services assessments frequently take the form of series of indicators estimated for a single period, using a maximum number of monetary magnitudes in order to infer from them the extrapolation and aggregation of "values" by service or by type of ecosystem, assumed to be comparable. These assessment approaches obscure the wealth of considerations relating to the notion ecosystem services. The sciences of ecosystem services mainly take their references from applications of the theory of systems in the study of ecological processes and Human-Nature relations, and from the concepts of conservation biology. Regarding the **dilemma that exists between preservation and the "sustainable" utilisation of ecosystems**, ecosystem services sciences always adopt, whether explicitly or not, the paradigm of **strong sustainability**, by virtue of which manufactured capital and natural capital are not substitutable but complementary, which makes the conservation of "critical natural capital" an imperative for sustainability. Their rooting in conservation biology, which postulates the need to participate in conservation policies without necessarily possessing all the methodological and empirical bases, always leads them to **tolerate uncertainty while adopting a holistic, i.e. global and multidisciplinary approach that associates certain stakeholders**. This type of integrative and participatory approach in support of the implementation of conservation policies is highly recommended in the case of marine ecosystems, due to gaps in knowledge and the high levels of uncertainty that characterise them.

From the outset ecosystem services sciences combined the viewpoints of two disciplines: **ecology and economics**. Ecosystem services sciences represent a field still under construction, in which questions remain insufficiently investigated, especially those relating to demands for services management, and disciplines insufficiently represented, in particular social sciences such as anthropology, sociology and the political sciences. However, these questions and disciplines could be very useful for better understanding marine ecosystems and their services, that remain the compartments of the living world least investigated by the present ecological and economic knowledge. Besides the utilisation of existing indicators linked to the state of marine ecosystems and the services delivered by them, and at the same time ensuring the internal consistency of the ecosystemic approach, EFESE Marine WG has attempted to contribute to **rebalancing both these questions and disciplinary approaches** by carrying out three specific research operations in addition to the synthesis of available knowledge. These three specific research operations are:
– **consultation with the stakeholders** interested in marine habitats and their uses;
– studying the **forms of demand** to which ecosystems and ecosystem services are subjected;
– analysing **processes of patrimonializing** ecosystems and ecosystem services.

[1] Mongruel R., Kermagoret C., Carlier A., Scemama P., Le Mao P., Levain A., Ballé-Béganton J., Vaschalde D. & Bailly D., 2019. Marine and coastal habitats: assessment of ecosystems and delivered services. Report of the study performed for the EFESE programme, IFREMER – UBO – AFB, 354 pages + Annexes.

Method

The ecosystems of the French maritime domain are still not wholly known, thus requiring that the available data are interpreted with caution. Generally, **knowledge of the structure and functioning of marine ecosystems decreases the further one goes from the coast to the high seas and abysses**. Some ecological processes and many ecosystemic interactions remain poorly understood, making it difficult to appreciate the ecological functions that depend on them. Monitoring networks cover only a limited number of species and habitat status parameters. Attempts to improve this knowledge therefore require specific efforts that, up to now, have above all been given to remarkable habitats such as coral reefs, the muddy sand zone of the Bay of Biscay, eelgrass and posidonia prairies, and canyons. When available, ecological indicators must be handled with great care. Indeed, any assessment of the state of an ecosystem requires a thorough synthesis of large masses of data, many of which contain significant measurement uncertainties, once again mirroring the natural variability of the parameters measured, and cannot be compared to a still poorly defined undisturbed reference state.

In this framework, the ecological dimension of the assessment carried out by EFESE Marine WG attempts to make visible what is and is not known, the level of precision (often low) of current knowledge, and given these uncertainties, the ecosystems and ecological processes for which diagnostics pointing to possibly critical situations can be established. **The assessment presented here relies on a synthesis of existing assessments**: most of them are produced in the framework of policy or management systems, in particular the Regional Seas Conventions, Natura 2000, the Framework Directive on Water (FDW), the Marine Framework Strategy Directive (MFSD) and the works of the International Council for the Exploration of the Sea (ICES). This review of available assessments is completed by a consultation with stakeholders on the subject, making it possible to capture both complementary and divergent viewpoints, and measure the alignment between the perception of the stakeholders and the current state of scientific knowledge.

Regarding **the economic assessments of ecosystem services**, particularly those expressed in monetary units, EFESE Marine WG considers that they **are not intended to be presented in an aggregated form and still less integrated in cost-benefit analyses**. Indeed, aggregating the benefits delivered by ecosystem services would imply that these services are considered as substitutable with each other, an assumption incompatible with the paradigm of strong sustainability. Also, employing monetary assessments to carry out “global” cost-benefit analyses would entail an even more serious violation of this paradigm: indeed, comparing the benefits and costs of nature conservation policies would amount to accepting the idea that the components of the ecosystems and ecological processes targeted are not irreplaceable and thus do not form a “critical natural capital”. Economic assessments of the benefits delivered by marine ecosystems, when they can be carried out, are above all useful **to know the type of advantages (individual or collective) perceived by society, their relative importance, the groups of actors involved, the cost for society of the associated management systems**, and possibly, **the way in which these advantages vary as a function of the evolution of the state of ecosystems and the modes of their utilisation**.

The EFESE-Mer study uses only economic assessments based on **observable data**, since they alone ensure a genuine comparison between types of ecosystem and types of service in the framework of an assessment performed at such a large scale. Thus, the monetary data comprise **market prices when such markets exist**, which is the case in particular for a certain number of goods produced by ecosystems, **and cost data**: costs of access, maintenance and replacement. The data of the costs incurred include public expenditure for the protection of certain ecosystems and services, household expenditure to benefit from certain services and, lastly, replacement costs imputable to the restoration of a service or the impacts caused by its lost. Data on the number of beneficiaries are displayed when they exist. The entire approach has consisted in defining as precisely as possible the service being assessed and the population that benefits from it.

Besides the members of the Marine WG, the EFESE study on marine and coastal ecosystems involved a large number of scientific experts who were called on to participate in workshops, and certain of them contributed directly to the preparation of the final report. In particular, consultation with these experts external to the Marine WG permitted validating the typologies of the ecosystems used and ensuring that the best knowledge available was employed. In addition, the stakeholders interested in marine subjects were invited to set out their expectations regarding the study and express their perception of the ecosystems with resources at risk and key ecosystem services. The involvement of the stakeholders took the form of two meetings and an electronic consultation carried out in two phases. The general schedule of the workshops and consultations organised by EFESE Marine WG is presented in Table 1.

Table 1. Schedule of the workshops and consultations of EFESE-Mer

Type of event	Place	Date	External participants
Scientific workshop devoted to overseas ecosystems	Brest	8 and 9 October 2015	18
Scientific workshop devoted to Atlantic ecosystems	Brest	8 December 2015	11
Scientific workshop devoted to Mediterranean ecosystems	Marseille	4 February 2016	21
National Committee of Stakeholders interested in the sea	Paris	26 April 2016	22
Electronic consultation of Stakeholders, phase 1	-	7/07 to 21/09 2016	97
Electronic consultation of Stakeholders, phase 2	-	19/01 to 27/02 2017	67
National Committee of Stakeholders interested in the sea	Paris	19 October 2017	8
Scientific workshop to consolidate the assessment results	Brest	21 November 2017	10

Typology of functions and services for scientific assessment

The conceptual framework of the EFESE requires making a **distinction between ecological services and functions**, which are seen as properties of ecosystems resulting from the combination of their state, structure and ecological processes, without any human intervention to influence them or benefit from them. However, ecological functions are necessary to ensure the supply of ecosystem services, and for this reason they can be subject to indirect user demands or to direct management measures, which denote the willingness of the society to invest in the conservation of ecosystems and their services. Marine ecosystems are considered to ensure about twelve major ecological functions: primary production; secondary production; food webs and their dynamics; preservation of species richness and genetic diversity; formation of habitats for living species; reproduction and nursery areas; biological control of populations; storage and regulation of wastes and pollutants; biogeochemical cycles; control of erosion and sedimentation; formation of physical barriers; formation of landscape diversity.

This list permits understanding the conventions adopted in the framework of EFESE Marine WG to identify the ecological functions to be assessed as such and those that can be assessed simply through their contribution to services. The first three ecological functions, i.e. primary production, secondary production and food web dynamics, are strongly interdependent and have been grouped in a single major ecological function: “food webs”. The following three, also strongly interdependent, include specific abundance and genetic diversity, habitat formation for living species and reproduction and nursery grounds, have been grouped into a single ecological function “reproduction and nursery”. It should be noted that the ecological functions “food webs” and “reproduction and nursery” were moreover considered during the consultation with the stakeholders as giving rise to major concern, despite them being absent from the list of ecosystem services proposed to the persons questioned. This is exemplified by the association of the service of food production with plankton, a key element in the functioning of marine food webs, and with specific ecosystems like estuaries, seagrass beds and coral reefs, which cannot be explained only by the reproduction and nursery function ensured by these ecosystems. Not all the other ecological functions were evaluated as such as this would have made the assessment procedure much too painstaking: they were treated via their contribution to regulation or cultural services. The function of biological control was dealt with through the pathogen regulation service, while the waste and pollution storage function and that of the contribution to biogeochemical cycles were dealt with via the nutrient regulation service and the climate regulation service; the services of erosion and sedimentation control and the formation of physical barriers were dealt with through the coastal protection service; and, lastly, the pleasant landscape function was dealt with through recreational cultural services and heritage building processes.

Regarding the **typology of ecosystem services**, the conceptual framework of the EFESE is an adaptation of version 4.3 of the *Common International Classification of Ecosystem Services* (CICES[2]). Besides the differentiated treatment of ecological functions, the main contribution of the EFESE consists in focusing on goods resulting from ecosystems rather than supply services and in distinguishing among cultural services, on the one hand, that which belongs to the heritage building on nature, and on the other hand, that which belongs to recreational activities, education and knowledge and landscape amenities. The typology of services adopted by EFESE Marine WG conforms to these conventions. Nonetheless, certain goods and regulation services must be further specified to take into account the particularities of marine and coastal ecosystems.

[2] https://cices.eu/

The last attempt to introduce consistency to the major typologies of ecosystem services, while specifying definitions to adapt them to marine and coastal ecosystems, was carried out in the framework of the project *Mapping and Assessment of Ecosystems and their Services* (MAES), at a time when CICES was only at version 3, in 2011. Then, an assessment was carried out on the evaluations available in 2012 for each service by major type of marine and coastal ecosystem. In addition to their identification as services potentially delivered by marine and coastal ecosystems, certain services were perceived as having been scarcely studied, especially among the regulation services: out of the 145 articles selected as pertinent in the framework of this systematic review of the literature, only 9 evaluated the service of water supply and storage, one study focused on biological regulation and another on air quality regulation; lastly, there was no evaluation of weather regulation*,* a service also called "local weather regulation" in certain classifications). Among these services, only biological regulation had been evaluated in the framework of EFESE Marine WG, which included the service of "pathogen regulation" due to its potential contribution to human activities such as marine farming and recreational activities.

Regarding the category of cultural and recreative ecosystem services, the last version of CICES of 2018 (version 5.1) was employed but simplified so that finally only 4 major groups of cultural services were chosen. The first three are quite classical, and can be defined as follows: *i)* recreational services, which involve a physical interaction on site with the ecosystems and are based on specific activities intended to provide in particular relaxation and pleasure in contact with nature; *ii)* contemplating landscapes, which implies presence on site but as an intellectual experience based on the beauty of nature and the inspiration it provides; and iii) the production of information and knowledge, which belongs to an intellectual and cognitive approach. In addition, cultural services in the CICES meaning (2018) are grouped in the analysis of patrimonialization processes (or heritage building processes), implying relations with ecosystems having spiritual and artistic dimensions as well as those pertaining to identity.

Box 1. Limits of the assessment and precautions of use

The assessments of the marine and coastal ecosystems and ecosystem services presented in the framework of the EFESE Marine WG study were performed exclusively in the conditions and for the objectives that follow:

- describe the state of marine ecosystems, taking into account the **gaps existing in current knowledge** and the priorities expressed by the stakeholders and/or reflected in existing management systems;
- reveal the **perception by the stakeholders** of the state of ecosystems and the level of service delivered;
- **estimate the advantages gained from each service separately**, according to an approach by bundle of services[3], it being understood that not all services can be assessed with the same precision and thoroughness;
- characterise the **diversity of types of demand for ecosystem services**, and possibly their conflicts and synergies in view to contributing to compromises and arbitrations;
- disseminate the final results in forms that systematically present the **methodological pluralism of the assessment approach** (ecological, economic, institutional and anthropological dimensions);
- present **quantitative assessments** that also present this methodological pluralism and the integrated dimension of the assessment, that is say which associate biophysical, economic and social indicators, or different value systems (for example, by simultaneously mobilising notions of individual and collective advantages), and **which in no way result in exercises aimed at aggregating or extrapolating fragmentary results**.

Lastly, choices of simplification and reclassification were made, consistent with the results of the consultation with the stakeholders in the general conceptual framework of the EFESE. The water purification service was analysed only from the angle of nutrient regulation since the other dimensions of this service (sequestration of chemical contaminant residues, ecosystem regeneration following accidental pollution of black tide type, etc.) are difficult to evaluate and, contrary to nutrient regulation, they are not subject to a clearly identifiable social demand, neither from the viewpoint of consumption of a service nor that of its preservation. In line with the conventions adopted in the conceptual framework of the EFESE, life cycle maintenance and ocean nourishment services (a service which can be likened to that of pedogenesis for terrestrial ecosystems) were evaluated as ecological functions via the "reproduction and nursery" and the "food web" functions, as explained above. Regarding the goods produced by marine and coastal ecosystems, the study included the products of professional fishing, as well as goods resulting from marine farming activities, which are especially important in certain coastal regions of France, and products resulting from macro-algae and the production of molecules, these two sectors currently undergoing dynamic growth. Conversely, goods resulting from marine ecosystems intended for energy production have been omitted from the scope of the study.

[3] The approach by bundle of services also involves taking into account interactions between services, but they still remain very poorly documented.

Finally, **15 ecological ecosystemic functions and services have been evaluated** on the basis of available scientific knowledge: the food web maintenance function (1), the reproduction and nursery function (2), the production of goods from fishing (3), the production of goods from marine farming (4), the exploitation of macroalgae (5), the exploitation of molecules (6), nutrient regulation (7), coastal protection (8), climate regulation (9), pathogen regulation (10), recreational services (11), landscape amenities (12), knowledge production (13), institutionalised heritage (14) and other forms of patrimonialization (15). The notion of **dis-service**, that is to say constraints and disadvantages that the functioning of marine ecosystems inflict on human societies is not dealt with in this evaluation.

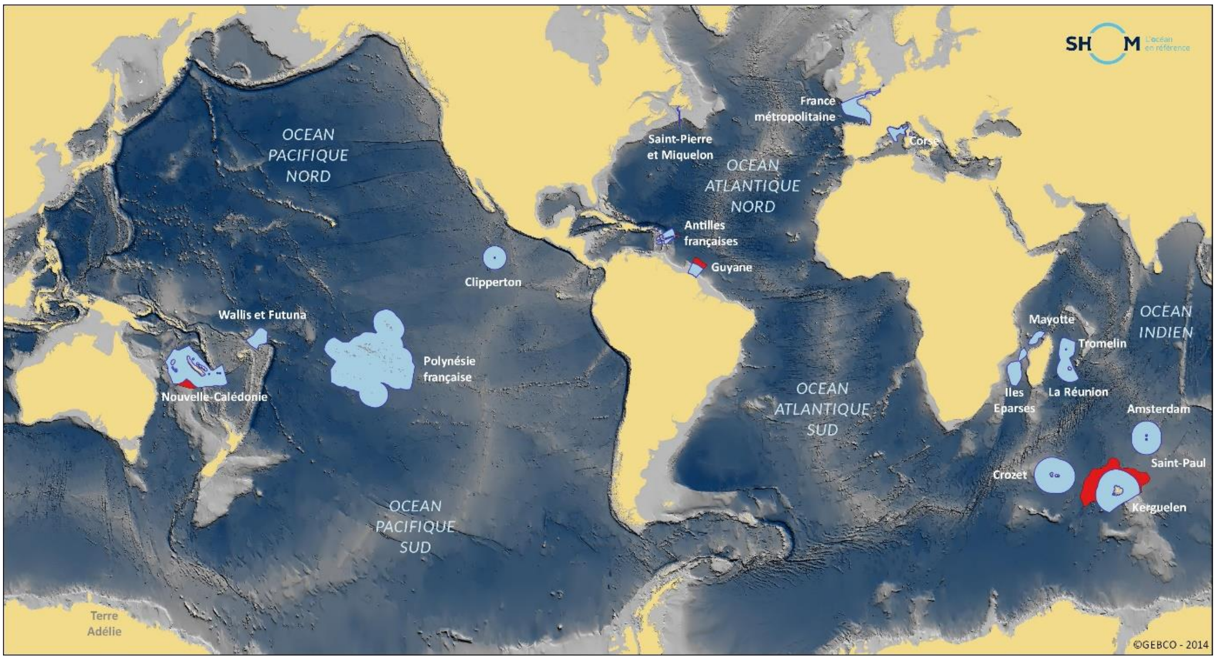
2. Marine and coastal ecosystems

The range of ecosystems

The territory considered by the EFESE-Mer covers diverse marine and coastal ecosystems, themselves composed of diverse habitats. **These ecosystems are distributed non-continuously in spaces with very varied biophysical characteristics and present highly diverse ecological modes of functioning**. Despite this discontinuous nature, this group of ecosystems can be defined in an overall and very general way as being the French maritime domain, then broken down more precisely into administrative and legal jurisdictions. The waters under French jurisdiction, including inland waters, the territorial sea, the contiguous area, the exclusive economic zone (EEZ) and possibly the wider continental shelf, allow setting an off-shore limit beyond which is located the international maritime area or high seas. Landwards, the definition of the natural Maritime Public Domain of the State, which comprises “the bed and the sub-bed of the sea between the external boundary of the territorial sea and, land-side, the shoreline”, provides a pertinent terrestrial boundary to what an assessment of marine and coastal ecosystems should encompass, since it specifies that the “shoreline of the sea is composed by everything it covers and uncovers up to where the high seas extend in the absence of exceptional meteorological disturbances”[4]. This meaning allows considering **the land-sea interface zones subject to tides where trophic and functional factors of great importance for marine ecosystems are at stake**.

The French maritime domain is immense. Indeed, **France’s overseas territories give it the second largest EEZ in the world, after that of the United States** (Figure 1). This EEZ covers a surface area of 11 million km², 97% of which is located overseas. Overseas France is localised in three oceans (Atlantic, Indian and Pacific) and in the two hemispheres. On 1 January 2017, 242,960 marine species were listed in the World Register of Marine Species (WoRMS). The French maritime domain hosts a large share of this global biodiversity, especially via its ultra-marine component which hosts more than 80% of French marine biodiversity. Overseas France also encompasses the world’s fourth largest surface area of coral reefs (55,000 km²).

Figure 1. The French maritime domain.



[in blue: the EEZ, in red: the extension of the continental shelf beyond 200 nautical miles according to Article 76 of the United Nations Convention on the Law of the Sea.]

[4] Ruling of the Council of State of 12 October 1973.

A typology of ecosystems adapted to the framework of EFESE-Mer

To meet the needs of the assessment, a typology of marine habitats and water masses, specific to the framework of EFESE-Mer and common to the Channel-Atlantic and Mediterranean seaboards and to overseas France, has been established on the basis of existing typologies (Table 2). It therefore includes the EUNIS typology, level 2, which permits covering all the marine and coastal ecosystems present in the French maritime domain and their stratification. The habitats of the coastal strip are defined according to a gradient linked to the nature of the substrate, from loose substrates (coastal **dunes and sandy shores (H1)** and **coastal pebbles (H2)** shaped by the wind and waves) to rocky substrates (**cliffs, ledges and rocky coasts (H3)**). The intertidal zone (zone under the influence of the tides) and subtidal zones (up to 200 metres depth) are also characterised with respect to the nature of the substrate by differentiating, on the one hand, the **intertidal sediment (H5)** from the **rock and other hard intertidal substrates (H4),** and on the other hand, the **subtidal sediment (H8)** from hard substrates. The former are characterised by the size of the sediment: silt, fine sand, medium sand, coarse sand, gravel and their various combinations. The latter comprise habitats of pebbles, blocks and rocks in place. In the subtidal zone can be distinguished **rock and other hard infralittoral substrates (H6), rock and other hard circalittoral substrates (H7)**, with the infralittoral zone being dominated by algae (except in turbid waters) and the circalittoral zone by animal communities. Lastly, the **deep habitats (H9)** extend from the continental slope up to, in this typology, the boundary of the French EEZ (bathyal and abyssal stages). These habitats are characterised by the absence of light and a steep slope gouged by submarine valleys and canyons, down which slide continental sediments.

Table 2. EFESE-Mer typology and correspondence with EUNIS (level 2) and habitat books.

	Designations of habitats and water bodies of the EFESE-Mer typology	EUNIS equivalents	Habitats listed in the habitat documents and included in the EFESE-Mer habitats
Benthic habitats	H1 – Coastal dunes and sandy shores	B1	1140.1; 1140.3; 1140.4; 1140.7; 1140.8; 1210
	H2 – Coastal pebbles	B2	1140.2; 1220
	H3 - Cliffs, ledges and rocky shores	B3	1170.1; 1170.10; 1230
	H4 – Rock and other hard intertidal substrates	A1	1170.2; 1170.3; 1170.4; 1170.8; 1170.11; 1170.12
	H5 – Intertidal sediment	A2	1130; 1140.5; 1140.6; 1140.9; 1140.10
	H6 – Rock and other hard subtidal substrates	A3	1170.5; 1170.6; 1170.7; 1170.9; 1170.13; 1170.14
	H7 – Rock and other circalittoral hard substrates	A4	
	H8 – Subtidal sediment	A5	1110; 1160
	H9 – Deep habitats	A6	
Particular benthic habitats	HP1 – Salt marshes		1150-1; 13; 14
	HP2 – Seagrass beds		1110.1; 1120.1
	HP3 – Coral reefs		
	HP4 - Mangroves		
	HP5 – Macro-algae fields		1170.2; 1170.5
	HP6 – Coralligenous		1170.14
Pelagic habitats/ compartments	ME1 – Mediterranean lagoons	X02	1150.2
	ME2 – Lagoons		
	ME3 – Estuarine and transition waters	X01	
	ME4 – Coastal waters under estuarine influence	A7	
	ME5 – Other waters over continental shelf		
	ME6 – Epipelagic zone of ocean waters		
	ME7 – Meso and bathy-pelagic ocean waters		

Besides the classical segmentation of benthic habitats, some **specific habitats** give rise to types of ecosystem on their own in the EFESE-Mer typology due to their **specific functioning**, their **dimension in terms of heritage** and the **strong challenge of conservation** linked to them. Some particular habitats have developed and overlap with the EUNIS habitats described previously. However, the organisation of space by certain gregarious species (forming banks, fields, prairies, etc.) has profoundly modified the environment and resulted in the establishment of entire habitats, suitable for the installation of species that would not all be present at such levels without these specific facies. **Coastal marshes (HP1)** develop in sheltered estuaries, coves and bays and are characterised by specific vegetation: the tidal flats, located in the lower part of marshes at the mediolittoral stage, differ from the salt marshes, or *sansouïre*, in the Mediterranean, located in the upper part of marshes. **Seagrass (HP2)** develops on certain loose beds of the medio-littoral and infralittoral, structured by one or more species of marine phanerogam plants: Posidonia, *Posidonia oceanica*, is an endemic species of the Mediterranean; eelgrass, *Zostera marina* and *Zostera noltei* characterise most of the seagrass of the Atlantic coast and Mediterranean lagoons; in tropical overseas areas, prairies of marine phanerogams have developed in lagoons, more rarely on the external slopes of coral reefs, and are structured by 16 to 18 species of phanerogam. **Coral reefs (HP3)** are ecosystems typical of shallow seas in the intertropical zone, that develop in particular, though not exclusively, around volcanic islands. They are carbonate structures bio-constructed by Scleractinia corals, and which compose a front reef and a back reef. **Mangroves (HP4)** develop on certain silty shallow beds of the intertropical zone and are structured by one or two species of mangrove tree. **Fields of macroalgae (HP5)** develop on certain rocky beds of temperate, subarctic and subantarctic zones and are structured by large brown seaweeds (fucales and laminaria) present in dense colonies. **The coralligenous (HP6)** makes up a hard bed of biogenic origin mainly produced by the accumulation of calcareous algae forming a crust and living in low light conditions, essentially found in the Mediterranean.

Furthermore, the EFESE-Mer typology proposes a typology of water masses in order to distinguish the pelagic compartment from the benthic compartment, while taking their interrelations into account. **Mediterranean lagoons (ME1)** are shallow bodies of coastal saltwater, of variable salinity and volume, wholly or partially separated from the sea by a barrier of sand, pebbles and gravel or more rarely a rocky barrier. **Lagoons (ME2)** are shallow bodies of coastal saltwater, located in the intertropical zone, inside an atoll or separated from oceanic water by a coral reef. **Transition waters specific to estuaries (ME3)** are defined by the DCE as waters located close to the mouths of rivers, that are partially saline but essentially influenced by freshwater currents. **Coastal waters (ME4)** are zones of effusion or floatability of freshwater over marine water, in the form of a plume extending several hundred kilometres from the river mouth. They are distinguished from the waters of the rest of **the continental shelf (ME5),** which include all the coastal waters not under estuarine influence. Regarding the vertical plane, the water column of the ecosystem offshore is split into two and includes: the **epipelagic zone of ocean waters (ME6)** (from the surface to 200 metres depth), sufficiently exposed to light for photosynthesis to occur; the **meso and bathypelagic zones of oceanic waters (ME7)** (> -200 m depth).

Ecosystem states

Although there is an abundance of marine biodiversity indicators in the scientific literature, **synthetic indexes applicable to vast geographic regions are rare**. Those that describe the global functioning of ecosystems are even rarer and complicated to formulate. Moreover, the evaluation of the current ecological state of habitats and species, analysed from the standpoint of various recent initiatives regarding the preservation of biodiversity, and aquatic and marine habitats, often comes up against the problem of choosing a reference state (i.e. undisturbed). In addition to this is the fact that fundamental knowledge on the distribution of habitats and the biology of species is lacking for much of this huge maritime domain. Therefore, it is quite difficult to determine the ecological state of marine habitats and water bodies on the scale of the French EEZ. Nonetheless, the assessments performed in the framework of European directives (DHFF, DCE, DCSMM) and national initiatives such as IFRECOR make it possible to partially ascertain the ecological state of certain ecosystems of the EFESE-Mer typology, which in most cases appears poor.

Thus, **only 2 habitats of the 26 assessed in the framework of the DHFF were in a good state in 2019**. This assessment showed that, generally, in comparison to other habitats, coastal and marine habitats (in particular lagoons, estuaries, Posidonia seagrass beds and Mediterranean beaches) are those most exposed to losses of surface area. Likewise, **the DCE assessments of bodies of transition and coastal water suggest that in 2015, less than a third and hardly half of these bodies of water, respectively, were in a good ecological state**. On the scale of the Channel-Atlantic coast, Mediterranean lagoons and lagoons of tropical zones, the failure to reach a good ecological state can often be explained by problems of eutrophication related to the presence of opportunistic algae and of phytoplanktonic blooms associated with disruptions in the nutrient cycle. The DCSMM pointed to this same trend and highlighted a certain number of other issues jeopardising the capacity to ensure the good state of marine waters. Regarding **commercial and exploited species,** for example, of the 120 stocks identified on the scale of the marine sub-regions of metropolitan France, 12 stocks were deemed in good ecological state versus 20 stocks in an unsatisfactory ecological state; **the ecological state of the remaining 90 stocks could not assessed due to a lack of available data**. The **deterioration of sea beds** points to issues *i)* on the scale of the continental shelf linked to fishing activities and dragging gears along the beds; *ii)* on the scale of coastal zones linked to the presence of ports, pollutions contributed by rivers and streams, sites where siliceous and calcareous materials are extracted, bottom trawling and laminaria harvesting; *iii)* and lastly on the scale of the Mediterranean coastal strip, linked to the urbanisation of the coastline and the mooring of pleasure craft (mostly adjacent to Posidonia beds). However, in addition to the identification of the main ecological issues in the French maritime domain, **all the works done in the framework of the DCSMM show that there is still no complete assessment of the state of French marine waters available at present, even in a qualitative form**. The last example concerned the state of coral reefs in the overseas territories, for which the first indicator based on the coverage of hard living coral was formalised by the IFRECOR for the National Observatory of Biodiversity (ONB). In 2017, this indicator showed that the coverage of hard living coral had fallen at 29% of the stations monitoring coral reefs in the French overseas territories. This indicator is highly synthetic and corresponds to a national reporting mission. The values of this indicator should be interpreted with caution since it gives only a very partial image of the state of health of coral reefs.

On the basis of a review of the literature completed by expert opinion, the works of EFESE Marine WG provide a synthetic image of the pressures acting on marine ecosystems on the scale of the coast of mainland France, from the zone offshore in the Atlantic and the Mediterranean and, lastly, overseas (Table 3).

Table 3. Intensity and trends of evolution of the five main factors of change chosen by the IPBES[5], presented by major biogeographic regions.

	Destruction and modification of habitats	Pollution	Over-exploitation	Climate change	Invasive exotic species
Littoral	↗	↗	→ ?	↗	↗
Marine habitats – Channel, North Sea, Atlantic	↗	↗	↘	↗	↗
Marine habitats – Mediterranean	↗	↗	→	↗	↗
Marine habitats – Overseas	↗	↗	↗ ?	↗	↗

[The colour represents the intensity of the change factor, i.e. yellow: low intensity, orange: average intensity, red: high intensity. The arrow indicates the direction of evolution, i.e. ↗ : increase, → : constant, ↘ : reduction and ? direction of evolution.]

The trends of ecosystem evolution

On the scale of all the marine water ecosystems under French jurisdiction, four main trends can be observed: (1) a continuous increase of pressures having an impact on marine biodiversity, whether direct and targeted (modification and destruction of habitats) or most often indirect and diffuse (growing demography, augmentation of maritime transport, introduction of non-indigenous species and climate change); (2) increased control of old pressures, notably fishing, at the origin of problems of over-exploitation of fish stocks; (3) increased control of certain pollutions of coastal waters (contaminations by wastewater and nutrients responsible for eutrophication), whereas other forms of pollution increase (plastics, drug residues, heavy metals); (4) an increase in marine biodiversity given protective status, through the increase of the surface area of protected marine zones.

The **destruction and fragmentation of habitats** are very considerable at the land-sea interface where they are caused by many sources of pressure. Further off-shore, the sources of pressure that cause this destruction and fragmentation are also present though less intensely than on the coast. These pressures are rising everywhere. In particular, there is **a growing trend towards artificialisation and anthropization spreading further from the coast** (the installation of wind farms at sea, bottom trawling, etc.).

Pollution is a very important factor of change for marine and coastal ecosystems. It is particularly present at the land-sea interface, where pollutions of multiple origins accumulate. Further off-shore, this factor of change is less strong due to the effect of dilution of pollutions of continental origin, but they nonetheless represent a major issue due to the existence of other sources of pressure leading to pollution (maritime traffic, mining and oil platforms, etc.). Although certain sources are now controlled, generally **pollution is increasing everywhere**. Pollution by **residues not eliminated by wastewater treatment plants** (compounds of drugs and cosmetics), non-degradable compounds (plastics), synthetic substances (pesticides) and pollution by heavy metals **are increasing problems for marine and coastal habitats**.

Between the two cycles of assessment of the DCSMM from 2012 to 2018, all marine sub-regions confounded, 34 new non-indigenous species were reported on the coasts of mainland France, including 28 corresponding to the first time these species had been seen off mainland France alone. In all, **there are 438 non-indigenous species present on the coasts of mainland France**. Among them, the number of exotic species is increasing everywhere, though their impacts are less strong than those caused by other change factors. The coast, and especially artificialized zones (ports, marinas)

[5] *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, https://www.ipbes.net/

and ecosystems targeted by shellfish farming, are far more impacted by invasive species than the ecosystems further offshore.

Regarding **fishing**, over-exploitation continues in all the fishing zones, immediately apparent when taking into account all the stocks. Nonetheless, the implementation of the Common Fishing Policy in European waters seems to have had positive effects on fishing resources ,with the observation of a reduction over the past few years of the number of stocks subject to deterioration. The efforts made by the professional fishing sector, better scientific knowledge and the introduction of new management tools, have led to promising results for the future of fish resources and the service they render. **Regarding the Atlantic – Channel and North Sea, it can be considered that overexploitation, although still present, is falling**. A large number of stocks appear to have undergone significant restoration, but black spots subsist for mainland France (examples of scallops, bass and sole in the east Channel, cod in the Celtic Sea). **Regarding the Mediterranean, the level of overexploitation is more worrying**. Although stocks of certain large pelagic species are undergoing restoration, stocks of small pelagic, demersal and benthic species are declining. It should be noted that the causes of the fall of certain small pelagic species (sardines and anchovies) are not fully imputed to overexploitation (possible influence of pollution and climate change).

Climate change is accentuating everywhere but it does not represent a major problem for the marine ecosystems of mainland France, since its effects remain barely visible, thus uncertain. Up to now, climate change has even been accompanied with an increase in biodiversity in certain places; conversely, **it raises problems from the functional standpoint, at least in the Mediterranean**. The Mediterranean is a sea that warms more quickly than the oceans: an accentuation of oligotrophic zones at the surface and anoxic zones at depth is hypothesised. The eastern Channel is also warming very rapidly in comparison to the rest of the Atlantic-Channel-North Sea seaboard.

The overseas ecosystems are more vulnerable to the effects of climate change, since species are closer to their limit of thermal tolerance overseas than those in temperate habitats. In particular, climate change contributes to the phenomenon of coral bleaching. Furthermore, **climate change is liable to modify the distribution of plankton in the oceans globally**.

3. What do we know of the service delivered?

Perception of the stakeholders

EFESE-Mer is an assessment with a dual mission, both exhaustive and strategic, since it aims to perform a diagnosis on the state of ecosystems and their potential to provide services, and to identify the main challenges relating to the conservation of these ecosystems. Consulting with the stakeholders is a means of responding to this strategic dimension of the assessment since it prioritises assessments in a context of incomplete knowledge; however, more generally it has also revealed their perception of the state of habitats and the services delivered. The consultation was carried out as follows: a questionnaire was drafted, relying in particular on a typology of ecosystems and ecosystem services that was more communicative than the scientific typology, then the consultation was performed online according to the Delphi method. This method consists in submitting the same questionnaire several times to a panel of experts in view to reaching consensus on complex subjects. At each round of the consultation, the experts can revise their responses in relation to the results of the previous round. The experts of the marine environment that participated in the consultation represented economic sectors, the State, the associative sector, territorial authorities and employees' unions. In all, 406 experts were contacted; 97 responded for the first round; these respondents were recontacted and 67 of them responded for the second round.

First of all, the strategic evaluation of the challenges relies on the hierarchisation of types of ecosystem and groups of species as a function of criteria of importance, exposure to change factors and the possibility of action (Table 4). **The more important the ecosystem, the more it is exposed and the more it is possible to act to conserve it, thus the more useful it is to assess it**. The consultation revealed four different issues:
1. Estuaries, beaches, seagrass beds, lagoons and protected and commercial species: considerable importance and exposure, also a strong capacity to act;
2. Plankton, mangroves and coral reefs: considerable importance and exposure but with medium to low capacity to act;
3. Aquaculture zones: medium importance, high exposure and strong capacity to act;
4. Rocky beds, loose beds and deep ecosystems: medium importance, less exposed and medium capacity to act.

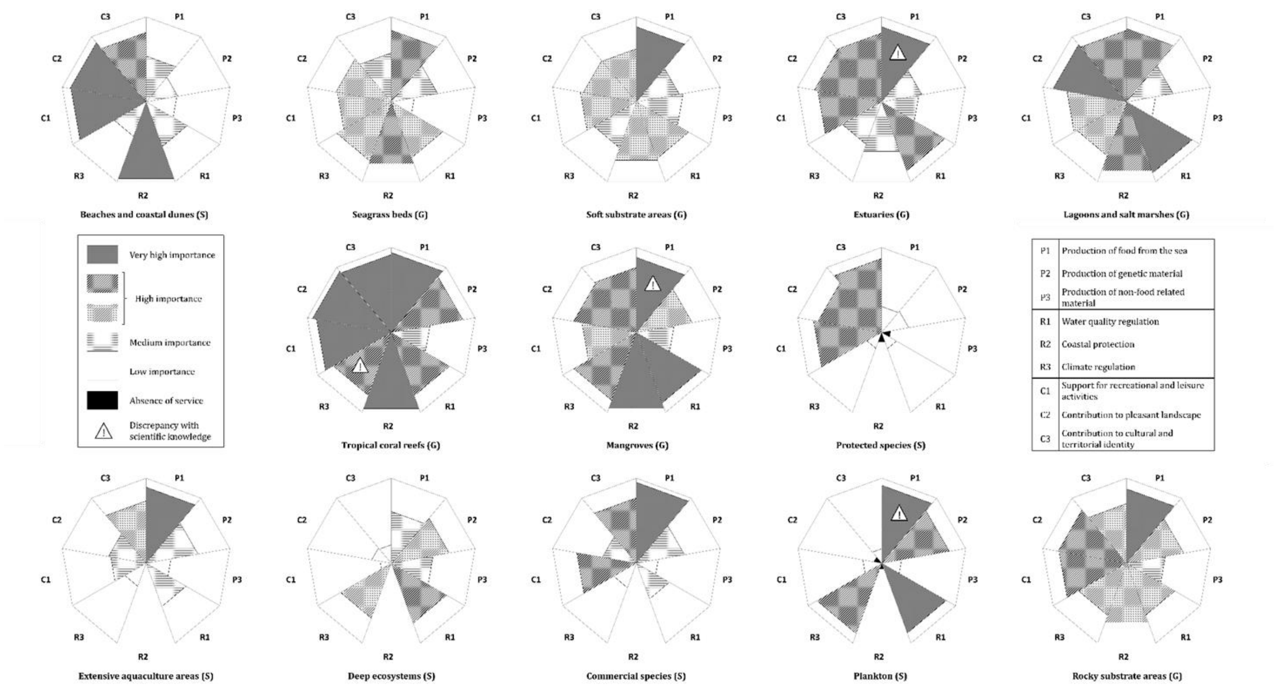
The experts also pronounced on the importance of the services delivered by each type of ecosystem and all the species (Figure 2), revealing the existence of two groups of ecosystem: **diversified ecosystems** (coral reefs, mangroves, lagoons, rocky beds, estuaries, loose beds and seagrass beds) that render a wide variety of services; and **specialised ecosystems** rendering specific services (beaches, plankton, aquaculture zones, commercial species, deep ecosystems and protected species).

Table 4. Hierarchisation of ecosystems and groups of species as a function of criteria of importance, exposure to change factors and capacities of action.

#		Importance			Exposure to factors for change			Possibility of action	
1	**=**	**Plankton**	**3.8**	**=**	**Tropical coral reefs**	**3.8**	**=**	**Commercial species**	**2.8**
2	=	Tropical coral reefs	3.7	=	Plankton	3.5	↑	Extensive aquaculture zones	2.6
3	=	Seagrass beds	3.6	=	Estuaries	3.5	=	Lagoon and salt marshes	2.6
4	=	Estuaries	3.5	=	Beaches and assoc. dunes	3.4	↓	Estuaries	2.6
5	=	Mangroves	3.5	↑	Mangroves	3.3	=	Protected species	2.5
6	=	Protected species	3.4	↓	Lagoon and salt marshes	3.3	=	Seagrass beds	2.4
7	=	Lagoon and salt marshes	3.3	=	Commercial species	3.2	=	Mangroves	2.4
8	=	Rocky substrate areas	3.3	=	Seagrass beds	3.2	=	Beaches and assoc. dunes	2.3
9	=	Deep ecosystems	3.2	=	Protected species	3.2	=	Tropical coral reefs	2.2
10	=	Commercial species	3.2	=	Extensive aquaculture zones	2.9	=	Soft substrate areas	2.1
11	=	Beaches and assoc. dunes	3.1	=	Rocky substrate areas	2.7	=	Rocky substrate areas	2.1
12	=	Soft substrate areas	2.9	=	Deep ecosystems	2.7	=	Deep ecosystems	2.0
13	=	Extensive aquaculture zones	2.3	=	Soft substrate areas	2.5	=	Plankton	1.8

[The signs = ↑ ↓ indicate the evolution of the classification between the first and second rounds of the consultation.]

Figure 2. Perception by the experts of the importance of ecosystem services associated with each type of ecosystem and group of species.



This evaluation permitted controlling the correspondence between the perception of the stakeholders and scientific knowledge (see section "Levels of services by type of ecosystem"). Only two inconsistencies came to light. The first concerned the association of plankton with the supply of food goods production services, which can be explained by its essential role in maintaining the proper functioning of food webs. The second concerned the idea that coral reefs render climate regulation services, and in a very significant way, though this does not correspond to any scientific observation. This type of inconsistency must not be neglected since it shows that certain challenges are undoubtedly ill-posed in the public debate and thus wrongly perceived by society. Lastly, the idea that estuaries and mangroves are major suppliers of food goods leads to some confusion, whereas these two types of ecosystem contribute to this service above all by accommodating habitats especially favourable for reproduction and nurseries.

Typology of the services evaluated

The assessment performed on the basis of available scientific knowledge covers 15 functions and services for which the most precise definition possible has been adopted.

[1] The **food webs** are composed of all the processes of transfers of matter and energy between living organisms (primary production, secondary production, re-mineralisation of matter). They participate in the organisation and functioning of all marine ecosystems. Each ecosystem presents certain particularities in the organisation of the food web, although interconnections exist between ecosystems via the pelagic compartment. The study of food webs groups organisms by compartment (trophic levels, trophic guilds) in order to simplify the description.

[2] The **reproduction support** function is ensured in spawning grounds, where a species gathers to reproduce, either in open water (most fishes), or on the seabed. The spawning ground is most often geographically separated from the nursery and corresponds to specific hydrological characteristics. The **nursery support** function is ensured by an area or a habitat in which the juveniles of a mobile species gather during the first months or years of their life to feed and continue their development. The reproduction and nursery support functions are vital to numerous services, in particular the production of food goods.

[3] The production of **food goods resulting from fishing** covers fishes, algae, crustaceans, shellfish, cephalopods, etc. intended for human consumption and taken from marine ecosystems by professional fishing activities that generate financial profits. Indeed, in France all the goods extracted by exploiting fishing resources are destined for human consumption: there is practically no exploitation of fishing resources in the waters of the French maritime domain to produce forage intended for feeding fish in marine fish farms.

[4] The **food goods resulting from marine cultures** are goods taken from marine ecosystems modified by humans for the purposes of reasoned utilisation (that is to say extensive or semi-intensive), based on breeding practices characterised by both a high degree of dependence on the natural functioning of marine ecosystems and a low level of intervention in this functioning. The activities included within this definition are shellfish aquaculture and algaculture.

[5] At present the production of **goods resulting from macro-algae** consists in extracting hydrocolloids (alginates, carrageenans and agar-agar), essentially from brown algae, to benefit from their gelling, thickening and film forming properties, usable in a large number of food (human and animal) and non-food (fertilisers, cosmetics) applications.

[6] The production of **goods resulting from marine molecules** is based on marine organisms from which are extracted molecules that are used or which could be used for medical purposes. Historically, research on marine biomolecules has mainly targeted fixed species (sponges, trunicates, algae) due to the array of chemical defences developed by these species to ensure their survival.

[7] Nutrients, or nutrient elements, are organic and inorganic chemical substances required for growth and other vital processes. The **nutrient regulation** service expresses the capacity of assimilation of nutrients through nutrition involving primary production, consumption and, more generally, food webs. The ratios of concentration between nitrogen (N), phosphorous (P) and silicon (Si) in seawater influence the optimal growth of phytoplankton, and their variations can prevent the development of certain groups or, on the contrary, favour the development of others. Thus, the excessive input of nutrients from catchment areas can lead to a major change in these ratios between concentrations and result in eutrophication phenomena.

[8] The **coastal protection service** relies on the capacity of marine ecosystems to slow down the effects of marine currents and surges. It comprises two components: the limitation of erosion, which participates in stabilising sea beds and the coastline, and protection against extreme events such as storms and tsunamis.

[9] The **climate regulation service** stems from the capacity of certain ecosystems to store and sequester in the long-term greenhouse gases such as carbonic gases, methane and nitrous oxide, thus participating in their extraction from the atmosphere to partially offset their anthropic emission. The main vector of this service is the storage of carbon, as CO_2 contributes more than three quarters of total anthropic emissions of greenhouse gases considered responsible for climate change.

[10] The term “pathogenesis” signifies microbes (bacteria, viruses and parasites) liable to cause infections and diseases in all living organisms. The **pathogen regulation service** results from the control of their concentration in marine and coastal habitats by ecosystems, as certain organisms are able to purify the habitat through the hyper-filtration process.

[11] The cultural ecosystemic **recreation service** is based on specific activities by which human beings can relax and find diversion through contact with nature. It therefore implies physical interaction on a site with ecosystems and reveals the attractiveness of marine ecosystems for practicing leisure activities such as shore angling, bathing, diving, sailing, sea angling, etc.

[12] Marine ecosystems contribute to forming pleasant landscapes that also render marine spaces attractive. The cultural service of **contemplating landscapes** involves a presence on site but implies intellectual experience founded on the beauty of nature and the inspiration that it provides. What is more, this service can be linked to the search for contact with the elements of nature that embody the feeling of belonging and heritage for the individual.

[13] The services **of information and knowledge** delivered by marine ecosystems involve the participation of these ecosystems in the production and dissemination of knowledge for society. They are immaterial services that have a mainly intellectual and social importance for society. The production of information and knowledge consists of an intellectual and cognitive approach that leads to the accumulation of scientific knowhow without it being necessary to be present on site.

Natural heritage can be considered as a particular type of cultural service: it groups an array of immaterial cultural services that comprise a collective, emotional and affective dimension, and is distinguished from other cultural services in that it testifies to a sensitive relationship with, and an attachment to, ecosystems and marine habitats. The entities and processes involved in this relationship cannot be wholly objectified. To characterise the process of patrimonialization of marine ecosystems, that is to say the production of places and objects that have been conferred a meaning that structures the collective memory and represents reference points that can be transmitted to future generations. The EFESE-Mer distinguishes two categories:

[14] **Institutionalised heritage**, which includes all the elements of marine ecosystems (sites, places, species, objects) that have been officially endowed with the status of protection or recognition at the instigation of expert communities (notably naturalists) and public institutions.

[15] The **other forms of patrimonialization** that refer to all the other forms of social construction (artistic, the organisation of events, as well as to less visible forms such as works of art and festivals), through which communities, most usually local, appropriate marine ecosystems for themselves and therefore choose to protect them and hand them on to future generations, a practice which in their relationship with nature "produces culture".

Levels of service by types of ecosystem

The synthesis of available knowledge allows making a qualitative assessment of the contribution of marine and coastal ecosystems to the provision of ecological functions and ecosystem services by major types of ecosystem at the scale of the French maritime domain. Table 5 summarizes this contribution according to four modalities: high, medium, low or non-existent. Because of their qualification as a constituent element of human well-being, ecosystem services (unlike ecological functions) are evaluated via the benefits that society derives from them, regardless of the specific features of the ecosystem that provides them, its size and even its state. From this perspective, it is necessary to take into account the total demand for services in order to estimate the contribution of major ecosystem types to the provision of services. This implicitly incorporates the effects of the size and distribution of ecosystems as a function of their ability to satisfy a demand that is itself more or less extensive.

Ecosystems with the most diverse bundle of services are the soft and rocky bottoms of the intertidal zone, specific habitats such as seagrass beds, mangroves and coral reefs, and finally estuaries, lagoons and water bodies under estuarine influence. Some services are provided in a significant way (*i.e.* with at least a moderate contribution) by only a limited number of ecosystems, which therefore play a key role with respect to these services. This is the case in particular for the production of goods, especially goods from shellfish farming, macro-algae fields and molecules. This is also the case for the climate regulation service, concentrated in particular habitats such as seagrass beds and mangroves and in the pelagic compartment where phytoplankton is found. The service of coastal protection is concentrated in coral reefs, mangroves and seagrass beds and to a lesser extent on beaches and dune chains, salt marshes and lagoons. Food production services through fisheries and shellfish farming are generally associated with a considerable contribution in terms of food webs and breeding and feeding services. A very wide variety of ecosystems provide a significant level of recreational services, with the exception of offshore ecosystems, where the contribution is low, and deep-sea ecosystems, where these services can be considered absent.

Table 5. Contribution of ecosystems of waters under French jurisdiction to the supply of functions and services.

	Food webs	Reproduction and nursery	Goods from fisheries	Goods from mariculture	Goods from macro-alae	Molecules	Nutrient regulation	Coastal protection	Regulation of climate	Pathogen regulation	Support for recreation	Provision of landscape	Knowledge production	Institutionalized heritage	Other forms of heritage
H – Coastal and Marine habitats															
H1 – Coastal dunes and sandy shores															
H2 – Coastal pebbles															
H3 – Cliffs, ledges and rocky shores															
H4 – Rock and other hard intertidal substrates															
H5 – Intertidal sediment															
H6 – Rock and other hard infralittoral substrates															
H7 – Rock and other hard circalittoral substrates															
H8 – Subtidal sediment															
H9 – Deep habitats							F								
HP – Special habitats															
HP1 – Salt marshes															
HP2 – Seagrass beds															
HP3 – Coral reefs															
HP4 - Mangroves															
HP5 – Macro-algae fields															
HP6 – Coralligenous															
ME – Water bodies															
ME1 – Mediterranean lagoons															
ME2 - Lagoons															
ME3 – Estuarine and transition waters															
ME4 – Coastal waters under estuarine influence															
ME5 – Other waters over continental shelves							F			F					
ME6 – Epipelagic zone of ocean waters							F			F					
ME7 – Meso and bathy-pelagic ocean zones							F			F					

[Dark green: high contribution; Light green: medium contribution; Yellow: low contribution; Grey: no contribution; F: function rather than service]

With respect to heritage processes, two findings emerge from the assessment. Firstly, so-called "special" habitats are globally those more subject to become heritage sites, whether through institutional action or through forms of attachment and value originating from civil society; or more precisely they are called "special" precisely because their heritage value is recognized. Secondly, this applies more to coastal than offshore ecosystems, particularly because ownership and management depend on the physical possibilities of access to nature and its constituent elements.

The availability of indicators

The categories chosen to organise the assessment of available indicators are adapted from the conclusions of a workgroup of the United Nations Environment Programme held in 2009. The first three categories are unchanged: they comprise the **state indicators** of the ecosystem of interest for the function or service considered, the **capacity indicators** of the ecosystem to fulfil the service and the **effective utilisation** of the service. The last two categories have been modified. The UNEP report distinguished the benefits, defined as "that which directly benefits human well-being" and the impacts on physical, economic and spiritual well-being. These distinctions do not appear sufficiently clear, thus EFESE Marine WG has preferred to opt for a distinction between the indicators showing an **individual advantage**, that is to say the increased well-being of an individual through their own direct interaction with the ecosystem, and indicators that show a **collective advantage** that benefits all social groups, including their moral and spiritual aspirations. The collective advantages therefore roughly reflect what the EFESE's conceptual framework considers as advantages different from "economic needs", i.e. health, the quality of the living environment, social relations and economic and physical security. This distinction between individual and collective advantages also echoes the convention adopted in the framework of the National Ecosystem Assessment (NEA) of the United Kingdom to distinguish "individual" and "shared" values. The indicators themselves stem from a review in the literature and proposals formulated by EFESE Marine WG for certain services. Not all the indicators presented as available on a large scale or punctually in a summary table (Table 6) have been systematically listed in the study, but the review of available knowledge has at least allowed deciding on the indicator's availability.

The assessment shows that **much knowledge is still lacking in order to globally fill every type of indicator for most services**. For certain services, there is no reliable indicator that allows estimating the advantages they procure. This the case of the service of producing goods resulting from marine biomolecules. This can be explained by the fact that this service essentially exists in a potential form, since many molecules of interest for pharmaceuticals and nutraceuticals remain to be discovered. But even if non-qualified, this service must be considered since it allows materialising the option value of certain ecosystems, still little known or used, such as deep ecosystems, and thus the need to conserve them and appreciate the integrity of their functioning.

Services at the limits of ecosystems and life

It wasn't until 2018 and its version 5.1 that the CICES explained the distinction between **biotic services** and **abiotic services**. Abiotic services do not rely on biological processes: given the intrinsic logic of the ecosystem service approach, which consists in focusing on the contribution of life and biodiversity to human well-being in order to justify conservation, **the EFESE-Mer study has adopted by convention** not to consider **abiotic services** as ecosystem services and thus **exclude them from the scope of the assessment**. This distinction is fundamental to avoid "catch-all" assessments and maintaining confusion regarding the effective contributions of ecosystems to a service when, moreover, strictly physical processes are also involved in supplying an analogous service that would be just as well ensured in the absence of real ecosystem and biodiversity conservation.

In the case of the **climate regulation** service delivered by marine and coastal environments, this convention leads to **distinguishing physical pumps from biological pumps** (see box 2). The problems of delimiting the contribution of ecosystems to services have also included **nutrient regulation and pathogen regulation services**, in which **dilution processes**, which are purely physical, can occur at considerable magnitudes depending on the characteristics of the site concerned. Conventional frameworks of ecosystem service assessments (CICES, IPBES) mention **aquaculture** as an activity that generates goods for human societies, without distinguishing a priori the type of aquaculture, or the breeding practices employed. However, there is a basic difference between **fed species** (in fish farms) and **non-fed species** (shellfish): the former require considerable action on the habitat, in particular by introducing food, and depend very little on its ecosystemic functioning (the physical parameters of seawater alone must match requirements, and breeding could be achieved just as well in closed basins), whereas the latter do not require any action on the ecological functioning of the habitat (since its natural food production functions are all that are required) and present considerable dependence on the functioning of the ecosystem, in particular via food webs and nutrient and pathogen regulation.

Table 6. Assessment of indicators available for assessing the functions and services delivered by the ecosystems of the French maritime domain.

Ecosystem services	Conditions / state	Capacity	Flow of service / utilisation	Individual advantages	Collective advantages
Food webs [Function]	Balance between food web compartments	Primary production Secondary production	*Contribution to all services*	Not relevant	*Protection measures (potential)*
Reproduction and nursery [Function]	Localisation and Biodiversity of suitable habitats	Surface area of suitable habitats	*Contribution to all services*	Not relevant	Protection measures Restoration measures
Goods from fisheries	State of exploitation stocks	Maximum sustainable yield	Quantities of fish caught	Consumption (volume & value) Jobs generated	Health, food security (number of beneficiaries, nutritional value)
Goods from mariculture	Number of sites suitable for shellfish farming	Load capacity of shellfish basins	Quantities of shellfish produced	Consumption (volume & value) Jobs generated	Health, food security (same as goods from fisheries)
Goods from macro-algae	State of exploitation stocks	Maximum sustainable yield	Quantities of macro-algae harvested	Consumption (volume & value) Jobs generated	Health, food security (same as goods from fisheries)
Molecules	Num. of species of nutraceutical and pharmaceutical interest	*NA*	Quantities of species of interest extracted	Consumption of derived products Jobs generated	Health, food security (num. of beneficiaries, nutritional and therapeutic value)
Nutrient regulation	Level of primary production	Rate of nutrient assimilation	Flow of nutrients emitted	Avoided costs of individual pollution clean-up	Costs of collective treatments
Coastal protection	Existence of ecosystems endowed with protective species	Surface area and density of protective vegetation in vulnerable zones	Intensity of erosion and frequency of extreme events in vulnerable zones	Avoided damage (economic activities)	Avoided damage (safety of people and living conditions)
Regulation of the global climate	Carbon storage (vegetation, soil, water bodies)	Net storage and net sequestration of carbon	*NA*	Avoided damage (economic activities)	Attenuation of climate change Avoided damage
Pathogen regulation	Density of pathogen populations	Density of anti-pathogen species	Quantities of pathogens emitted	Costs avoided for the exploitation of sensitive species	Improvement of habitat of wild species
Support for recreational activities	Quality of beach angling sites Quality of bathing water State of populations observed (*nature watching*)	Capacity for sustainable utilisation	Number of users	Individual expenses for practicing a recreational activity	Costs of collective treatments Expenses of user associations Health, well-being (number of beneficiaries)
Production of pleasant landscapes	*NA*	*NA*	Number of users	Difference of housing prices linked to marine landscapes	Well-being, quality of living environment (num. of beneficiaries)
Knowledge production	Not relevant	Not relevant	Number of publications Number of training courses, etc.	Number of scientists Number of students in marine sciences	Expenses on research and education Sensitivity of public to nature
Institutionalized heritage	Number of species of heritage interest Number and extent of sites of heritage interest	Not relevant	Number of protected species Number of listed or protected marine sites	Individual expenses for reaching sites of heritage interest	Expenses for protecting species and sites of heritage interest
			Number of visitors of listed or protected sites	Attachment to preserving natural heritage	Well-being, quality of living environment (num. of beneficiaries)
Other forms of heritage	Traditional and artistic practices related to marine ecosystems	Not relevant	Number of events Number of artistic works Number of users	Attachment to maritime culture Feeling of belonging	Well-being Social relations Quality of living environment (num. of beneficiaries)

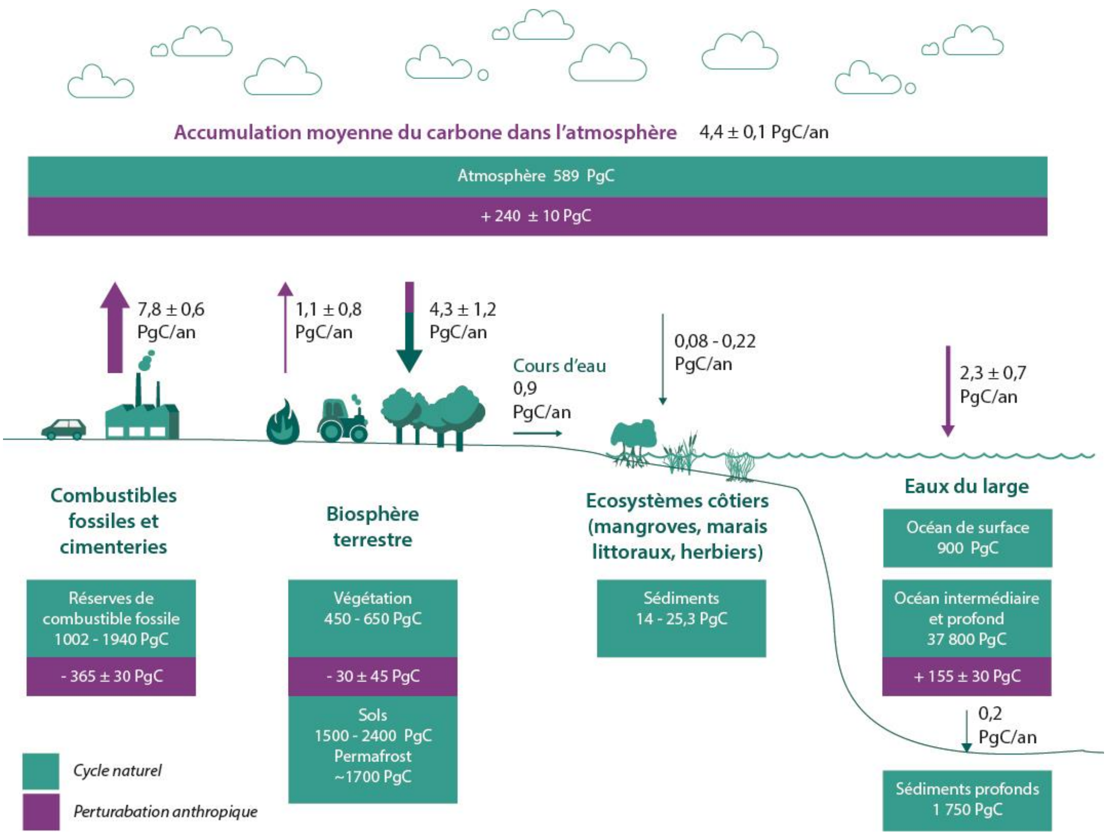
Green: almost generally available indicator for ecosystems of waters under French jurisdiction; Blue: indicator available only punctually; Grey: indicator not available; NA: absence of indicator mentioned in the literature.

Thus, **EFESE Marine WG has limited its assessment of goods produced from marine farming to shellfish and algae-culture**. Lastly, **cultural ecosystem services** are an extremely complex and multiform category, whose assessments often give rise to the production of **"catch all" indicators**: thus in the case of recreative activities, assessments are usually performed by estimating the resources deployed to practise them, without specifying whether this deployment may lead to **joint productions** that go beyond the sole advantages provided by an ecosystem, such as **advantages resulting from the sporting nature of the activity practiced on a site**. That is why assessments proposing available estimations of ecosystem services should be associated when necessary with precautions regarding indicators that are insufficiently linked to the service targeted, with the risk of overestimating the advantages it provides.

Box 2. Marine ecosystems and climate regulation service

Different global carbon balances estimate that about **46% of anthropic carbon emissions are stored in the atmosphere, 28% absorbed by the biosphere and 26% by the oceans**. Since the beginning of the industrial era, the ocean – through physical, chemical and biological processes – plays the role of carbon sink in the same way as the terrestrial biosphere does for climate regulation. Two major processes can be distinguished in global assessments to explain the carbon sink effect of the ocean: 1) **the "solubility pump" or "physical pump"** that permits exchanging CO_2 at the air-sea interface between the ocean, then transport of the dissolved CO_2 by vertical mixing in the atmosphere, and the displacement of masses of ocean water; (2) **the "biological pump"** fed by planktonic ecosystems that fix dissolved CO_2 and convert it into particulate matter. This plankton production, at the base of marine food webs, and which is globally in surplus, redistributes the carbon on the surface waters to intermediate and deep-water levels. A small fraction of this organic matter is buried in the deep sediments. The latest reports of the IPCC signal an accumulation of anthropic carbon of 155 ± 30 PgC in the intermediate and deep ocean over the industrial period from 1750 to 2011. **In the coastal zone, a third process concerns the fixing of carbon by plant ecosystems.** Coastal marshes, mangroves and seagrass beds trap and store carbon, either by photosynthesis or by capturing sediments and natural debris in their complex root systems. This process is an emerging issue in the discussion on climate regulation and "Blue Carbon". **The physical pump represents 90% of the oceanic carbon sink.** Blue carbon represents low capture values due to small surface areas, although it permits storage over thousands of years.

Figure 3. Global carbon budgets.



[Carbon flows are in PgC/year. In violet: accumulation of anthropic carbon. In green: flows and natural stocks.]

4. What advantages for society?

Contribution to human well-being

The conceptual framework of the EFESE distinguishes five types of advantages that individuals can obtain from ecosystems: **economic needs**, **health**, **quality of the living environment**, **social relations** and the **need for economic and physical security** (see Table 7). The key ecological functions of marine ecosystems, which are not subject to direct social demands, make only medium contributions in terms of security and small ones in terms of health and quality of the living environment. All the goods produced by ecosystems make large contributions to economic needs and health; they also provide a medium contribution to advantages in terms of security. The nutrient regulation service above all contributes to economic needs, health and the quality of the living environment. Coastal protection and climate regulation make a large contribution to security; coastal protection can also make a significant contribution to economic needs and climate regulation to quality of life. Lastly, cultural, cognitive and recreational services mainly contribute to quality of life and social relations.

Table 7. Contribution of functions and services delivered by marine and coastal ecosystems to different dimensions of human well-being.

	Economic needs	Health	Quality of living environment	Social relations	Security
Food webs					
Reproduction and nursery					
Goods from fisheries					
Goods from shellfish farming					
Goods from macro-algae					
Molecules					
Nutrient regulation					
Coastal protection					
Climate regulation					
Pathogen regulation					
Support for recreational activities					
Production of pleasant landscapes					
Knowledge production					
Institutionalized heritage					
Other forms of heritage					

[Dark green: considerable contribution; Light green: medium contribution; Yellow: small contribution; Grey: no contribution.]

Individual and collective advantages

Another way of characterising the contributions of ecosystem services to the well-being of human societies consists in distinguishing **individual advantages** and **collective advantages**. Individual advantages can be obtained by individuals independently of any consideration on possibly irreversible impacts suffered by ecosystems and the possibility of sustainably maintaining the flow of services in the long term despite possible rivalry regarding use. **Collective advantages are those that benefit the whole of society** and are visible in ways different from economic and individual benefits: the existence of collective advantages leads society to take into account the maximum capacity of ecosystems to supply flows or to absorb disturbances and **incite conservation measures**. Understanding the distinction between individual advantages and collective advantages on the one hand, and the conditions for maintaining these advantages or not on the other, requires a specific analysis of the **types of demand** made on ecosystem services (see box 3).

Indicators relating to individual and collective advantages obtained from marine ecosystem services for which estimations exist are grouped in Table 8 for mainland France and in Table 9 for the overseas territories. These tables do not seek to make a distinction within the category of collective advantages. The assessments presented in these two tables highlight the **considerable lack of available quantitative indicators** to evaluate the advantages provided by the following services: **molecule production, nutrient regulation, coastal protection of mainland France, climate regulation, pathogen regulation, recreational activities and knowledge production overseas and, lastly, types of patrimonialization other than institutional**. It should be noted that the **indicator of collective advantages**, for which EFESE Marine WG proposes to use estimators in terms of number of beneficiaries and the cost of maintaining the capacity of ecosystems to supply services, **are less subject to shortage than the indicators of individual advantages**, especially regarding **regulation services** and **patrimonialization**.

Box 3. The different types of demand for ecosystem services

The EFESE Marine WG proposes to distinguish the different types of demand that actors make for ecosystem services. These different types of demand are classified according to whether they are expressed **directly or indirectly** from the standpoint of the benefit sought. They are also classified according the mode of interaction with the ecosystem: the demands can entail **a subtractive utilisation or not**, a **utilisation having an impact or not** and lastly concerns relating to the **conservation of the ecosystem** and the services it renders.

The demand is considered as **direct if the benefit is drawn directly from the use or consumption** of an ecosystem service. It is indirect **when the benefit is drawn from an activity for which the service is a mobilised factor**, which is generally the case for regulation and support services. Whether direct or indirect, the demand for use will be **subtractive if it consists in withdrawing part of the flow of the ecosystem or of its capacity of absorption**. Pollutant activities will thus have an indirect demand for a subtractive utilisation of water quality regulation services, since they impair the capacity of the habitat to absorb pollutant flows. On the contrary, a demand for use is not subtractive from the ecosystem if it neither withdraws flows nor lessens absorption capacity. Bathing activities, for example, represent a non-subtractive use of water quality regulation services.

A demand can also be characterised by its impact. A demand has an impact **if it affects an ecosystem process or its structure**: this is the case of unsustainable practices of producing goods resulting from ecosystems. Regarding **regulation services**, a typical type of **demand with an impact** is that represented by **pollutant activities that utilise these services beyond the ecosystem's absorption capacity**: this is the case, for example, of excessive emissions of nutrients in the watersheds of eutrophicated coastal areas. Generally, the pressures exerted on the ecosystem from non-subtractive demands is low, but in the case of greater pressures, a demand of this type will have an impact as in the case of excessive occupancy linked to the consumption of certain leisure-cultural services.

The **demands for conservation**, when **direct**, seek a form of **"nature sanctuary"** and are often driven by environmental protection associations. Persons or bodies **making indirect demands for conservation**, but also sometimes direct demands for conservation, are concerned with **collective advantages** from which benefit groups of actors, or the whole of society. Indirect demands for conservation are generally associated with a demand for an activity, product, standard or regulatory measure requiring the restoration or the maintenance of certain ecological functions. They can take the form of a demand for the reduction of negative externalities or the increase of positive externalities.

Table 8. Individual and collective advantages obtained from functions and services provided by ecosystems of the maritime domain of mainland France.

	Individual advantages		Collective advantages	
	Indicators	Estimation	Indicators	Estimation
Food webs [Function]	Not relevant		*Mesures de conservation*	*NA*
Reproduction and nursery [Function]	Not relevant		Functional protected fishing zones	*Zones being defined (2018)*
			Costs of measures to preserve marine biodiversity - including restoration and compensation	28 062 000 € (2009) 28 610 678 € (2016) 12 272 000 € (2009) 3 761 000 € (2016)
Goods from fisheries	Volumes of sales Values of sales	240 000 tonnes (2014) 680 Million € (2014)	Num. of consumers Annual consumption	80 to 96% of the population 24 kg/person/yr
	Direct jobs	9 681 FT (2014)	Management costs	133 700 000 € (2008) 85 822 811 € (2016)
Goods from shellfish farming	Volumes of sales Values of sales Direct jobs	154 500 tonnes (2013) 535 Million € (2013) 8 500 FT (2012)	Num. of consumers Annual consumption	20 to 33% of the population 10 kg/person/an
			Management costs	38 970 000 € (2008) 25 000 000 € (2016)
Goods from macro-algae	Volumes of sales	40 to 70 000 tonnes	Num. of consumers	58 % de la population
	Values of sales Jobs generated	NA NA	Annual consumption	NA
Molecules	Consumption of derived products Jobs generated	NA	Num. of consumers Annual consumption	NA
Nutrient regulation	Avoided costs of individual pollution clean-up	NA	[-] Costs of eutrophication treatments	52 714 600 € (2009) 273 829 300 € (2016)
Coastal protection	*Avoided damage (economic activities): Hotel infrastructures possibly protected*	NA	*Avoided damage (personal security and living conditions)*	NA
Climate regulation	Avoided damage (economic activities)	NA	*Reduction of climate change*	*Burial of carbon: 1.66 to 7.01 TgC/yr*
			Avoided damage	NA
Pathogen regulation	[-] Costs of individual pollution clean-up	NA	[-] Social costs caused by contamination	NA
			Management costs	1 247 056 000 € (2009) 1 394 042 000 € (2016)
Support for recreational activities	Expenses of recreational anglers Turnover from diving	1 250 000 000 € (2006) 20 925 000 € (2016)	Number of recreational anglers	France: 2 450 000 € (2009)
			Number of divers	Mediterranean: 50 000 (2012)
Production of pleasant landscapes	Share of landscape in consumption of recreational activities (GNB)	GNB: 46% marine landscape 4% submarine landscape	Attraction of coast - number of inhabitants - tourists / night	 7 786 264 (12 %) 123 900 000 (31 %)
Knowledge production	Jobs in marine science research	4 084	Public expenditure on research	335 000 000 € (2016)
	Number of students in marine sciences	3 000	Expenditure on	NA
Institutionalised heritage	Annual number of visitors to protected marine sites	NA	Number of protected marine species protégées Number and surface area of protected marine sites Expenses dedicated to protect marine sites	National and local: 332 CL (2015): 720 sites 164 000 ha AMP (2017): 327 sites 90 331 km² (23,99% des eaux) 75 169 000 € (2009) 69 356 390 € (2016)
Other forms of patrimonialization	Number of participants at cultural events linked to the sea	NA	Number of cultural events linked to the sea	NA

[Green = expanded estimation; Bleu = punctual estimation; Yellow = proxy, value probably very overestimated; Italics = potential advantage; Grey = no estimation available; [-] losses due to exceeding ecosystem capacities]

Table 9. Individual and collective advantages obtained from functions and services provided by the ecosystems of the maritime domain of French overseas territories.

	Individual advantages		Collective advantages	
	Indicators	**Estimation**	**Indicators**	**Estimation**
Food webs [Function]	Not relevant		*Conservation measures*	*NA*
Reproduction and nursery [Function]	Not relevant		Protected functional fishing zones	*No designation in progress (2018)*
			Costs of measures to preserve marine biodiversity	NA
			Including restoration and compensation	NA
Goods from fisheries	Volumes pf sales Values of sales	30 000 tonnes (2014) 100 Million € (2014)	Annual consumption Management costs	NA
	Direct jobs (including partial income)	15 000 professional fishermen (2014)	Number of households obtaining a source of income or food	50 000
Goods from shellfish farming	Volumes des ventes (raw pearls) Values of sales (raw pearls) Direct jobs	14.3 tonnes (2014) 10.5 tonnes (2016) 72. 2 Million € (2014) 53.8 Million € (2016) 1 300 jobs (2012)	Num. of consumers Annual consumption	NA
			Management costs	NA
Goods from macro-algae	Not applicable		Not applicable	
Molecules	Consumption of derived products Jobs generated	NA	Number of consumers Annual consumption	NA
Nutrient regulation	Avoided cost of individual pollution clean-up	NA	Avoided costs of water treatment	Guadeloupe: 11 Million € (2012) Martinique: 9.4 Million € (2009)
Coastal protection	*Avoided damage (economic activities): Hotel infrastructures possibly protected*	*155 211 to 258 683 m² (Polynesia) 180 000 m² (Guadeloupe) 25 554 m² (Reunion)*	*Avoided damage (personal security and living conditions)*	*87 000 to 94 000 protection of individual and collective dwellings (Total overseas)*
Climate regulation	Avoided damage (economic activities)	NA	*Reduction of climate change*	*Burial of C: 6.75 to 7.93 TgC/yr*
			Avoided damage	NA
Pathogen regulation	[-] Costs of individual pollution clean-up	NA	[-] Social costs generated by contamination	NA
			Management costs	NA
Support for recreational activities	Value of food/recreational fishing	85 000 000 € (2016)	Number of recreational anglers	NA
	Turnover from diving	NA	Number of divers	NA
Production of pleasant landscapes	Jobs generated by the "blue tourism" sector (coral reefs)	Directs: 2 800 (2016) Indirect: 35 000 (2016)	Attraction of ecosystems - coral reef users	1 000 000 (2014)
Knowledge production	Jobs in marine science research	NA	Public expenditure on research	110 000 000 € (2016)
	Number of students in marine sciences	NA	Expenditure on education	NA
Institutionalised heritage	Annual number of visitors to protected marine sites	NA	Number of protected marine species Number of surface area of protected marine sites	National and local: 1264 (including 676 only at international level) AMP (2017): 117 sites 2 199 690 km² (22.24% of waters)
			Expenses dedicated to protected marine sites	NA
Other forms of patrimonialization	Number of participants at cultural events linked to the sea	NA	Number of cultural events linked to the sea	NA

[Green = expanded estimation; Bleu = punctual estimation; Orange = proxy, value possibly underestimated; Yellow = proxy, value possibly overestimated; Italics = potential advantage; Grey = no estimation available; [-] losses due to exceeding ecosystem capacities]

The patrimonialization of nature

Historically, marine and coastal habitats were among the first to be given a heritage status. They have greatly contributed to the emergence of patrimonialization dynamics since the 19th century at different scales. For example, the notion of a heritage common to humanity was used for the first time for deep sea beds in 1970, then in 1982. In France, actions to conserve coastal sites and marine species gave rise to several laws having a general scope during the 20th century, notably the Law of 21 April 1906 organising the protection of natural sites and monuments of an artistic nature.

Nowadays, different appreciations of the category of natural heritage coexist and must be taken into account when considering the great diversity of patrimonialized objects and types of patrimonialization. This diversity of approaches is especially poignant regarding coastal and marine heritage, since the natural habitats concerned are extremely complex, fragile and group a wide range of uses, social and institutional actors, and management methods and instruments. **The patrimonialization of marine ecosystems and the services they render is therefore both a historic process and a contemporary social and political issue**.

The natural marine heritage has long emerged from its "wild" dimension, making the distinction between nature and culture increasingly blurred, so that more and more diverse objects are included, from the integral reserve to the smallest element of biodiversity (like plankton), and natural marine parks. Several types of patrimonialization can be identified regarding marine and coastal biodiversity that all participate in the valorisation and acknowledgement of its importance. In particular, two dynamics are involved:
- the **continuation of the patrimonialization processes already established at the initiative of often local communities**, to protect traditional practises and trades, acting as a basis for cultural practices that endure through celebrations, places of remembrance, and/or the labelling process;
- the **strengthening of institutionalised nature heritage**, focusing on remarkable items of marine biodiversity or sites that should be protected (e.g. IUCN list, Coastal Conservatory sites, Natura 2000 zones, natural marine parks).

Few of these dynamics are conflictual in themselves; they appear to generally reinforce each other or else coexist without conflict. However, mention should be made of:
- the sometimes substantial difference between the valorisation of certain ecosystems by those advocating issues springing from civil society and institutional and scientific priorities. This is the case, for example, for certain beaches and dune systems;
- the persistence of conflicts that essentially concern the extraction of natural resources from sensitive ecosystems subject to protection procedures.

Furthermore, the distinction between natural heritage and cultural heritage has no meaning regarding patrimonialization processes undertaken in the continuity of practices specific to a given coastal society (see box 4 for examples of patrimonialization situated socially). Although heritage is an open category, whose definition and scope vary in time and space, observing the dynamics of patrimonialization does not suffice to identify the diversity of forms of attachment to coastal and maritime nature. This is insofar as certain forms of attachment do not result in an organisation or collective action, a discourse, or material realisation making it possible to identify the attribution of a value. The strength of these attachments is nonetheless clear when observing the abundance and diversity of works of art inspired by the sea, the attraction of coastal environments and the results of surveys on the relation between the French people and the sea.

Lastly, **methods that permit taking into account the extent and nature of natural heritage elements have not been standardised**: they can be identified by inventories and approached through indicators of action of social and political actors, provided that longitudinal approaches are privileged. Once patrimonialization is considered as a process involving the whole of society and not only the institutions responsible for implementing nature protection policies, the natural marine heritage should also be considered as a biocultural heritage linked to the sea, whether material or immaterial, by the most participatory methods possible.

Box 4. Three examples of the patrimonialization of marine ecosystems

Illustration 1. The sardine in Douarnenez bay: the patrimonialization of a commercial species

The town of Douarnenez was active in blue fish fishing from the middle of the 19th century to the middle of the 20th century. “The capital of the sardine”, Douarnenez shared with other ports of the Atlantic coast the same working class, dissident port culture linked to the installation of many fish canneries. Many observers underlined the fact that although sardine fishing had almost disappeared for about fifty years, sardines were everywhere at Douarnenez.

From left to right: the logo of the Bagad (a traditional music group) of Douarnenez, shop window of the “Penn Sardin” shop (sale of vintage sardines and derived products); local interpretation of the legendary siren: in 2003, for its 150 anniversary, the cannery Chancerelle (Connétable brand) offered to the municipality of Douarnenez a statue of a woman-sardine in stone and bronze. The work of the sculptors Véronique Millour and Philippe Meffroy.

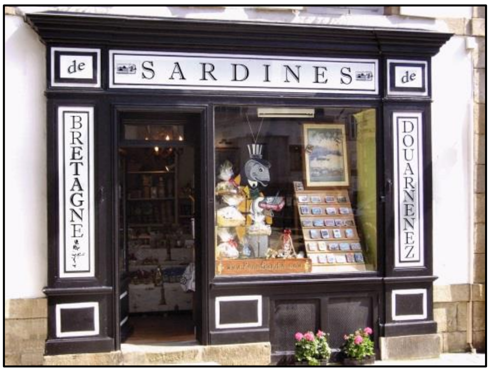


Illustration 2. The Coast Conservation Office and patrimonialization by sensitivity

The Coast Conservation Office funds a large number of artistic works that use its sites as subjects. Here, the photographer and filmmaker R. Depardon shows the Pointe du Raz (*Piétinements, parcours. La Pointe du Raz, 1991*). His photographs illustrate the great sensitivity to degradation of the area surrounding the site. He returned ten years later, when restoration actions were carried out by the Conservation Office.

Source: Kalaora and Konitz, 2004 (credits: Raymond Depardon, Magnum Photos/Conservatoire du littoral).

Illustration 3. Palikur shamanic sawfish seat in French Guiana

The Amerindian and Creole populations of the estuaries of the River Oyapock, on the border between French Guiana and Brazil, are linked to the sea by myriad material and idealised connections. Several marine species of the high seas can be identified in the culture of the Palikur people. Their mythological tales include the story of *awat*, the swordfish. The sawfish is a recurrent symbol among the zoomorphic shamanic seats of the Palikur.

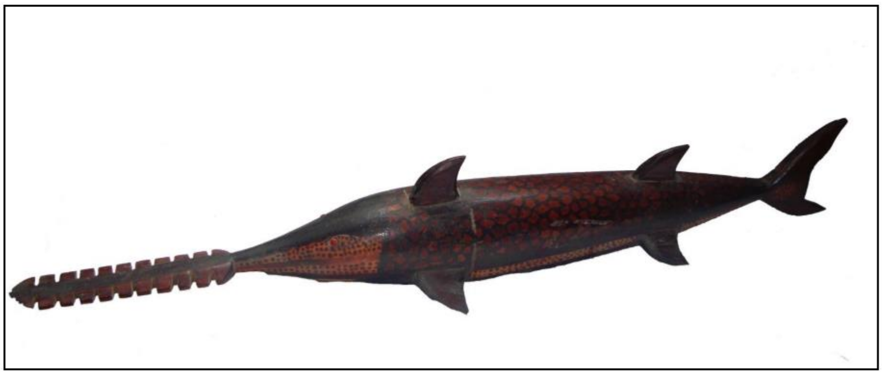


Photo credit: P. Laval

Key services and the ecosystems at stake

According to the stakeholders interested in the sea, the main services that marine and coastal ecosystems provide are the production of food goods, the regulation of water quality and cultural services.

The compromises relating to the production of **food goods extracted by fishing** have for long consisted only of orienting the levels of catches from stocks towards the **objective of maximum sustainable yields**. These compromises henceforth tend to become more **complex** due to the interactions that the catches made by professional fishing maintain with those of recreational fishing on the one hand, and with the functioning of food webs on the other. Regarding **food goods extracted from marine farming**, the ecosystems dedicated to shellfish farming, although belonging to the categories of modified ecosystems due to the input of a biomass of shellfish bred in densities far higher than those found naturally, have long been seen more as ecosystems impacted by other anthropic pressures, in particular those flowing from catchment areas (mainly health and chemical contaminations). However, shellfish farming is subject to recurrent problems, some of which are subsequent to increasingly intensive monoculture, associated with the possible genetic depletion of the populations of animals cultivated.

Water quality regulation appears to be a key service above all supplied by coastal ecosystems such as estuaries, lagoons and coastal marshes, coral reefs and mangroves, but also by pelagic water bodies where plankton develops. Water quality regulation includes several components: nutrient regulation, the sequestration of residues of chemical contaminants, the regeneration of ecosystems following accidental pollution like black tides, etc. The issue regarding the need to preserve marine and coastal ecosystems liable to contribute towards water quality regulation is therefore always associated with that of managing water quality as such, and hence raises ever more acutely the question of **the consistency and integration of terrestrial and marine management policies**.

The last category of services considered as key by the stakeholders interested in the sea is that of **cultural services**. As submitted for consultation with the stakeholders, this category comprised the support of recreational and leisure activities, the provision of pleasant landscapes and the contribution of territorial and cultural identity. The importance given to these services highlights the **fundamental tension that exists between increasing demands for new uses of marine and coastal ecosystems and growing demands for preservation**. The new compromises concerning these services, notably regarding recreational and leisure activities as well as the consumption of landscapes, will have to take the direction of developing frequentation capacities and educating the public to pursue more responsible activities.

The main ecosystems facing challenges that emerged from the consultation with the stakeholders interested in the sea, on the basis of ecological importance and exposure to change factors, were the following: plankton, coral reefs, estuaries, seagrass beds, beaches and dune systems. It should be noted that all these ecosystems present a range of diversified ecosystem services, with the exception of plankton, beaches and dunes systems.

Plankton, beaches and dune systems belong to the category of specialised ecosystems. **Plankton** is the compartment of marine ecosystems perceived most ambiguously. Clearly identified by the stakeholders interested in the sea as essential for the good functioning of marine ecosystems, in particular through its role in food webs, plankton remains poorly identified by the general public, and although highly sensitive to change factors, it has not as such been the subject of any regulatory measure, except indirectly by those aimed at reducing processes of eutrophication and greenhouse gas emissions. Plankton therefore represents an essential challenge for reducing the considerable gap between its very high level of ecological importance, and the very low capacity of society to understand its functioning and to implement adapted conservation measures. **Beaches and dune systems** are mainly exploited for their contributions to cultural services, the most important of which is the role of support for recreational activities and the provision of pleasant landscapes, followed by their role in territorial culture and identity. Thus, ultimately, a conflict exists between the very high level of demand for the direct use of these ecosystems with possible subsequent impacts left by mass tourism and recreational activities, and growing awareness of the fragility of these environments, justifying stronger protective measures.

Coral reefs are precious ecosystems in the marine environment and are subject to a large number of conservation measures, due to their ecological role by which they provide a wide range of ecosystem services, and due to their emblematic nature. Thus, they have benefited from determined decisions such as the prohibition of any form of extraction of materials. Demand with respect to access to coral reefs and ecosystems nonetheless remains high, firstly because these ecosystems comprise a major source of food and income for local populations, and also because they support the booming industry of blue tourism. Hence, the concerns of the stakeholders interested in the sea turn increasingly towards assessing the efficiency of management methods in order to improve them.

Historically, **estuaries** are places subject to intense social demand that leaves traces: port developments, extraction activities in these highly productive areas, leisure activities. Moreover, they are exposed to high levels of pollution, particularly by chemical contamination. Estuaries therefore belong to those marine ecosystems which are most threatened. Nonetheless, French estuaries and especially the largest of them (Seine, Loire, Gironde, Rhone) are subject to many protective measures, above all aimed at protecting fragile habitats that sustain key ecological functions, notably reproduction and nurseries. The recent changes in the compromises made regarding the utilisation and conservation of these ecosystems shows greater vigilance regarding the development of their utilisation and greater concern given to the preservation of ecosystems, which in certain cases can go as far as launching projects to rewild estuaries.

Seagrass beds offer a bundle of highly diversified services. Due to the wealth of their functions and the spaces in which they develop, they are subjected to strong demands for recreational and professional activities that are sometimes conflictual and impact ecosystems. Seagrass beds are subject to different preservation measures both internationally and locally, although their local implementation leads to often complex compromises in terms of management.

5. The utilisations of the assessment

Integration in accounting

Economic estimations of the ecosystem services produced in the framework of the EFESE-Mer fall within the paradigm that postulates the **absence of identity between a stock and the sum of the flows it generates**: these are two intrinsically different entities that cannot be assessed by the same method. A stock of capital, natural or manufactured, combined with other production factors, can generate more or less significant flows, more or less sustainably, without this leading to an accurate reflection of the monetary value of the flows and still less that of the capital. At most the monetary value of the flows, known for certain goods supplied by ecosystems such as the fisheries products, or that of stocks, for which there is no robust example of natural capital, will reflect the utility that an individual will obtain from using this flow or stock or by trading it in return for another consumer or durable good. Since EFESE-Mer focuses on marine ecosystems liable to be subject to conservation measures, the question that its economic assessments must answer is not that of knowing whether one wishes to use this natural capital or trade it, but that of knowing how much should be invested to benefit from its potential for sustainably supplying services, thus for protecting or restoring it.

Proposals to include the assessments of natural capital and “environmental assets” in accounting systems have been made in the framework of the United Nations System of Environmental-Economic Accounting (SEEA). The central framework of this environment accounting system (or SEEA-CF for *SEEA Central Framework*) comprises four types of account: (a) jobs-resources tables in physical and monetary values; (b) natural active accounts in physical and monetary values; (c) a series of accounts establishing the value adjusted for ecological losses of economic aggregates; and (d) functional accounts recording transactions and information relating to activities implemented for environmental reasons. Since 2013, an extension was attached to the SEEA-CF: SEEA Experimental Ecosystem Accounting, which should in principle start from the perspective of ecosystems and link them to the economy and other economic activities. The SEEA-EEA focuses in particular on the evaluation of ecosystems and ecosystem services. Since the capital is natural capital, the SEEA-CF and the SEEA-EEA recommend assessing it using the technique of net discounted value of the benefits it generates. The drivers of these recommendations thus repeat the conceptual error of the proponents of the systematic monetarisation of ecosystem services which consists in believing that measuring flows of services allows estimating the value of natural capital using future projection and discounting techniques[6].

[6] The error consists in assimilating the values of marginal utility of the services (revealed, for example, by the purchase price of a “unit” of a service in the case where such a price exists) with a mean for measuring the value of the total stock of capital by

The assessment of recent experiences and the debates they have stirred tend to show that **estimating the monetary value of ecosystems**, which are portions of natural capital or environmental assets, **is neither pertinent nor feasible**. In France, it is more or less accepted that the interest of integrating the environment in national accounting is not to try to give a monetary value to stocks and assets, that is to say to the natural environments themselves, but only to the evolution of the state of these stocks according to whether they are subject to degradation or possible restoration. Among the diverse possible approaches for answering this type of interrogation, EFESE Marine WG privileges the approach by expenditure on environmental protection: this type of approach is particularly adapted to evaluating the cost borne by society to maintain the capacity of marine ecosystems to provide goods and services, or prevent their degradation. Finally, the types of account that seem to be the most pertinent to incorporating available and reliable evaluations of marine ecosystems and ecosystem services is the **jobs-resources of goods and services account**, that allows accounting the effective uses of flows of ecosystem services in physical and monetary terms, and the **functional account of marine ecosystem protection** (for ecosystems themselves or for their functions). In other words, in the perspective of ecological accounting with strong sustainability, the results of the EFESE-Mer study make a considerable contribution to the construction of a satellite account[7] of marine and coastal ecosystems by defining the boundaries of such a satellite account, that is to say the ecosystems, ecosystem services and institutions to be taken into account.

Contribution to public policies

The analysis of services delivered by ecosystems highlights the links between the ocean and human activities, and on a more general level between practices, representations, rules and institutions. It also permits: *i)* **documenting certain socioeconomic stakes linked to marine and coastal ecosystems**, and *ii)* **fuelling certain national strategies relating to the sustainable utilisation of protection of the marine environment**.

Activities that directly exploit marine biodiversity are highly dependent on the quality of the marine environment. Many local economies are structured by production activities as well as the distribution and processing sectors that stem from them. The pressure of fishing generates impacts on ecosystems beyond exploited catches alone, due to its interactions in food webs, collateral catches, discarded catches and the impacts of certain trawling gears. They are also subject to the degradation of the environment, especially reproduction grounds and nurseries. These two-way relationships, to which must be added the stakes linked to controlling access to resources, plead in favour of ecosystemic management and international cooperation. Regarding shellfish farming, it is the activity that covers the largest surface area of the French marine domain. The shellfish farming economy depends on the good functioning of certain regulation services, and the management of pressures from the mainland, both conditions essential for maintaining a high level of supply service. The challenges for fish farms concern their impacts on the marine habitat due to pollutions, genetic interactions with wild species and the appropriation of genetic resources. Furthermore, the biotechnology industry raises questions about the modalities of appropriating life, from the economic standpoint for companies, and from the social and moral standpoints regarding access to, and sharing, resources. The other activities involving the extraction of resources from the sea (minerals and energy-related) are less hindered by problems of dependence on the functioning of the marine environment than the use of space at sea. Navigation is faced with the problem of the dissemination of marine species and pollution caused by chemicals, sound and fuel. Implementing strategies to reduce these risks of pollutions entails high costs for maritime transport and ports. Activities at the interface between land and sea and the mainland, with the exception of tourism and recreational activities, for the most part do not depend on the state of marine biodiversity, but the need to preserve marine ecosystems generates strong economic and social challenges linked to these activities. Whether linked to the treatment of household and industrial wastewater, to artificialisation, the excessive enrichment of habitats by agricultural practices, the spreading of chemical substances and the use of plastics, practically no sector is spared of the need to take into account aquatic habitats and, ultimately, the marine environment. Constraints generated by regulatory obligations and voluntary adhesion to more ambitious objectives entail costs for society. The stakes of competitiveness, the lags involved in disseminating innovations and a certain number of postures, are all challenges that ecological transition must face.

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aggregation. This reasoning is incorrect since the value of certain services in certain situations is incommensurable: it is in reality infinite if the service is indispensable, such as in the case of the first food consumed to feed oneself or of a compound capable of curing a serious disease (this is what economists call a “infra-marginal value”: there is no question of wishing to trade one unit of this service for any quantity of another service).

[7] According to the INSEE, a satellite account is a framework for presenting economic data in a specific area in relation with the global economic analysis of the central framework of accounting at the national level.

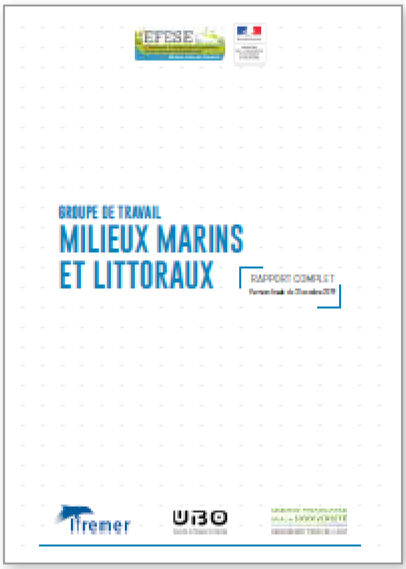
By contributing to revealing and setting out these interdependences and socioeconomic challenges, EFESE-Mer has produced a reference report at the national level, in the spirit of what various national strategies require. In addition to making available the state of the art relating to marine and coastal ecosystem services, EFESE-Mer proposes a methodological framework that is both strategic and operational for their characterisation that can be reused, notably through the application of the **national strategy for the creation and management of protected marine areas** (SNCGAMP) or in the framework of the territorial analyses mentioned by the circular of 20/01/2012, relating to the **sustainable and integrated management of the public natural maritime domain**. By doing this, the works of EFESE-Mer contribute to making effective the principles of integrated management that provide structure to **the national strategy for biodiversity, the national strategy for ecological transition to sustainable development, the national sea and coast strategy (SNML), the SNCGAMP, and the national strategy for the integrated management of the coastline**. These works also contribute to rebalancing perceptions of marine and coastal ecosystems and the services they render, from the standpoint of their importance for the functioning of marine habitats. For example, a social demand exists for services of maintenance and support, which are given less prominence by strategies than supply services and cultural services. The prioritization resulting from the consultation with the stakeholders permitted identifying the marine and coastal ecosystems faced by challenges and the key services they render. This can be used as a decision-making aid for the process of revising national strategies and the next action plans associated with them. For the SNML, for example, some ecosystems "deserve particular attention" (Action 1: Better know the sea, develop a society of marine and maritime knowledge), but the list of ecosystems that follow covers a very large number of habitats, species and functionalities. The approach of prioritization undertaken by EFESE-Mer permits identifying "important" ecosystems according to three criteria (importance for the functioning of marine habitats, exposure to factors of change, the possibility to act) and to combine them to identify the ecosystems facing challenges.

Knowledge gaps

Although the data and current knowledge on the functioning of marine and coastal habitats are sufficient to implement a framework for integrated management, much progress remains to be made and is possible. **Improving our understanding of the state and functioning of ecosystems first of all requires that we complete our fundamental knowledge regarding the extent of ecosystems and their biodiversity.** This knowledge is currently acquired through dedicated research programmes and monitoring carried out in the framework of management systems such as large-scale marine conservation tools and policies (AMP, DCSMM). The link between fundamental research and management systems in this case is a decisive factor for orienting efforts aimed at filling gaps in knowledge. Regarding the management of marine ecosystems, it is above all necessary to focus, on the one hand, on the **integrity of the components of the ecosystems most exposed to anthropic pressures** and, on the other hand, on the **key ecological functions for supplying ecosystem services**, namely the functions of reproduction and nurseries and food webs. Thus, the main needs for knowledge concern **coastal ecosystems with high stakes** and require developing the **monitoring of certain pressures** given little attention (recreational fishing) and **modelling capacities** (sediment dynamics, nitrogen cycle, habitat connectivity, pathogens, etc.). The **ecosystems of the high seas and abysses** are subject to gaps in fundamental knowledge. For certain ecosystems already considerably invested by regulations imposed by public policies (exploited species, coral reefs, beaches), **the assessment of the efficiency of management systems** may become a priority research topic. Lastly, taking into account the effects of **climate change** is necessary and requires specific knowledge, especially regarding **plankton**.

Regarding the services delivered by marine and coastal ecosystems, the need for knowledge is revealed by the synthesis of available indicators in Tables 8 and 9). This need for knowledge can cover the **capacity of ecosystems to provide a service** and the **effective utilisation of the service** just as well as the assessment of **individual and collective advantages** that society obtains from them. As for collective advantages, lack of knowledge mainly concerns the following services: goods from macro-algae, molecules, the attenuation of climate change, improving the habitat of wild species through pathogen regulation, services linked to recreational activities, the supply of landscapes and the patrimonialization of nature. Regarding individual advantages, the gaps in knowledge mainly concern the number of consumers of macro-algae and products derived from the molecules extracted from marine ecosystems, the avoided costs of pollution clean-up permitted by the nutrient regulation service, the damage avoided thanks to the climate regulation service, the costs of individual pollution clean-up of producers, especially shellfish farmers, working in zones where the pathogen regulation service is saturated and, lastly, the number of beneficiaries of an institutionalised heritage and more generally any other form of patrimonialization of marine and coastal ecosystems. The production of knowledge of the attachment of our society to its marine and coastal ecosystems remains essential for facilitating understanding and **taking into account the heritage dimension of these ecosystems in public policies**.

Further reading



Groupe de travail « Milieux marins et littoraux » : évaluation des écosystèmes marins et côtiers et des services rendus

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