OCEANOGRAPHY AND MARINE BIOLOGY SERIES

SEAS AND OCEANS SET

Value and Economy of Marine Resources

Edited by
André Monaco and Patrick Prouzet

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Contents

From the *Seas and Oceans* Set
coordinated by
André Mariotti and Jean-Charles Pomerol

Value and Economy of Marine Resources

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Foreword

We have been asked by ISTE to stimulate work in the area of the environment. Therefore, we are proud to present the "Seas and Oceans" set of books, edited by André Monaco and Patrick Prouzet.

Both the content and the organization of this collection have largely been inspired by the reflection, initiatives and prospective works of a wide variety of national, European and international organizations in the field of the environment.

The "oceanographic" community, in France and internationally – which is recognized for the academic quality of the work it produces, and is determined that its research should be founded on a solid effort in the area of training and knowledge dissemination – was quick to respond to our call, and now offers this set of books, compiled under the skilled supervision of the two editing authors.

Within this community, there is a consensus about the need to promote an interdisciplinary "science of systems" – specifically in reference to the Earth's own "system" – in an all-encompassing approach, with the aim of providing answers about the planet's state, the way it works and the threats it faces, before going on to construct scenarios and lay down the elementary foundations needed for long-term, sustainable environment management, and for societies to adapt as required. This approach facilitates the shift of attention from this fundamental science of systems (based on the analysis of the processes at play, and the way in which they interact at all levels and between all the constituent parts making up the global system) to a "public" type of science, which is finalizable and participative, open to decision-makers, managers and all those who are interested in the future of our planet.

In this community, terms such as “vulnerability”, “adaptation” and “sustainability” are commonly employed. We speak of various concepts, approaches or technologies, such as the value of ecosystems, heritage, “green” technologies, “blue” chemistry and renewable energies. Another foray into the field of civilian science lies in the adaptation of research to scales which are compatible with the societal, economic and legal issues, from global to regional to local.

All these aspects contribute to an in-depth understanding of the concept of an ecosystemic approach, the aim of which is the sustainable usage of natural resources, without affecting the quality, the structure or the function of the ecosystems involved. This concept is akin to the “socio-ecosystem approach” as defined by the Millennium Assessment (http://millenniumassessment.org).

In this context, where the complexity of natural systems is compounded with the complexity of societies, it has been difficult (if only because of how specialized the experts are in fairly reduced fields) to take into account the whole of the terrestrial system. Hence, in this editorial domain, the works in the “Seas and Oceans” set are limited to fluid envelopes and their interfaces. In that context, “sea” must be understood in the generic sense, as a general definition of bodies of salt water, as an environment. This includes epicontinental seas, semi-enclosed seas, enclosed seas, or coastal lakes, all of which are home to significant biodiversity and are highly susceptible to environmental impacts. “Ocean”, on the other hand, denotes the environmental system, which has a crucial impact on the physical and biological operation of the terrestrial system – particularly in terms of climate regulation, but also in terms of the enormous reservoir of resources they constitute, covering 71% of the planet's surface, with a volume of 1,370 million km^3 of water.

This set of books covers all of these areas, examined from various aspects by specialists in the field: biological, physical or chemical function, biodiversity, vulnerability to climatic impacts, various uses, etc. The systemic approach and the emphasis placed on the available resources will guide readers to aspects of value-creation, governance and public policy. The long-term observation techniques used, new techniques and modeling are also taken into account; they are indispensable tools for the understanding of the dynamics and the integral functioning of the systems.

Finally, treatises will be included which are devoted to methodological or technical aspects.

The project thus conceived has been well received by numerous scientists renowned for their expertise. They belong to a wide variety of French national and international organizations, focusing on the environment.

These experts deserve our heartfelt thanks for committing to this effort in terms of putting their knowledge across and making it accessible, thus providing current students with the fundaments of knowledge which will help open the door to the broad range of careers that the area of the environment holds. These books are also addressed to a wider audience, including local or national governors, players in the decision-making authorities, or indeed "ordinary" citizens looking to be informed by the most authoritative sources.

Our warmest thanks go to André Monaco and Patrick Prouzet for their devotion and perseverance in service of the success of this enterprise.

Finally, we must thank the CNRS and Ifremer for the interest they have shown in this collection and for their financial aid, and we are very grateful to the numerous universities and other organizations which, through their researchers and engineers, have made the results of their reflections and activities available to this instructional corpus.

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1

The Services Provided by Marine Ecosystems: Economic Assessments and Their Usages

1.1. Marine ecosystem services

1.1.1. *Ecosystem services*

According to the *Global Footprint Network,* humanity is, metaphorically speaking, contracting a considerable “debt” to the environment because our consumption is not sustainable in the long term. This results in an erosion of the natural capital on which we depend to feed, warm, hydrate and house ourselves, and to engage in leisure activities. To render this understandable, this organization has established, based on the use of the ecological footprint indicator, that humanity has consumed a year’s worth of natural capital by a point in the year situated around the middle of August. Between this date and the end of the year, humanity lives on with a debt. To make this idea of ecological debt even more coherent, a large number of scientists and also stakeholders in civil society have turned to the notion of “ecosystem service”.

Ehrlich and Mooney [EHR 83] seem to have been the first to mention the notion of ecosystem service explicitly in an article entitled "Extinction, substitution and ecosystem services". But it would be necessary to wait 14 more years to see this concept benefit from intense publicity through two widely-circulated publications: "Nature's services: Societal dependence on natural ecosystems" [DAI 97] and "The value of the world's ecosystem services and natural capital" [COS 97].

"The services that ecosystems offer are the benefits that people take from the ecosystems" (*Millennium Ecosystem Assessment,* [MEA 05, p. 9]). Ecosystem services contribute to human well-being from access to the essential goods that they provide (food, drinking water, etc.), the security that they offer (security against hazardous events, mitigation of the effects of climate warming, etc.) or simply the pleasure that they provide (observation of natural countryside, recreational activities in the open air, etc.).

The *Millennium Ecosystem Assessment* [MEA 05] carried out between 2001 and 2005 under the auspices of the UN and involving 1,360 scientists aimed to describe these ecosystem services precisely. The MEA is distinguished into the following four categories of ecosystem services:

– provisioning services equate schematically to the natural resources that are used through a process of extraction for mankind's direct consumption;

– regulating services, which represent ecological functions enabling the productivity and resilience of ecosystems to be guaranteed;

– cultural services, which are both recreational (activities in the open air) and subjective in nature (spirituality, identity, etc.);

– supporting services, in conjunction with ecological processes, enable the renewal of life on Earth.

Through these categories, a new approach of the ecological and economic dynamics is available to us. The approach of using the idea of ecosystem services effectively allows us to put forward an unprecedented discourse on the conservation of biodiversity by underlining the trade-offs that are necessary to make between the different types of services furnished by biodiversity and means that the process of economic development and biodiversity conservation objectives are no longer systemically opposed. The notion of ecosystem service also provides a common semantic and theoretical base for different disciplines to work on the problem of interaction between the question of conservation and the question of development, and also a unit for assessment that allows interaction with decision-making bodies [DAI 08, RUF 09].

The MEA focused on ecosystem services but also on the pressures that are exerted on them. In effect, it underlines which human activities today cause the greatest threats to these services through their consumption of space, their exploitation of resources, the emission of greenhouse gas or the introduction of invasive species. Through their activities, people destroy a significant quantity of ecosystem services and thus, finally, their collective well-being (Figure 1.1).

Figure 1.1. *The Millennium Ecosystem Assessment*

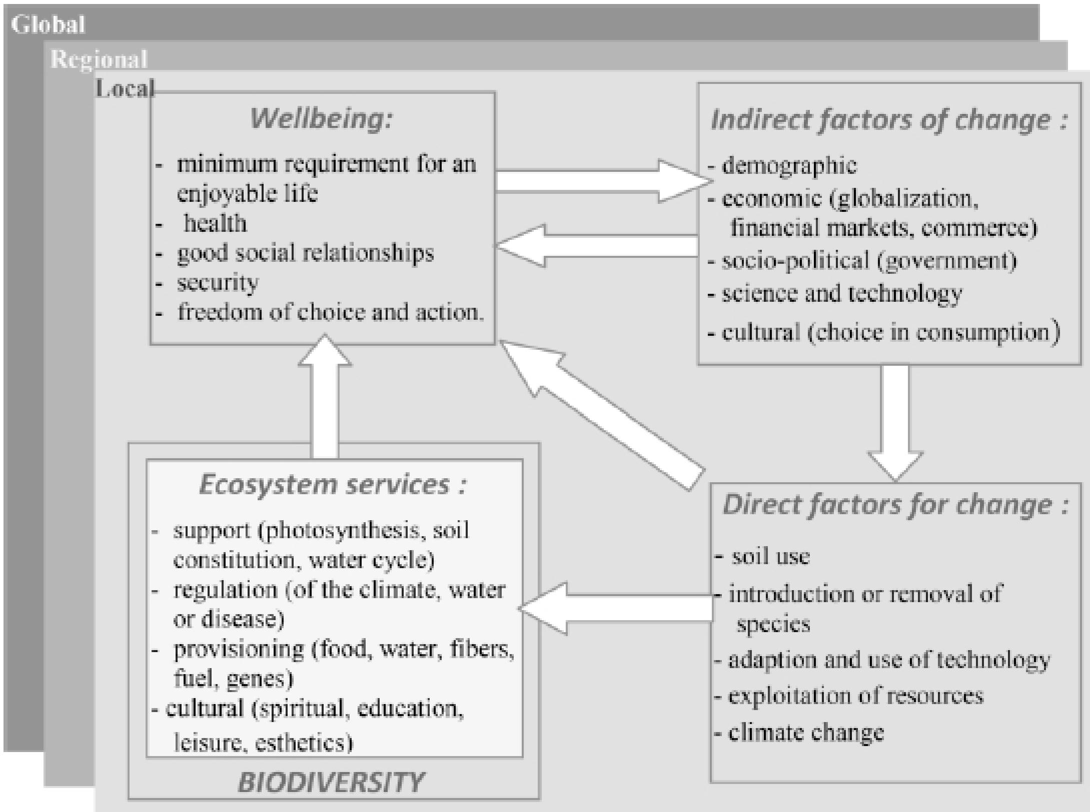


Table 1.1. *Evolution of ecosystem services between 1950 and 2005 [MAE 05, p. 46]*

Category of services	Services	Evolutions
Services for provisioning or supply	Agriculture	+
	Farming	+
	Fishing	–
	Aquaculture	+
	Wild food materials	–
	Wood for construction	±
	Cotton, hemp, silk	±
	Firewood	–
	Genetic resources	–
	Biochemical products, natural medicines, pharmaceutical products	–
	Freshwater	–
Regulating services	Regulation of air quality	–
	Regulation of global climate	+

Category of services	Services	Evolutions
	Regulation of regional and local climate	−
	Regulation of the water cycle	±
	Regulation of erosion	−
	Purification of water and treatment of waste	−
	Regulation of diseases	±
	Regulation of parasites	-
	Pollinization	-
	Regulation of natural risks	-
Cultural services	Spiritual and religious values	−
	Esthetic values	−
	Recreation and ecotourism	±

"+" stands for an increase, "–" stands for a reduction and "±" stands for an increase in certain regions of the world and a drop in others. The support services are not mentioned here, as it is difficult to evaluate their evolution.

1.1.2. *A historic balance leading to an inefficient exploitation of ecosystem services*

At the present time, man only uses a very small part of the services furnished by ecosystems. In effect, mankind has focused for the past 10,000 years on a single category of ecosystem services: the "provisioning services". The regulating and cultural services have always been neglected in favor of provisioning services. Thus, Table 1.1, which succinctly summarizes the evolution of the main ecosystem services over the course of the second half of the 20th Century, allows us to highlight that regulating services and cultural services have, for the most part, been neglected in comparison with provisioning services. Even if this tendency is easily justified by the need to keep up with the dramatic demographic increase that the world has known in the course of this period, the productivist model that is at its origin is today being pushed to its limits, and one of the main indicators that allows us to note this is the erosion of regulating services, which are also, indirectly, absolutely necessary for the human species.

This focus on ecosystem provisioning services has led to great inefficiency in the exploitation of biodiversity. Thus, most of the time, the strategy for biodiversity exploitation is based on the desire to maximize the production of particular provisioning services and neglect to take into account other categories of ecosystem service.

The marine ecosystem is a perfect example of this. A marine ecosystem will, in effect, be most often used to provide a single ecosystem service – fish for food – although this ecosystem is fundamental for a large number of ecosystem services for man – climate regulation, providing a habitat for species, a place for recreational activities, molecules or genes for the development of medication, etc.

The inefficient use of biodiversity and the services that it provides is one of the first factors that explains why our mode of development is not sustainable. The MEAs conclusions are indisputable. They emphasize that 60% of ecosystem services have decreased during the last 50 years. Among them, the renewal of fishing stocks and the production of freshwater seem to be most threatened. This degradation has been more significant over the course of the last 50 years than over the entire course of the rest of human history, and it will be even more significant in the 50 years to come. The ecosystem services that are disappearing are those of a collective or public nature and those that are not sold on the markets (recycling of waste, reproduction habitats for animals or countryside for mankind, etc.). Conversely, those that have been developed over the last 50 years are services of a private nature that can be sold on the markets and which today form the basis of the forestry, agriculture and aquaculture sectors.

This is why our systems for exploiting nature need to undergo radical change and take into account the ensemble of ecosystem services and most particularly communal or public cultural and regulating ecosystem services.

1.1.3. *Marine ecosystem services*

Ecosystem services with coastal habitats as their origin are so numerous that they could account for 43% of the ensemble of services furnished by the biosphere, although coastal ecosystems only represent 6.3% of the globe's surface [COS 97].

For France, the relative importance of ecosystem services associated with the sea and the seashore for the national economy can be evaluated as an initial approximation via the source revenue generated by these areas. This initial approximation is particularly simple for provisioning and recreational services. Thus, the sea product industry generated an added value of 2.363 billion euros in 2007, whereas the coastal tourism industry generated 9.220 billion euros for a total added value of activities depending on marine ecosystems state 27.6 billion euros *(Données économiques maritimes 2009*)*.* The maritime economy is moreover the source of 486,000 jobs, including 242,558 linked to the tourism sector. An important part of this wealth is linked to the provision of services by marine biodiversity.

It is in effect the more or less direct origin of numerous ecosystem services such as:

– bioturbation, primary production or the water cycle (supporting services);

– the renewal of fisheries, the production of aragose (derived from algae) or renewable energy (provisioning services);

– the control of erosion and silting, the recycling of waste and the control of pollution (regulating services);

– visual tourism, recreational fishing or simply bathing (cultural services).

By relying on a review of the literature, it is possible to identify 74 services directly linked to marine and coastal biodiversity, including seven for support services, 20 for provisioning services, 27 for regulating services and 18 for cultural services ([COS 97, DUA 00, HOL 99, JAC 01, KAI 11, KRE 05, MEA 05 (Chapters 18 and 19), RON 07, SOL 04, WOR 06]; Tables 1.2–1.5).

Table 1.2. *Marine ecosystem support services and their sources (n = 7)*

Support services	Source of service’s production (structure or function)
Bioturbation	Benthic invertebrate species biodiversity and fish that carry out activities in the substrate (spawning, searching for food, sheltering)
Primary productivity	Genetic and species biodiversity through a complementarity effect of redundance and selection
Secondary productivity	Genetic and species biodiversity through a complementarity effect of redundance and selection
Cycle of nutrients and mineralization	Gas fixing and decomposition of organic matter by species biodiversity, fundamental to the nitrogen production necessary for primary production
Water cycle	Oceans as an essential base of the water cycle
Creation of habitats for animals and vegetables (formation of soils)	Biodiversity of soil invertebrates, microorganisms in the soil, nitrogen fixing plants, plants and animals that produce organic waste
Oxygen and carbon cycle	Oceans as an essential base of the oxygen and carbon cycles

Table 1.3. *Marine ecosystem provisioning services and their sources (n = 20)*

Provisioning services	The service’s source of production (structure or function)
Renewable energy	Marsh, swell, current, oil from microalgae

Provisioning services	The service’s source of production (structure or function)
Fish for food	Genetic and species biodiversity helps limit the risks of extinction for fisheries as well as the variability of takings and facilitates the renewal of fisheries in crisis
Crustaceans for food	Abundance and diversity of crustaceans
Molluscs for food	Abundance and diversity of mollusks
Algae and derivatives (agarose) for food	Abundance and diversity of algae
Materials for construction	Abundance and diversity of primary materials necessary for construction (marine sediments, sand and stones, nodules)
Materials for clothing	Abundance and diversity of primary materials necessary for clothing (skins, viscera, etc.)
Non-renewable energy	Abundance and diversity of petrol and gas deposits
Spat (for farmed shellfish)	Spat biodiversity
Fish meal for animal food	Fish biodiversity
Fish oil for animal food	Fish biodiversity
Fertilizer	Biodiversity enabling organic fertilizers to be produced (algae, kelp, fish bone, etc.)
Molecules for pharmaceutical products	Molecular diversity of renewable and non-renewable resources in coastal and marine zones
Chemical models	Biodiversity possessing the necessary characteristics to provide organisms with tests
Genetic resources	Marine and coastal genetic biodiversity
Materials for artistic productions (pearls, mother of pearl, etc.)	Biodiversity that gives rise to the production of materials useful for artistic productions
Support for the transport of merchandise and passengers	Oceans and seas as supports for marine routes
Organisms with tests	Biodiversity of organisms possessing the necessary characteristics to provide organisms with tests

Provisioning services	The service’s source of production (structure or function)
Molecules for industrial and cosmetic products (glues and creams)	Molecular diversity of renewable and non-renewable resources from marine and coastal zones
Freshwater storage (estuaries)	Estuaries in good ecological state

Table 1.4. *The marine ecosystem regulating services and their sources (n = 27)*

Regulating services	The service’s source of production (structure or function)
Dynamic of soil fertility	Biodiversity of soil invertebrates, soil microorganisms, nitrogen-fixing plants, plants and animals that produce organic waste
Control of the phytoplankton dynamic	Diversity and abundance of zooplankton
Control of the zooplankton dynamic	Diversity and abundance of zooplanktivores
Control of the dynamic of fish populations	Diversity and abundance of piscivores
Maintenance of hydrological equilibrium	Water cycle assured by the oceans and coastal habitats
Spawning grounds for species	Biodiversity of seagrass, wetlands, salt marshes and oyster beds
Refuge zone for species	Diversity of marine and coastal habitats
Resilience in the face of natural or human disturbances	Genetic and species biodiversity through the effect of complementarity, redundance and selection
Control of pathogens and harmful materials	Species biodiversity via the role of populations of predators and filtering organisms
Regulation of herbivores	Species biodiversity via the role of populations of predators
Mitigation of the eutrophization effects	Species biodiversity via the role of filtering organisms
Control of pollution and detoxification	Species biodiversity via the role of filtering organisms

Regulating services	The service’s source of production (structure or function)
Transfer of energy from the substrate to higher trophic levels	Species biodiversity that makes up the food chain
Control of waves and energy currents	Diversity of marine and coastal habitats that act as buffer zones (seagrass, dunes, etc.)
Control of erosion and silting	Seagrass biodiversity
Mitigation of the effects of rising sea level and floods	Species biodiversity in vegetation (mangroves)
Protection against ultraviolet	Oceans and seas have an important role in the biogeochemical cycles and shelter microorganisms useful for protection against UV
Air purification	Oceans and seas have an important role in the oxygen and carbon cycles
Regulation of the global climate	Oceans stabilize the quantity of CO_2 in the atmosphere and regulate the temperature of the global atmosphere
Regulation of local climates	Oceans stabilize the quantity of CO_2 in the atmosphere and regulate the temperature of the local atmosphere
Retention of soils	Root species biodiversity
Control of water turbidity	Species biodiversity via the role of filtering organisms
Regulation of water quality	Species biodiversity via the role of filtering organisms
Control of human diseases	Microbiological diversity
Transport of species	Currents and tides
Recycling of waste	Species biodiversity of soil invertebrates and aquatic microorganisms
Regulation of salinity	The salinity levels of coastal zones are dependant on fluxes of freshwater from land
Carbon stocking	Biodiversity of phytoplankton, macroalgae and seagrass

Table 1.5. *Marine cultural ecosystem services and their sources (n = 18)*

Cultural services	Source of the service (structure or function)
Feelings of well-being	Marine and coastal ecosystems
Support for “traditional” jobs for coastal populations	Abundance of resources on which local communities depend
Cultural identity of coastal populations	Natural coastal countryside in connection with traditional practices
Views (coastal countryside)	Countryside biodiversity
Ecotourism	Countryside biodiversity
Visual tourism (whales, dolphins)	Animal biodiversity
Bathing	Biodiversity of filtering species
Walking	Countryside biodiversity
Recreational fishing	Biodiversity in species valued for recreational fishing
Pleasure sailing	Seas and oceans devoid of very large floating objects (invasive species, macrowaste, other boats) and without excessive eutrophization
Deep-sea diving	Marine biodiversity
Surfing and windsurfing	Waves and wind
A source of inspiration	Countryside biodiversity
Support for religious beliefs	Sacred natural places and objects
Preservation of marine and coastal biodiversity for ethical reasons	Marine and coastal biodiversity
Source of knowledge	Marine and coastal biodiversity
Scientific usage (a marine model for basic research)	Marine and coastal biodiversity
School excursions	Marine and coastal biodiversity
Monitoring of global changes affecting the natural environment	Monitoring of phenological characteristics and species distribution

1.2. The monetary evaluation of ecosystem services

1.2.1. *The factors that motivate demands for monetary evaluation*

1.2.1.1. *The demands for monetary evaluation of ecosystem services in an institutional framework*

From the 1990s, the evaluation of ecosystem services has been recommended as a tool to aid decision making on the question of biodiversity, and this applies within a variety of governing bodies.

Different international organizations therefore promote the use of economic evaluations of ecosystem services. In its IV/10 decision, the Conference of the Parties (COPs) at the Convention on Biological Diversity (CBD) considers that "the economic evaluation of biological diversity and biological resources constitute an important tool for well-targeted and well-distributed economic incentives" [CON 98]. In its principle 4, the COPs decision VII/11 calls again for "the incorporation of the ecosystem and social aspects of goods and services resulting from ecosystems in decisions relating to national compatibility, politics, planning, education and the management of resources" [CON 04, p. 217].

In 2007, a report on biodiversity from the Parliamentary Office for the assessment of scientific decisions [LAF 07] underlined that “the sustainable development of biodiversity is a necessity and an opportunity. Two axes are profiled in this domain: the remuneration of services provided by ecosystems and the exploration of a reservoir of goods that could be a key tool for the fourth industrial revolution ...: it is necessary to evaluate ecosystem services monetarily and to provide economic sanctions for their destruction for private ends”.

More recently, the OECD (Organization for Economic Co-operation and Development) has recalled that “appropriate economic evaluations of biodiversity and its loss will result in better, more efficient decisions, and can prevent inappropriate compromises” [OEC 12, p. 191].

From the point of view of many political decision makers, the monetary evaluation of biodiversity seems to have become a tool that could better help protection of biodiversity, and this point of view is not unique to economists. Conservation biologists, and more broadly environmental non-governmental organizations, defend this approach to show that biodiversity “is worth” something. Public administrative bodies in charge of environmental policies highlight this approach to allow using new financial methods or for optimizing their projects for public development. Economists seek to place monetary units on ecosystem services to promote work on the question of biodiversity and to put in place tools for market regulation. For most institutional bodies, it ultimately involves the most used standard of measurement in a society with a market economy and we cannot avoid it when discussing the conservation of biodiversity.

To resume, the key argument to justify granting a monetary value to biodiversity is that if an ecosystem service has no monetary value, it will at best remain unused and at worst will be wasted. And it is evident that public representations are strongly influenced by the monetary standard, which is the most used indicator for transactions in our market society. Thus, the monetary evaluation of ecological phenomena would offer a strong tool for argument in societies with market economies.

Then, from a very pragmatic point of view, the question of the monetization of biodiversity and the services that it provides seem essential in many cases.

First, for insurance, because the monetary value enables the economic risks associated with the destruction of biodiversity to be taken into account, monetization should in particular enable us to evaluate the indemnity linked to external factors (e.g. pollution by hydrocarbons or increased risk of flooding), but also, possibly, premiums for good practice.

Then, for fiscal policies, monetization seems necessary for putting in place systems for taxation and subsidies that should ideally reflect the societal costs and benefits associated with the evolution of ecosystem services, with a view for creating the necessary incentives and leading to changes in behavior.

Finally, for the choice between public or private investments, including the question of biodiversity in investment, decisions require the ability to carry out cost-benefit evaluations for the different projects in order to be able to compare and prioritize them.

For the “market” finally, since biodiversity has a economic value, it can give rise to commercial exchanges, can be valued and can inspire investment in its preservation and restoration.

1.2.1.2. *The regulatory effect of the monetary evaluation of ecosystem services*

There are two opposing theories concerning the regulatory effect of establishing a price for biodiversity. According to Timothy Swanson's analysis [SWA 94], a high price would be an incitement to conserve a natural renewable resource since it is imperative not to "kill the goose that lays the golden eggs". On the other hand, according to Clark's analysis [CLA 73], the placing of a higher price on renewable natural resources would trigger a rapid and unsustainable use of the latter. In particular, practices on the luxury market can be observed, which do not necessarily respond to conventional economic rules. So, the increasing rarity of a consumed species (for food, collection, etc.) will cause the costs of sourcing it, and therefore the market cost, to increase this without causing a drop in demand. There is an anthropogenic "allee effect" with which we can underline the value that mankind attributes to rare species and which accounts for their exploitation down to the last individual Franck Courchamp *et al.* [COU 06]. Gault *et al.* [GAU 08] emphasize, moreover, that this behavior is based above all on the perception of rarity and not on real biophysical rarity.

In this respect, the two theories are exactly the same. In effect, high or low prices can have inverse effects depending on the contexts in which they occur. The important element in this context is access regulation. So, in cases where a natural renewable resource has a strong monetary value, the consumers who benefit from this exclusive access will tend to seek a management method that assures the effective renewal of this source of revenue. On the other hand, if access is not secure, or indeed free, then it is rational to use it down to the last unit of resource so long as there is a solvent demand for this resource.

1.2.2. *Monetary evaluation methods and their limits*

1.2.2.1. *The values of ecosystem services*

To respond to institutional demands concerning the monetary value of biodiversity, the *The Economics of Ecosystem and Biodiversity* (TEEB) was launched in 2007 (www.teebweb.org) through the initiative of the G8 and five developing countries. The goal of this work was to achieve a better understanding of the economic benefits resulting from biodiversity. The TEEB "promotes the integration of economic values for biodiversity and the services provided by ecosystems in the decision-making process" [TEE 10, p. 27].

But the economic evaluation of ecosystem services began much earlier than the TEEB, which was instead an opportunity to take stock of what already existed. Thus, Laurans *et al.* find 5,028 references issued from 1,419 sources corresponding to the following key words: "evaluation" and "ecosystem services", "natural capital", "environment" and "evaluation", "biodiversity" and "evaluation" and "total economic value"[1] [LAU 13, p. 210].

For marine ecosystems, a quick search on ScienceDirect using the key words "ecosystem services", "evaluation" and "marine" returns around 1,026 references[2].

The creation of economic evaluations of marine ecosystems is not only found in the academic literature. So, governments and governmental agencies, non-governmental organizations and *think tanks* also produce economic evaluations. In order to collect these evaluations, the database *Marine Ecosystem Services Partnership* (www.marineecosystemservices.org/explore) aims to collect existing economic evaluations on marine ecosystems, including the gray literature.

The idea of putting a price on ecosystem services to take account of the consequences of environmental degradation on social well-being is based on a utilitarian principle [BON 07]. This approach depends on the notion of sustainability, which enables us to derive an economic value reflecting individuals' attachment to the different goods and services to which they have access. Thus, according to a economic value, it implies that environmental breakdown has an impact on the utility functions of individuals. It is this impact that is important to measure in monetary terms in order to offer adapted price signals.

To do this, a classification of the different forms of value that biodiversity can take is required [BON 07]:

– the use value equates to a direct and current use of the asset;

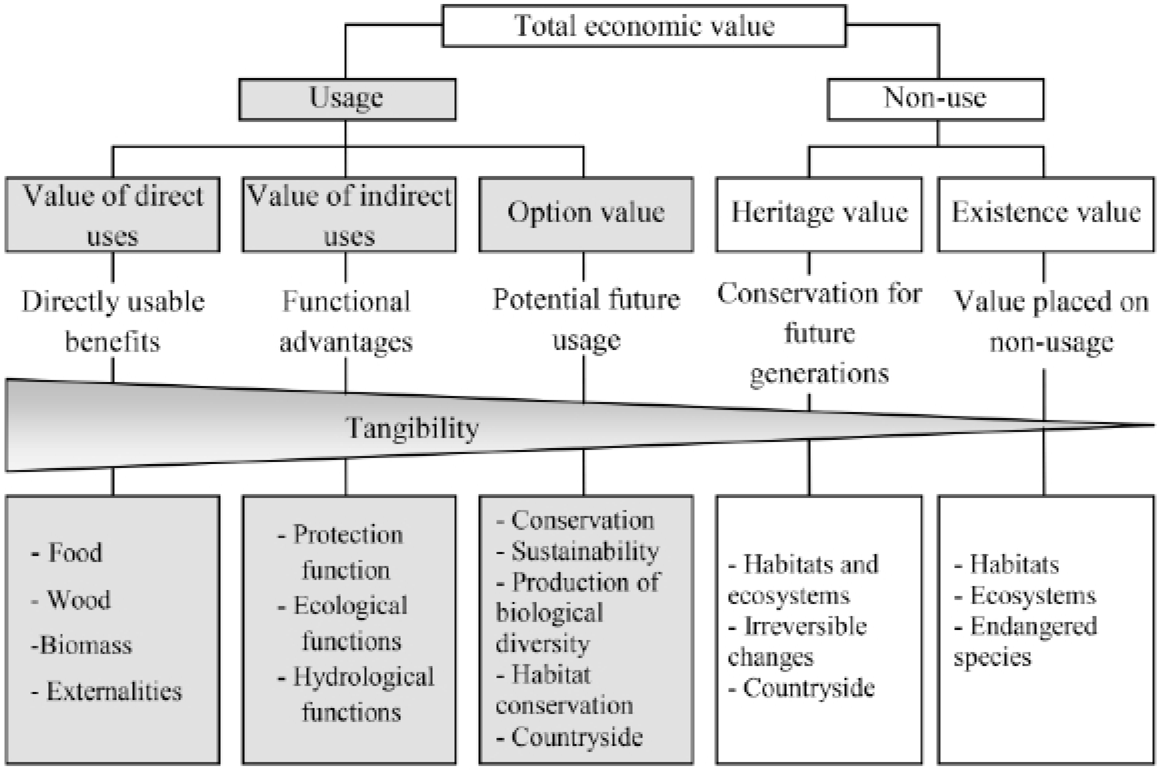
– the non-use value equates to a direct, future use of the asset by the present generation (option value) or for future generations (legacy values);

– the existence value equates to the value of the asset for its own sake, regardless of usage.

The sum of these three types of value corresponds to the total economic value of biodiversity (Figure 1.2).

Figure 1.2. *The total economic value of biodiversity and ecosystem services*

(source: Centre d'analyse stratégique, 2009)



It is evidently considered possible to evaluate monetarily the benefits provided by ecosystem services and the biodiversity that generates them – hence the desire to give them a monetary value. However, to carry out the monetization of ecosystem services is very much complex.

If provisioning services are associated with exploited resources for which there is a market price, the three other categories of services provided by the ecosystems are not, for much of the time, the object of any commercial transaction and for this reason cannot be measured in monetary terms using a market price. Also, different methods have been developed by environmental economists to try, in spite of everything, to attribute a monetary value more or less directly to these ecosystem services.

1.2.2.2. *Assessment methods for regulating services and cultural, recreational services*

Where regulating services are concerned, methods often rely on real market processes: by estimating the contribution of regulating services to the creation of products and services sold on the markets (for example the contribution of breeding habitats for the fish that make up fishing stock); by estimating the cost of restoration or damage prevention to regulating services important for society (for example the cost of putting in place a dyke to replace the protecting function furnished by destroyed coral ecosystems). It is a question, above all, of creating a link between natural habitats and the production of ecosystem services, directly or indirectly useful to mankind.

For recreational cultural services, environmental economists have adopted the reconstitution method for market price. The reconstitution of market price is based either on the travel costs method or on the hedonic pricing method. The travel costs method consists of evaluating the time that some individuals and groups are prepared to “spend” to benefit from the services offered by a particular ecosystem [APP 04]. The hedonic pricing method is based on the hypothesis that some goods – notably housing – have a value that does not depend only on the characteristics of the object itself, but also on the natural environment in which the latter is situated [TRA 08].

Although these assessment methods carried out using preferences revealed by the market are relatively robust, they are hampered by two limitations.

The first is the cost of developing them, since they require information to be collected on site and since they use a large quantity of very precise data and require the use of