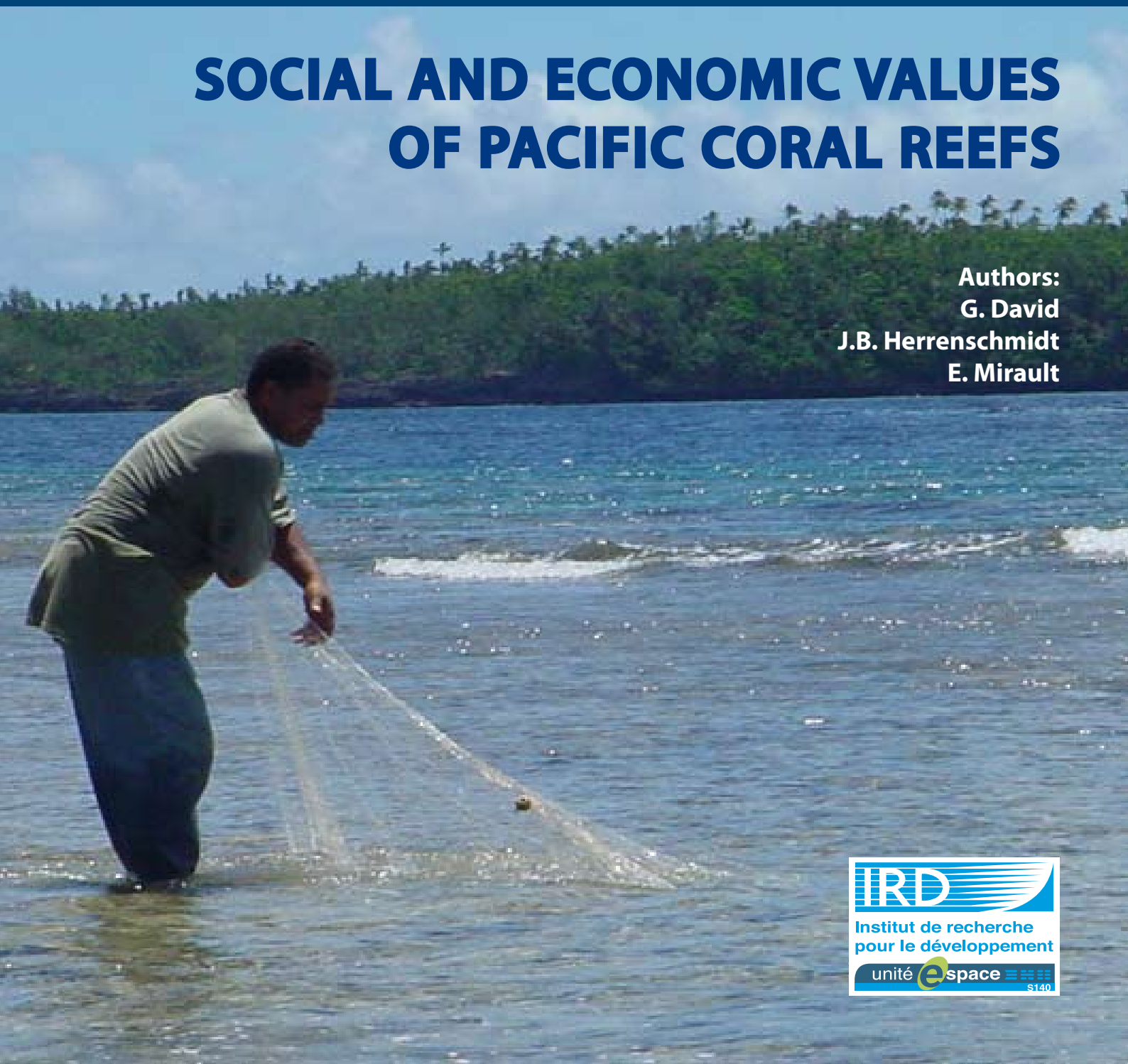
CRISP
Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

COMPONENT 1A - Project 1A4
Integrated Coastal Management

June 2007

Approach & Methodology

SOCIAL AND ECONOMIC VALUES OF PACIFIC CORAL REEFS



Authors:
G. David
J.B. Herrenschmidt
E. Mirault

IRD
Institut de recherche pour le développement
unité espace S140

CRISP

Coral Reef InitiativeS for the Pacific
Initiatives Corail pour le Pacifique

SPREP/PROE

The CRISP programme is implemented as part of the policy developped by the Secretariat of the Pacific Regional Environment Programme for a contribution to conservation and sustainable development of coral reefs in the Pacific

The Initiative for the Protection and Management of Coral Reefs in the Pacific (CRISP), sponsored by France and prepared by the French Development Agency (AFD) as part of an inter-ministerial project from 2002 onwards, aims to develop a vision for the future of these unique eco-systems and the communities that depend on them and to introduce strategies and projects to conserve their biodiversity, while developing the economic and environmental services that they provide both locally and globally. Also, it is designed as a factor for integration between developed countries (Australia, New Zealand, Japan, USA), French overseas territories and Pacific Island developing countries.

The CRISP Programme comprises three major components, which are:

Component 1A: Integrated Coastal Management and watershed management
- 1A1: Marine biodiversity conservation planning
- 1A2: Marine Protected Areas
- 1A3: Institutional strengthening and networking
- 1A4: Integrated coastal reef zone and watershed management

Component 2: Development of Coral Ecosystems
- 2A: Knowledge, monitoring and management of coral reef ecosytems
- 2B: Reef rehabilitation
- 2C: Development of active marine substances
- 2D: Development of regional data base (ReefBase Pacific)

Component 3: Programme Coordination and Development
- 3A: Capitalisation, value-adding and extension of CRISP Programme activities
- 3B: Coordination, promotion and development of CRISP Programme

CRISP Coordinating Unit (CCU)
Programme manager : **Eric CLUA**
SPC - PoBox D5
98848 Noumea Cedex
New Caledonia
Tel : (687) 26 54 71
Email : ericc@spc.int
www.crisponline.net

Project 1A4 (GERSA)

Integrated coastal reef zone and watershed management

The purpose of GERSA is to foster the emergence of an integrated cross-cutting approach based on public policy tools and monitoring methodology and local-scale stakeholder dynamics. Ultimately, the goal is to have a scientific foundation and indicators suited to Pacific Island settings so as to set up country sustainable development observatory networks as part of the introduction of MPAs. GERSA is then a cross-cutting project relating also to project 1A2 (MPAs).

The project 1A4 is composed of 4 working packages:

- *WP 1 - SPATIAL APPROACH*
- *WP 2 - TERRITORIALITY AND SOCIO-ECONOMIC VALUES*
- *WP 3 - ENVIRONMENTAL INFORMATION SYSTEMS AND MODELISATION*
- *WP 4 - DYNAMICS AND MODELISATION OF WATERSHED*

Head of project: Gilbert DAVID
Contact : Jean-Brice Herrenschmidt
IRD - Unité ESPACE
101 Promenade Roger LARROQUE
BPA5
98848 Nouméa Cedex
Nouvelle-Calédonie
Tel/fax : (687) 26 08 27
Email : herren@noumea.ird.nc

This CRISP project is funded by the following agency:

CONSERVATION INTERNATIONAL

FFEM

TABLE OF CONTENTS

INTRODUCTION

Environmental economy is a recent field of studies (Cropper et Oates, 1992 ; Barbier,1993 ; Barbier *et al.*, 1994) ; Faucheux et Noël, 1995 ; Harou et Stenger, 2005) that really took off after the publication of the article by R. Costanza et *al*. (1997) relative to the economic value of the planet ecosystems, considered as natural assets. Studies on coral reefs economy were still very scarce at the beginning of the decade but their number is ever increasing with an average of 10 new articles being published internationally each year (Brander *et al.,* 2007). After the innovative work of D. Mc Allister (1988) on the Philippines and the first methodological synthesis presented by J. Spurgeon in 1992, F Moberg and C. Folke (1999) adapted the Contanza *et al*. (1997) method to the reefs. The lead role was played by the World Bank, though, who has been developing field economic studies, commissioning two pilot studies in the mid 90's. The first one, focusing on the Marine reservation of Montego Bay in Jamaica, aimed at showing the economic value created through coral reef biodiversity conservation (Gustavson, 1998 ; Ruitenbeek et Cartier, 1999). The second one, assessing the global value of the Indonesian reefs, aimed at convincing this country to create Marine Protected Areas in exchange for a significant debt reduction. The team leader is a young economist from The Netherlands, H. Cesar, who following this work (Cesar 1996, 1999, 2000; Cesar *et al.,* 2002, 2003) ended up with a front row seat in the little community of reef environment economists. ICRI (International Coral Reef Initiative), created in 1994, is the second main actor in the development of reef economic value studies. Following its initiative, several workshops have been organized to compare and improve valuation methods.

The Millennium Assessment for the Ecosystems was another big step towards the development of studies relative to reef economic value. Chapter 2, thus, offers a standard method to assess ecological services and goods provided by ecosystems that will allow the multiplication of this kind of studies (Millennium Ecological Assessment, 2003). At this time, first semester 2008, economic or socio-economic valuation of coral reefs has become a priority issue for many funding agencies and studies are multiplying. Considering the recreational value of the reefs only, 160 studies have been listed by Brander *et al. (*2007). According to a recent report from the French Ministry of Ecology and Sustainable Development and management, only 11 out of the essential 33 relating to goods and services provided by coral reef ecosystems are anterior to 1997. The 1997-2006 period has clearly been more productive in that respect than the previous decade (Blanquet, 2008).

The fact that the number of studies on reef economic value has been increasing over ten years is excellent news. On the other hand, one can be surprised by the disparity in the results. Thus, the total economic value of an hectare of reef over a year varies from 1,430 USD in Western Samoa (Spurgeon *et al.,* 2004) to a range between 69,800 and 72,500 USD in Montego Bay, Jamaica (Ruitenbeek et Cartier, 1999), with intermediate values going from 8,000 to 17,100 USD respectively estimated in Saipan, Micronesia (Van Beukering, 2007), and Moorea in French Polynesia (Charles, 2005), while Costanza *et al*. (1997) give a worldwide average estimation of 6,075 UDS per ha/per year. Recreational services and tourism industry contribute for a large part to the reef value but in this area too huge differences appear depending on the authors or country considered. Over the whole planet Costanza *et al* (1997) estimate at 3008 USD/ha/yr the recreational and tourist value of the reefs, which equates to half of their total economic value.

Meanwhile, in Moorea, tourism contributes up to 90% to the reef value (15,320 USD/ha/yr instead of 17,100 $/ha/yr) (Charles, 2005). The Australian Great Barrier reef shows the highest value: 38,400 USD/ha/yr (Hundloe, 1990), more than twice those calculated for the islands of the Andaman sea in Thailand (15,118 USD/ha/yr) (Seenprachawong, 2004) or Moorea (15 320 USD $/ha/yr) which is the island of French Polynesia with the biggest tourist activity.

Those differences between the values extracted in the bibliography bring about a problem. Four reasons can be advanced; a) heterogeneity of the economic situation for the countries of studies, b) coral reef health status, obviously variable, c) differences in calculation methods, d) lack of rigor for some of them which gives some unreliable results.

Those two last points specifically prompted the need for such a report. In fact, the multiplication of studies relative to coral reef value could lead to believe that everything is clear from a methodological or conceptual point of view. It is far from being the case. On the contrary, and on many levels, we think that coral reef environment complexity challenges the usual tools used for economic or econometric analysis. As G. Lescuyer (2005) underlines it, «the quantification of natural assets remains difficult because of the partial knowledge we have on ecosystems ». Consequently, two epistemological approaches appear:

- either “sophisticate” the tools and analysis methods in order to « force » this complexity into the conceptual and methodological patterns of the neo-classical analysis ; that is the option elected by a majority of economists,
- or make the valuation of natural environments, including reef ones, a multidisciplinary topic. This approach forces the economist to accept the critical look of the biologist, geographer or the sociologist on his topic of study and to forge common concepts (even though they do not comply with the principles of neo-classic economy) in order to elaborate and validate new tools and methods.

This last approach seems more fecund to us, even though it is longer than the first one and is partially lacking its « scientism » by casting aside equations and models to favor a critical approach of the concepts and methods commonly used in environmental economy. Nowadays, when mathematical models have become the main forecasting tool and are considered like the true essence of science, it appears legitimate to us from a scientific ethical point of view to criticize; and then to « harden» the simplifying hypothesis those models are based upon instead of making the equation composing the models sophisticated.

Thus, the present report invites the reader to an exploration of the reef values as a multidisciplinary research topic. In a first point we will question the relevance of assessing the socio-economic value of a natural environment. In a second point, the reef will be considered as natural asset. The emphasis being then put onto reef use values. In a fourth point, existence value, bequest value and option value will be elicited.

1. WHY ASSESSING THE SOCIO-ECONOMICAL VALUE OF A NATURAL ENVIRONMENT?

2.

1.1. GOING BEYOND THE SCIENTISTS POINT OF VIEW

Why wondering about the socio-economic value of a coral reef? In particular, isn't it immoral to try to give a monetary value to a natural environment that, by essence, escape the market economy?

- **First element of answer.** From a biodiversity point of view, coral reefs are amongst the richest environments of the planet. Coral reef ecosystem shelters roughly a third of the seas and oceans biodiversity (M Allister, 1991; Moberg et Folke, 1999), but it suffers increasingly serious anthropogenic aggressions which either causes the disappearance of surfaces occupied by this ecosystem, or causes a drop in productivity (Salvat, 1987; Belwood *et al*, 2004). As a consequence, local population whose professional activities and daily life depend on reef exploitation or associated fisheries resources suffers evident social and economical disturbances, such as loss of jobs in the fishing industry and growing malnutrition caused by the loss of productivity of subsistence fishing. Those disturbance, stem from the economic circle and are measured in a monetary form: de facto, reefs can't escape the economic reality.
- **Second element of answer.** For a decade, economists have been more and more involved on the environmental stage and the two biggest international non-governmental agencies in the conservation field, IUCN and WWF, are now using their services (IUCN/WCA, 1998; Emerton, 1999;

Cesar *et al*., 2003; IUCN/TNC/World Bank, 2004), de facto legitimating economy as a discipline enlightening environmental issues.

➥ **Third element of answer.** Despite very relevant points about biodiversity and ecological wealth of reef and mangrove environments, scientists (naturalists and ecologists) have not really succeeded so far to stem the tide of destruction happening over the last 30 years. Their message is obviously inadequate to their objective: convince the actors, possibly developing, damaging or protecting this natural environment, to adopt this last solution. How do those actors perceive the message from the scientists? Do they agree? Is this comprehension enough to influence their actions in relation to the reef in the direction advocated by the scientists? Disseminated via written press, television and the Internet network, the message relative to the necessary protection of coral reefs is worldwide. It is thus logical for the message to target actors intervening at this level, but those have little means to act on a local level where decisions affecting the reef are taken daily. Confined to the international scene, the scientists' message simply remains in a state of useless wishes or translates into financial incentive to undertake complementary researches.

At a local level, this message though has some effects, but only actors already aware of the need for reef protection feel really concerned, whether they are environment conservation organizations or private parties whose economic activities or daily lives have been threatened in the past because of the damage suffered by the reef, that they consider now like their heritage. On the other hand, all the other users, like the majority of local stakeholders are very little responsive to the points advanced by the scientists.

The « fishing » message, by its content. Fruit of researches exclusively centered on the understanding of reef ecosystem, it focuses on biological or ecological aspects, ignoring mankind, except to mention it as 'the reef enemy ». It is also failing in its form: too far from the standards and realities of the stakeholders (elected representatives, administration, economical partners), for whom it is barely comprehensible.

When scientists see in a coral reef flat a unique ecosystem, with exceptional biodiversity, economical stakeholders see a free space because there is no obvious owner, or big use for the society –except for a few standing fishermen- and moreover because it is shallow which means it is easily and cheaply constructible if the shoal is not exposed to the offshore swell. So when decision makers are facing lack of space to enlarge a road, create a parking lot or a marina, they have no qualms proceeding to the embankment of the coral reef shoal. For them, it is a logical economic and social decision.

Very little receptive to the scientists' points, even though they make a real effort from a didactical point of view, stakeholders are ready to agree with the thesis of the reef advocates – that they consider as an ethical or moral rhetoric- as long as the conservation efforts does not cost them too much and does not lead to conflicts with other users, potential vote casters or residents. On the other hand, if preservation of a reef's productivity requires an economic activity to be stopped or at least

reduced, or that a project, source of employment and future income, to be abandoned, then the stakeholders choice is quick: economic activity always comes before environmental concerns. Essentially perceived in its scientific or moral dimension, ecology is then considered as a brake to economic development. As it seems illusory to hope for the stakeholders to radically change their way of thinking, modifying the message seems to be the unique solution to convince them of the necessity to stop the multiple damages inflicted to the reefs and to include reef conservation into their land development schemes.

The content of the message must be clear: coral reefs are not free space, without economical or social value. Belonging to the maritime public area, it plays a role as any other ecosystem, providing functions, goods and services. Functions are of two types: the ones related to the biotope – principally habitat provided to animal or vegetal species populating the reef-, the ones related to the biocenosis and that are assimilated to the numerous ecological process linking species to each other. Goods and services are the benefits that the populations draw directly or indirectly from the ecosystem functions (Costanza *et al*., 1997). In this regard, reef has collective or individual uses. Those are declined both into non-commercial outputs for domestic and alimentary uses, and activities related to commercial trade or avoiding it but ultimately generating incomes or non-commercial outputs for domestic or alimentary uses. Indirectly the reef provides economic and social functions stemming from its ecological functions that scientists are trying to translate into monetary terms.

By giving a monetary value to the reef, the environment gets integrated in the economy field and to the stakeholders get a message in a language they do understand, which leads thus to a change in attitude and decision. The debate is not anymore in the same old terms: “I protect the natural environment, therefore I renounce to economic activity”, which comes down to oppose ethics and moral to economy, but in new terms which stress the fact that the decision maker has the choice between two strategies:

- firstly, protecting the reef, which is supporting X activities, employing Y people and generating Z in income every year, while providing services to the local community worth an annual income amounting to W, which would mean giving up A jobs and B income generated by the activity C in competition with reef conservation.
- or, on the contrary, favoring this last activity to the expense of the natural environment.

Taking position, thus, results from a cost/benefits or cost/advantages analysis between conservation, supporting an economy, and the transformation or destruction of the reef, supporting another type of economy.

If the assessment of an ecosystem monetary value, in this case a coral reef, allows adequacy on a form level between the scientist discourse and the practice of the decision makers, we can still question, on the other hand, its quasi-exclusive nature in the environmental economic analysis.

Is a reef's worth limited to its monetary value? For the authors of this report, who consider excessive the thought that everything that counts can be counted, the answer is obviously no. The monetary value is just one aspect of the economic and social value of an ecosystem. As to what is assigned and estimated as being the total economic value of an ecosystem, it is only really the formulation in monetary term of others value systems (social, recreational, ethical…), some of them being based on the notion of collective wellbeing. Contrary to what classic economy says, collective wellbeing goes well beyond a simple sum of individual preferences, in particular in numerous society of the insular Pacific where individual behavior still frequently serve collective strategies.

This point of view is leading us to come back to the notion of value.

1.2 Questions around the notion of value

1.2.1. General considerations

Fundamental in the sociology vocabulary, and more generally in social sciences, the value is a standard enabling to judge whether a reality is good or not, useful or not, beautiful or ugly, moral or immoral… in a given society or part of it. It encompasses "the whole of moral and ethical principles, defines in a society, or part of it, what is desirable and guide the actions of its members" (Guédez, 2003). "Value" comes from the Latin *valor,* declined from the verb *valere* which means *"to be powerful", "to be healthy", "to be strong and vigorous".* The term "value" suggests a positive value, in contrast with neutral or negative (Lemos, 1995). To say that an individual or a society prizes something means that they like this thing or that they consider it as good. The reason why one thinks something is valuable can come from many origins. For the economists S. Faucheux and J.F Noël (1995), the notion of value is tightly linked to the satisfaction of human needs. Borrowing the definition by Jevons (1909), they consider that *"the value is the importance taken by individual possessions or quantities of goods in our life, when we become aware that we depend on the control of those goods to satisfy our needs".*

The philosopher, M. Scheler, established a hierarchy of values representing different levels of human experience. According to him, like all other living organisms, we take interest in what pleases us, in the enjoyable, in what satisfies our needs (the useful), in what is fueling life in us, (the vital), in what make us more human (the beautiful, the fair, the truthful…) and in what help us to escape the limitation of being human (the divine).

Authors, a lot more recent, have borrowed this idea (Lemos, 1995). The notion of value, thus, is accomplishing a balancing act between economy, moral, religion, science, art, politics, law and culture… a balancing act that makes it vulnerable to the current public opinion: to the "air du temps". During the Age of Enlightenment, the philosophers were carrying values, so logically they tended to be of moral or political influence. As for medieval times, they almost exclusively were from religious inspiration, at least in Christian Europe. With the worldwide globalization of the market economy and of its associated commercial values, the value is nowadays more and more related to the economy field.

1.2.2. VALUE ACCORDING TO THE ECONOMISTS

Let's start with an historical perspective, pointing out that the question of value has been one of the most debated economic notions of the XVIIIth and XIXth centuries and underlining the "modernity" of the antique Rome concerning this notion. Roman law indeed considers that a good's value is defined by the market price: « *res valet tanti quanti vendi postest* » (an object is worth as much as it can be sold). Such conclusion comes from the objective observation of economical facts and is based on a simple question: How is a good value fixed? This questioning has allowed several centuries later the development of the economic science. In the middle Age the outlook is completely different. Society is dominated by religious values and the research of phenomena essence: the accent is thus stressed on the Why of the value. In a world created for mankind by god, where everything comes from and goes back to god, things have a value only because they serve human beings: they are useful. With this notion of "value-utility" comes the idea that the quality of a product equates its intrinsic quality and therefore imposes itself to the commercial value that must tend towards a fair price.

Profit is presented under a very negative light in the scriptures: "it is easier for a camel to go through a needle eye than for a rich man to enter the heavenly kingdom" [1]. The church considers that trade should not be productive, following in that Aristotle and its sterility of the exchange doctrine. This right price is determined by the cost of production plus a fair remuneration corresponding to the sale person service, this service following a superior order, of divine essence, that is supposed to overrule the fluctuations of the offer versus demand. The value here is submitted to a normative foundation.

This conception of the law, seen as a sub-product of god's will imposing itself to humans and their practice, will last until the Age of Enlightenment. Philosophers will then stress the interest of observation and reason (opposed to the divine) to conduct human business: it is the notion of "law based on observation", notably formulated by Montesquieu. In the economic field, this approach by observation leads to re-question the notion of value. The development of the reformed religion, that is

[1] Gospel of Matthew quoted in Nouvel Observateur, issue 2195, p.20.

praising work and abstinence as a glorification of god, brings a growing number of economists and philosophers of North Europe to contest the utility as the value foundation. In a world where the ideal of man is to work to produce goods self-consumed at a family or community scale, it is not surprising that work appears as the foundation of goods value. The fair price of a product reflects its cost work-wise, but it depends more on intuition than on actual economic demonstration. Not surprising either that in the countries stayed faithful to Catholicism, economists don't really question the notion of "value-utilily" and totally refute the notion of "value-work". In 1776, the "Trade and Government Treaty" by Abbot de Condillac underlined that cost does not determinate the value, but on the contrary that it is the value that determines the cost of a product. But the main breakthrough of this treaty is somewhere else. It is in the introduction of the new notion of "value-desire": if a product has value, it is because it is desired. This is a modern point of view: the influence of god has disappeared and the subjective foundation of the value is favored.

Adam Smith, a philosophy teacher in Glasgow, whose book "Research on the nature and causes of the nations wealth" also published in 1776 and that propelled him "father of political economy", opposes an integrator point of view. According to him, the economic value of a product can be broken up in a) a use value, a subjective value that reflects the attachment a person can feel for an object (we are close to the 'value-desire"), and b) an exchange value which he assimilates to the "quantity of work that the good enables to buy or order". In any case, the use value is subordinated to the exchange value. This concept is derived straight from the protestant moral that almost assimilates value-exchange to value-work and considers that the exchange value constitutes the price of a product, the quantity of work being the measuring unit of the value. Thereby it is logical, according to Adam Smith, for the price of water to be nil because water is obtained with very little work, while the price of diamond is high because it requires huge quantities of work, whether it is for the research and the mining extraction or the transformation and the enhancement of the product.

Thirty years or so later, David Ricardo adds a new point of view by referring to production costs as foundation of the value of a product. When production costs are equals, if fluctuations appear on the markets they can only be minor, like waves at the surface of the ocean, underlines Stuart Mill. This theory of the "value-production cost" is the first try since the middle Age to transform the value into a totally objective notion. It will be borrowed and developed further by Karl Marx who will substitute in its place the notion of "value-work" that he re-actualized: the value of goods, comes from human's work. Marx breaks up the "value-work" into two parts: the value relative to the intensity (quantity or time) of the implemented work and the value of the product generated by work which can be assimilated to the value of the good on sale, represented by its price. The difference between those two values, is what Marx call the "surplus value", or source of profit. Marx theory represents the last attempt to transform the concept of value into an objective data. All the economists, so called "liberal", coming after Marx will favor the subjective foundation of the value, considering that its root does not come from things but from man, and more specifically from the demand for goods he expresses on the market. The encounter between this demand and the offer of goods leads to the formation of prices. Consequently, the price is the expression, in terms of exchanges, of the economic value of a

good or a service. This point of view is today essential in economy and inspires the majori ty of environmental economists.

1.2.3. THE NOTION OF NATURAL ENVIRONMENT VALUE IN ECONOMY

The value concept is essential in economy: "what is a valuation all about if not about attributing a value to a good or service? (Garrabé, 1994). As seen in the previous paragraph, integrating ecology into the economic field equals considering that the ecosystem, as generator of economic and social uses, is carrying values (Pinchemel, 1997), in a wide acceptation of the term, values contributing to the individual and collective wellbeing. Generally, a commercial good can be assessed according to 4 methods, each one referring to a specific value:

- **the historical value,** is the paid price for the acquisition of the good when first put on the market.
- **the hedonic value,** equates to the current market price at the time of the transaction.
- **the replacement value, or reproduction cost of the good**, is distinct from the initial production cost, but comes from a Marxist approach of the value too, according to whom "the value of each good is proportional to the quantity of work necessary to its production" (Alquier, 1987, p. 82). The replacement value equals to the cost that would be necessary to restore a natural capital or reach a level of quality equivalent to the initial situation[2].
- **the capitalization value** applies to any asset generating a monetary income during a given period and is based on the hypothesis that the value of an asset (which can be part of a capital) is equal to the sum of income expected from that asset, which means a) that this asset has a limited lifetime, b) that this information is known, c) that we are able to estimate the variation in annual income depend on the year. Knowing the amount of this income at the beginning of the period, noted (rt1), we try to estimate its equivalent for the end of the period, noted (rtx), using an actualization rate, noted (i). This is why this capitalization value is also named actualized value of the expected incomes[3].

For the economists, the difficulty to give a value to an ecosystem, or to the public natural goods part of it, comes from the fact that the services and functions it provides completely elude monetary estimate because this public natural capital can not be exchanged on a market. Yet, the encounter between offer and demand is the only method used in classic economy to give a value to a good. And yet, the value of an ecosystem indeed belongs to the economic field because any increase or drop in the quality or quantity of these services and functions can affect the utility and the wellbeing directly or indirectly taken by the user populations. In fact, as notes Comolet (1994): "natural goods get a

[2] On the contrary, as underlined by Comolet 1994, p. 76, the cost of environment damages is sometime evaluated depending on the preventive spending necessary to avoid environment destruction.

[3] The actualized income rtx at a time t is calculates by adding x times the expected income at time t+1, such as rtx = rt1 (1 +i) + rt2 (1+i) ….. + rt(x-1) (1+i) or rt2 = rt1 (1 +i). Thus, with an actualisation rate of 5%, a rental income of 1.000 euros per month will reach 1.551 euros after 10 years for a capitalisation value of 150.950 euros, equating to all the received rents.

value only when they start to become scarce and that it requires spending money to keep using them". Thus, the value of coral reefs remains "hidden" until they become so rare that a fee will be established to limit frequenting. The amount of those fees is not fixed but increases accordingly to the demand. A market enabling to assess the economic value of the reef put into use is thus being born.

Except in this exceptional context of great scarcity, economists face a major contradiction: the environment indeed belongs to the economic field but eludes monetary estimate because it is not made of commercial goods. In such situation, the "neo-classic" or "orthodox" economy approach recommends a simple solution: to "internalize" (to introduce into the market economy and trading economy) the externalities, in this case, services and functions provided by the ecosystems, in order for the environment to be analyzed according to the monetary evaluation methods (Griculas et Gondar, 1995; Dixon *et al*., 1997). Thus, economy puts at the center of its considerations the concept of price by considering that environmental valuation is just a question of preference (easily assimilated to a demand) of the agents for the use or the conservation of a natural capital. The value of this capital can then be assessed depending of a price revealed either by the environment users behavior (travel cost or hedonist prices methods) nor by a consent to pay or be paid, which translates their demand relative to the use or the conservation of this capital, which basically can be summed up to the artificial creation of a market that does not exist (Tacheix, 2005). Nevertheless, whatever method is used, the commercial transaction, real or fictional, of a natural good reflects only part of its economic value. That is why the travel cost method, essentially applied to the tourist activity, is being used. To avoid this type of problem, environment economists (more specifically the London School) forged the concept of Total Economic Value of a natural capital (Pearce, 1990).

1.3 The Total Economic Value of a natural asset

The reefs total economic value notion has presented by J.P. Spurgeon (1992). These are not only considered as goods but as natural assets constituted by a natural capital and the environmental services it provides. The total economic value of the coral reefs as natural assets sums up the use value, the option value, the existence value and a bequest value (Figure 1).

The use value touches all the activities depending on the environment (fishing, tourism, aggregates extraction…). It is composed of a direct use value, in the shape of consumer goods (fishing catches, hotel overnight stay) and of an indirect use value, in the shape of ecological services (supply of fish-feeding for the pelagic species who come occasionally feed near the reefs) or economic services (conservation of the coast from surf erosion or bathing space offered by the beach). Because of the new importance given to environment goods and services, the World Bank proposes to make a distinction between direct use value and indirect use value to create a total economic value for natural

assets (Munasingue, 1993)[4]. The direct use value is measured with the added value of a good, either produced or consumed, or a producer's surplus, which equates to the sale price on the market minus the production costs.

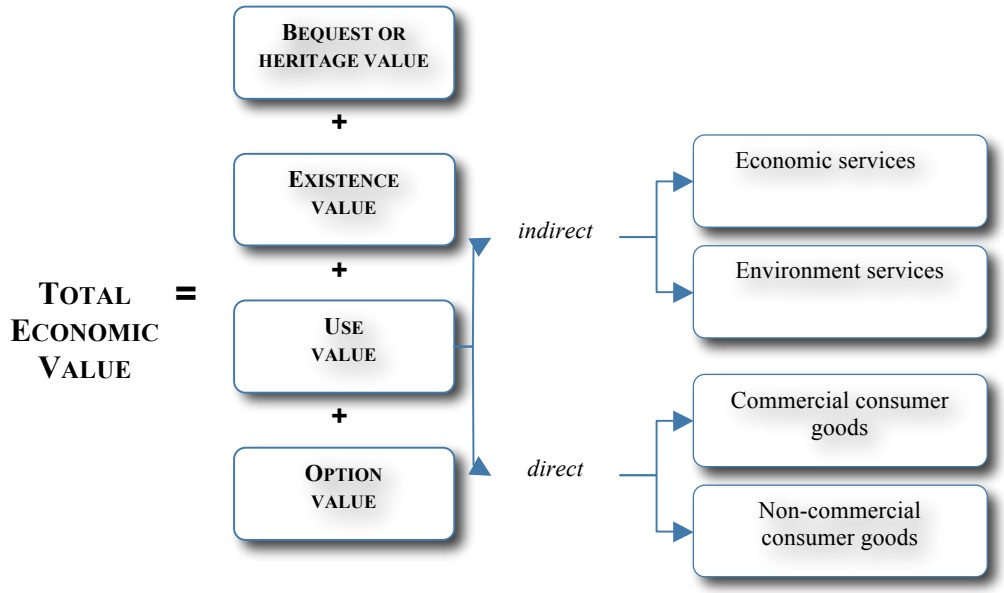


Figure 1 – Composition of the Total Economic Value of a natural asset like a coral reef.

The existence value is given to a natural environment, which has no present or future use. In the western collective imagination, inter-tropical island reefs are not only symbols of purity and virginity but of abundance and fecundity of the marine world too. Tourists visiting the Pacific Islands are consciously seeking, or more often unconsciously, this virginity associated to coral reefs. Even though they only sunbathe on beaches and swim in a-meter deep water without seeing any coral during their stay, they feel in communion with the reef and the images it carries. It is enough to think that it is close and that fulfills them with happiness. If nowadays the existence value is commonly integrated into the total economic value of a natural asset, it hasn't always being the case. Some neo-classic economists used to consider that only values related, in whatever fashion, to a present or future use should be retained (Faucheux et Noël, 1995). The existence value is used today as a vector by the economists trying to include social and cultural values into their analysis. In general, the existence value is estimated by a contingency evaluation that, based on a questionnaire, specifies the amounts the population is willing to pay for the reef to be preserved. To avoid confusion between existence value and use value, the most logical solution is to only assess the existence value with non-users of the reef.

Come next, the questions of the population size to be sampled and its localization. Thus, in the case of Reunion Island, where two authors of this present report live, we will avoid the western coast sheltering the island reef and Saint-Denis, the capital, where are concentrated numerous users of the

[4] This new form of total economic value is the sum of the direct use value, the indirect use value, the option value and the existence value.

reef environment. Instead, we will focus on the eastern and southern populations, the most remote sites from the reef ecosystem. A lot of inhabitants of Reunion Island, living in France, also need to be taken into consideration. The existence value will define places and a lifestyle associated to the reef (somehow a memory of use). But why should we stop with the local populations or the people from Reunion origins? Other people can be interested in the Reunion Island reef or in reefs in general. How to take this opinion into consideration? In launching a worldwide survey via Internet? Or do we limit ourselves to Europe, the Indian Ocean? But on what criteria should we choose one or the other option? At any rate, the survey representativeness is a major problem.

In the Pacific Islands, where reef users are often the majority of the coastal population, it is convenient to only question tourists but then how is it possible to reflect the cultural and social dimension supposed to be expressed by the existence value, knowing that this dimension can only be touched with the local population, mainly made of reef users? Two choices are possible:

integrating the reef users into the sample to be surveyed, but it comes down to accepting a permeation between use value and existence value, and to admitting the unclear nature of the latter ; this is the solution chosen by Spurgeon et al. (2004) in Western Samoa.

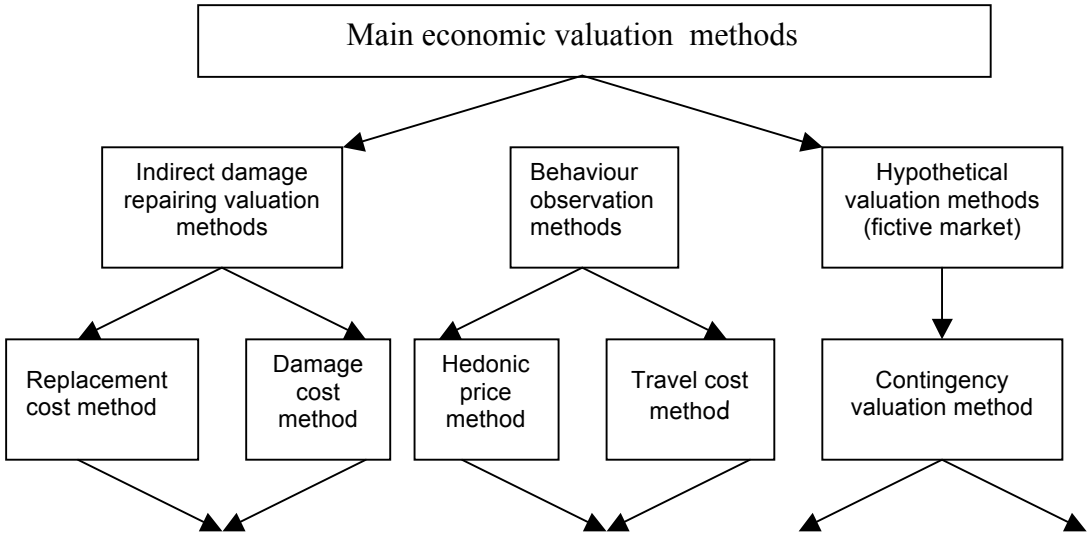
taking the cultural and social dimension out of the reef economic value to be processed in a different section, the “cultural function value”, and considering that the total economic value do not represent all the values associated to the reef. P Lal (2005) mentions a total environmental value that would be the sum of the total economic value, the “Ecological process value” and the cultural process value.

The option value is what an individual is willing to pay to keep an option on a future use of the environment, whether it is known or not. It is not the effective and present use of the asset that is being considered but its potential future benefit. Just as underlined by (Faucheux and Noël (1995, p. 213): «in uncertainties time, and for an individual hating risk taking, it can be rational to keep an option open in case of a future need». The option value can be compared to an insurance premium paid now to avoid an uncertain future. The contingency valuation is the only method to estimate this value.

The bequest value is the projection of the existence value into the future. Same methods will be used to define this value with all the problems previously encountered with the sampled population representativeness. For the World Bank, existence value and bequest value are so tightly associated that they are joined under the term “existence value” in the calculation of the total economic value (Munasinghe, 2003). For other authors, likeness is to be looked for as much as with the option value than with the existence value (Spurgeon et al., 2004). In fact, populations questioned on the value of an environment like a reef have a hard time making the difference between bequest and option values. Caring to bequeath a healthy environment to its children and grand-children is based on the hope to see them use it and benefit from it in the future. On the other hand, when future uses are unknown, because not based on the continuation of the current uses, then the option value plays its

role fully and can easily be distinguished from the bequest value. The bequest value and the option value can be joined under a common term: the bequest value who expresses the wish to transmit to the future generations the reef itself (this is more the existence value than the use value field), as well as the resources it shelters and their current or potential uses.

Figure 2 presents the different methods used to estimate the economic value of a natural asset. The most common two are the contingency valuation method and the travel cost method. Simple to implement, they are both based on the handing out of questionnaires to the tourists and the local population. Focusing on tourist activity, the travel cost method has its limitation: it leads to largely underestimate the reef value by assimilating to its simple tourist and recreational value. The first method is even more criticisable (Willinger, 1996). Measuring the will to pay in order to preserve natural environment, it reduces the total value of the natural asset to the existence, option and bequest values, forgetting the use value which is the only significant parameter of the real value of a natural environment. The option, bequest and existence values are only the result of individual opinions, which widely varies according to criteria completely exogenous like the socio-professional status of the interviewed people, their age, their address, their political ideas, their hobbies, the type of media they usually consult, the economic and political unexpected events happening in the tourist destinations countries they are from. The opinion of one individual is even often changing when the person does not really feel involved in the reef management. Under those conditions, any attempt to estimate the value of a natural asset, like a coral reef, on a simple monetary base based on option; bequest and existence values, can only lead to inaccurate results, even though the contingency valuation method have been sophisticated in the last years. The respect of the underlying postulates of the neo-classic economic approach requires, in the case of a transparent market situation (even though it might be fictive), the future buyers of a natural asset to be fully informed and free of their choices, in order to maximize their utility. Before interviewing them on their will to pay, it is necessary to inform them about what is at stake when it comes to environment conservation and its implementation. Their choices, thus, will be as rational as possible and leave aside the *a priori*, representations and perceptions originating from their daily lives, and more specifically from their social and economic status.



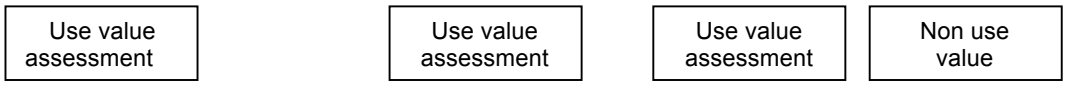


Figure 2 – Principal economic valuation methods for a natural environment, such as coral reef

Even though it is widely being used, this neo-classic approach of environmental economy is not exclusive. Logic would want the estimate of the reef monetary value to be based on the knowledge in coral reef ecology and coral reef uses. The studies in that field are still scarce and their approach focuses on ecological goods and services, according to a multidisciplinary perspective. After the innovative work of Mac Allister, in 1988, which envisioned ecological services through the social cost of their destruction, Spurgeon (1992) then Moberg and Folke (1999) and Ruitenbeeck (1999) have studied coral reefs as a natural capital, generator of ecological services and goods. This approach has been extended to the sea grass beds and mangroves (Moberg , Rönnbäck 2003), considered, in association with the coral reef, part of an ecological system (a seascape). This concept of ecological system applied to the marine and coastal environment is close to the eco-socio-system forged by the geographer J.P. Corlay (1988), inspired him-self by the geo-system concept developed by the geographer G. Bertrand (1972) for the mountain environment (his PHD thesis was dedicated to the European peaks in Spain) then borrowed and further developed by Rougerie and Beroutchavili (1991).

As underlined by Folke (1996), economic, social, institutional and cultural factors are the « ultimate » variables of this system, whose resiliency capacity should be preserved (Gunderson, 2000; Moberg, 2001). The study of environmental goods and services gives the opportunity to start thinking about economic and social resiliency of the coastal populations, whose habitat is suffering biodiversity erosion. In a second time, it is easier to elaborate management actions enabling to minimize these populations vulnerability and to maximize their resiliency. This multidisciplinary approach, led by what we could call the « Swedish school » is rich in prospects and goes well beyond the simple estimate of the monetary value of an ecosystem or the natural goods composing it.

Another interesting perspective is brought about by environmental economy (Reveret and Weber (2005). It aims to study the complex interactions between human economy and ecosystems activities[5]. Those tools are borrowed, both from nature sciences and economic studies on the functioning of human material economy, Tacheix (2005), and could contribute in the future to a better estimate of the reefs economic value. Indeed, as underlined in paragraph 1.1, if presenting research results in a comprehensible language is essential to be integrated into the decision process relative to development and management of coral reefs seashores, it is imperative for those results to be accurate, which means that they have to come from studies on eco-socio-system activity, a whole comprising coral reef ecosystem, the associated socio-system and intersystem relationship. Such is the philosophy of the current undergoing study on the social-economic value of coral reefs in La

[5] This perspective appears to be innovative, but it already has been outlined by the natural heritage accounting school in France (Weber, 1986), who failed to impose itself on the international scene.

Reunion Island, considered both as natural asset and natural heritage. 8 parts compose this work, which has already been the subject of a PhD thesis:

definition of the functions or services provided by the reef in relation to the local eco-socio-systems;

recognition of lands or land-resources providing those functions or services (the concept of land-resource integrates into a same entity the land and the resources it shelters as management object and use object).

identification of the users and other beneficiaries of the functions or services provided by the reef;

study of the users perceptions relative to the reef environment, in order to find out the differences between the actual and the perceived reef;

study and diagram modelling of the relationships between functions or services provided by the reef, lands or land-resources and the benefiting users ;

simplified analysis of the reef eco-socio-system functioning and of the reef's place in it ;

estimate of the social and cultural value of the reef heritage ;

estimate of the monetary value of a whole reef, after estimating the monetary value of each function or service provided by the reef, then the monetary value of lands and land-resources generating those functions.

2. THE REEF, A NATURAL ASSET

Generally speaking, a natural wealth may be assimilated to a resources and environmental aids providing over time, flows of ecological, social or economical services (Faucheux & O'Connor, 1999). There are three ways if assessing the value of an environment as a natural wealth : either to carry out a so called « economic appraisal » monetary evaluation (Faucheux & Noël, 1995) ; or to set up an bookkeeping of elements, ecosystems and agents that are part of the natural heritage (Weber, 1986 ; Comolet, 1994) ; or merge both views and widen the field of study by performing "a socio-economic assessment" emphasizing resource-spaces and sub-spaces that make up the reef as structuring elements of the assessment.

2.1. RESOURCE-SPACES AND STAKEHOLDERS

The resource-space concept combines within a single entity the space and resources it shelters as a management object and use object. The reef thus comprises twelve resource-spaces : The outer reef submarine wall, the outer shoal, the submarine wall, the fairways, the coral keys (called « motus » by Polynesians), the lagoon, the keys, the coral pinacles, the inner reef submarine wall, the inner shoal, the muddy-sandy flats (usually populated by phanerogrammes meadows), the beaches (figure 3). Each and every one of these is being put to one or several uses. Altogether, about twenty types of uses have been listed within Table 1. It is rather rare for a resource-space to be subject to a single use. Whenever several users operate over a single resource-space, it is quite rare for the whole of the resource-space to be equally affected. Some areas are being used extensively – one or more users expressed over a large area, others are so in an intensive way, several users being expressed over a small area.

Each and every resource-space may thus be broken down into several sub-spaces out of which two types may emerge:

- The user-resource-spaces, each corresponding to a single user,
- The multi-users-resource-spaces made up of two superimposed user-resource-spaces.
-

The superimposition of all of these user-resource spaces and multi-user-resource-spaces outlines the intensity with which each area of the resource-space is put to use and constitutes the structure of this same resource-space. The reef is thus made up of two interlocked structured, themselves relating to a rating scale: resource-spaces and user-resource-spaces.

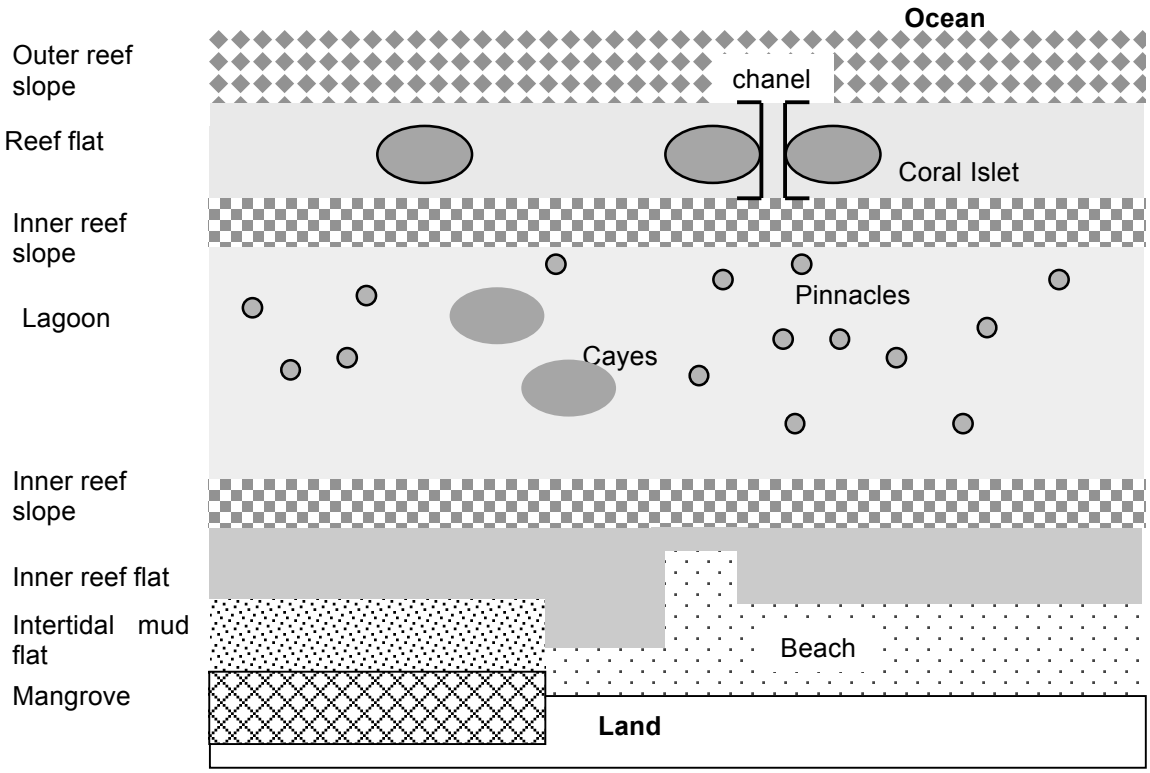


Figure 3 – The coral reef resource spaces

Should each and every user-resource-space correspond to one and only user, it often occurs for several types of users to take advantage of a same user-resource-space; furthermore, no resource-space is used by a single type of user. Overall, twelve main reef user types were listed within Table 1. They incorporate into three well marked population types;

- The tourists, who, in essence do not dwell in the island harbouring the reefs subject of the survey ;
- The resident population (characterized as local population) and the local economic operators : small-scale and informal fishermen, hotels, sand gatherers, coral strippers, fish farmers ;
- The Island's non-local, mostly urban or suburban population among which yacht sailors, informal fishermen, travel agencies and recreational users, only occasionally frequenting the reef littoral for leisure purposes.

Fishermen do not constitute an homogeneous role-player group. Daily costs of fishery, closely correlated to the fisherman's locomotion mean, help setting up a primary classification amongst food-producing fishermen (by far the most numerous amongst insular fishermen), commercially oriented small-scale fishermen and yacht sailors.

Table 1: Resource spaces, stakeholders and uses of the Indian Ocean reefs

RESOURCE-SPACES	STAKEHOLDERS	USES
Beaches	Tourists, local population and Island's urban population	Beach activity
	Sand collectors	Sand collection
Inter-tidal mud flats	Island's urban population* and Local population**	Seashells, crustaceans gathering, Net-fishing
Inner reef flat	Island's urban population* and Local population**	Seashells, crustaceans and coral gathering
Lagoon or wide craft channel	Coastal and informal fishermen	Net fishing and angling
	National yacht sailors and tourists	Yachting including boat mooring
	Sand collectors	Sand collection
	Fish farmers	seashells, algae and fish farming
	Travel agencies	Glass-bottom boat ride
Coral pinacles	Coastal and informal fishermen	Net fishing, spear fishing and angling
	Local yacht sailors and tourists	Scuba-diving
Inner reef slope	Coastal and informal fishermen	Angling and spear fishing***, Sponges and coral gathering
	Local yacht sailors and tourists	Spear fishing
Outer reef flat	Local yacht sailors and tourists, Informal fishermen	seashells, crustaceans, coral and fish, collection
	Coral extractors	Extraction for Public works & building
Cay or islet	National yacht sailors and tourists	Beach activities
	Hotels	Tourist accommodation
	Local population	Habitat
	Sand collectors	Sand collection
Outer reef slope	Coastal and informal fishermen	Angling and Scuba diving***, Sponges & coral collection
	Local yacht sailors and tourists	Scuba diving Spear fishing
Channel	Coastal and informal fishermen	Angling & Net fishing, Scuba diving

* with an available mean of transportation
** informal fishermen and beach attending population
*** fish, crustaceans and seashells

One double-entendre remains regarding the difference between yacht sailors and commercially oriented small-scale fishermen. We will consider that yacht sailors are well off enough not to have to rely upon fishing to meet their protein intake and that their income is higher than the food-producing fishermen's. Generally speaking yacht sailors are urban people operating from cities or tourist centres and have crafts that are much more powerful than those of the coastal fishermen.
Within each of these three types of fishermen, several sub-groups can be identified according to the fishermen fishery profile depending upon:

➥ The operated resource-space, in this field, the fishing territory exceeds by far in order to encompass coastal waters and deep-sea areas skirting the fish aggregating devices (FAD)[7] ;

➥ The type of implemented harvesting devices,

➥ The fishermen's mean of transportation : on foot, diving, on-board, itself ranging into several types depending upon the craft's type and its engine's power whenever dealing with a powered craft ;

➥ Their geographic origin. Generally speaking, a distinction will be operated as follows: **a)** urban or suburban fishermen, **b)** rural fishermen from an island with an existing urban centre or a major consumption centre, **c)** fishermen from suburban areas, not easily linked to urban centres, with a well developed road network.

2.2. THE REEF, AN ECONOMICAL ASSET GENERATING BENEFITS

2.2.1. THE REEF CAPITAL AND ITS BENEFICIARIES

Even when considering a natural habitat such as the reef or the mangrove from an economic viewpoint, its value may be wrongly perceived due to an often occurring delinking between the environment value and the value of its productions, or of the mix up between natural elements reserves and the production flow it breeds.

Thus, the decision-makers do not always make the connection between sand production and the reef, between a lagoon based halieutic production and the adjoining barreer reef, between a mangrove at the head of open bays and the fringing reef about a hundred meter away that enabled a dissipation of the swell's energy and , indirectly to favour sedimentation that allowed mangrove's implantation . The natural capital can then only be generally apprehended through the value of its productions; this amounts to considering this capital only from the angle of paid interests (the capital's revenue) if using a banking analogy. And yet this capital is collective, and the beneficiaries of these interests are thus many but their exact number is unknown.

Besides, all of them do not acknowledge themselves as beneficiaries of the capital. The only ones doing it are those earning their living fully or partially from a reef generated activity or associated to the reef (fishing, tourism). It is then frequent for them to consider themselves as sole users or at least as having priority over resource-spaces the reef is made of. In that case, any attempt at a rational Reef capital management proves to be hard to implement. The most difficult thing is to make each beneficiary become aware of the fact that:

➥ He is not alone, in other words fishermen living off the reef must become conscious that the tourism operator is also a reef user whose activity is as legitimate as their own ;

➥ The interest rate paid to each beneficiary of the « Reef capital » is not steadfast but may vary, particularly in relation with all of the rates paid to the other beneficiaries. In other words, the reef users or those associated to it cannot apprehend each other in a sectional manner. All reef related activities are bound to each other by interdependence links. It is those relationships that led to consider reef management along an integrated approach aiming, not only, at optimising relationships

[7] The FAD are made up of a wooden raft , anchored to the seabed at depths ranging from 500 to over 1000 m using a thick fag end tied to a mooring. Under the raft, are anchored one or several soft plastic structures: the « Christmas trees » upon which marine molluscs are settling and that are attracting fish pelagic larvae (Cillaurren, 1987).

for each activity with the reef, but also those relationships the activities have woven among themselves ;

➥ The overall capital represented by the reef reaches far beyond whatever capital is necessary to generate interest rates. Beyond the value of activities it induces, the reef has thus its own value, that comes into a monetary component , relating to the reef's intrinsic economic value such as the protection of the coastline against waves, and monetary component of a social and cultural order such as the social link's revival at the time of "traditional" collective fishing sessions such as stone fishing or New Caledonia's sea clans structuring, whose function consists in working the reef on behalf of the chiefdom (Leblic,1999).

Thus, as a natural capital, the reef could be considered as made up of three sets : one natural elements reserve generating a commodities flow (all products or income from this capital), commodities flows generated by this capital, and another natural elements reserve generating non-commercial services. Put together those two reserves constitute the capital proper.

Within the scope of the implementation of a sustainable development policy for the coral littorals, a common goal for all of the South Pacific Islander countries, it is necessary to consider the reef capital as an inheritance to be passed down to future generations. The latter are thus meant to become the future beneficiaries of this capital, which implies a specific management. Indeed, there is a fundamental difference between a capital and an inheritance. Just as emphasized by **Humbert and Lefeuvre (1992)** : a capital is managed with a view to increase it while and inheritance is managed in order to be passed down. Does this acknowledgement apply to coral environment? In other words, is then the Reef capital extensible? If so, is its extension so sustainable that it could be compatible with a proprietary assets management aiming at passing down to the next generation a Reef capital as productive in terms of goods and returned services as the present capital?

Structured as it is around the coral ecosystem, the Reef capital's temporal evolution relates more to ecosystems dynamics than to a financial capital. At best, when adequately managed and protected, a reef in good general condition does not deteriorate. But it is not growing either, its dynamics leading to a balance between processes of construction and destruction. In a caricatured manner, the coral ecosystem could then be viewed as a climax. Constrained as it is by the coral ecosystem's operation and productivity, the Reef capital keeps the same productive capability upon reaching the climax stage, and the amount of interest it generates remains steadfast with time. Thus, the Reef capital could be assimilated to a financial capital whose returns are spent in full by their beneficiaries. To the contrary of a classical financial capital, it thus doesn't increase yearly with the worth from paid interests. In that respect, the reef is at the same time a natural capital but also a natural inheritance, as its optimal management, aiming at sticking to its productive capability amounts to a kind of proprietary assets management whose objective would rest in the transmission of this optimal productive capability.

However, from a theoretical point of view, it is possible to increase every year the amount of revenue paid by the Reef capital, and in the same way the latter's value. Such an evolution has never been observed as occurring naturally but it is conceivable in one case: whenever the reef's unique development is a tourist one. Let's consider a 25km long reef littoral along which stand only one international hotel. The site's relative vacuity, its beauty and the services offered by this hotel are

entailing a strong demand, in excess of the room availability. A second hotel is then built by the same group. This setting up stimulates the interest of a competitor group, who then decides to build its own hotel along the littoral. Another group jumps in. A strong promotional policy of this littoral may then ultimately lead to a full development of the suitable littoral, which corresponds to approximately 40 to 50 hotels along a 25km shoreline. With some regularity in time, the pace of these hotels openings leads to a progress in the littoral tourism development and in the reef's economic value, just as if a discounting rate was applied to the Reef capital. This development will then come to an end by the last possible hotel's building and opening. Two questions may then be asked: is the then attained reef value liable to perpetuation? Is the reef's good ecological condition the main reason for this perpetuation?

Should we, in the present situation, consider tourism as the reef's only development, then the reef's value perpetuation is in full correlation with the hotels' occupancy rate and the price for a night. Should the destination be considered as attractive by tourists, both may keep up, which requires a proper and quality worldwide scale promotion, such a variable goes with a strong satisfaction rating following a stay. On the contrary, should the attendance decrease, then a two-steps dynamics might be triggered that would lead to a significant debasement of the reef's value: **a)** lower prices in order to attract a, less well-off than the previous one and then larger, customer base **b)** the withdrawal of top of the range hotel groups, who, considering the site as having been profitable enough, sell their hotels to groups aiming at a lower range market share. In fact, such an outline amounts to associate the reef value with the seaside hotels profit. The reef's value perpetuation would then depend upon the perpetuation of tour operators' profit. The assertion is even more questioning as the tour operator's profit appears by far independent from the reef's good ecological condition.

Indeed, tourists satisfaction rate in hotels mostly depends upon the quality of service and the lack of social or environmental inconvenience. Amongst the latter, bathing waters' poor quality with pollution for an origin are the main factors liable to affect tourist attendance, (save for natural disasters). By comparison, natural hazards, such as coral bleaching or crown-of-thorns starfish invasions with significantly lower impact owing to the reduced number of tourists interested in reef habitat and select their destination based upon the latter's health condition. It is then perfectly conceivable that the ecological debasement of a reef should in no way impact the tourists attendance rate and the seaside hotels' profit.
The reef value being correlated to this very profit, we may then conclude that whenever tourism is the reef's sole development, the latter's economic value is by far independent from its good ecologic state of health.
This assertion sanctions a delinking between the notions of reef capital and reef inheritance. There is a risk in considering that a natural capital such as the reef's is not an inheritance and could be managed, with in mind the sole purpose of a short-term financial revenue increase (interests), thus incurring the risk of a reef biotope and biocenoses worsening, and consequently of the reef capital itself, which in the mid-term, is unacceptable for coral reef biodiversity conservation conscious scientists and citizens. An optimal management of the Reef capital could only be proprietary and consider future generations as legitimate beneficiaries as the present ones.

2.2.2. INTERESTS FROM THE REEF CAPITAL

Those interests are comparable to goods flows generated by the stock (Reef capital), most of them, being direct or indirect consumption goods that will end generating monetary incomes[8]. Those interests from the Reef capital occur under three main shapes:

a) Macroscopic size living matter flows, namely fish, and various mineral materials (sand, dead coral) exported by the reef's various resource spaces. The major share of these exports does flow past the reef and related ecosystems limits (phanerogam meadows). These flows may be assimilated to a resource that reef user's, through their labour, turn into a consumption good, such as shown in figure 4 with fish.

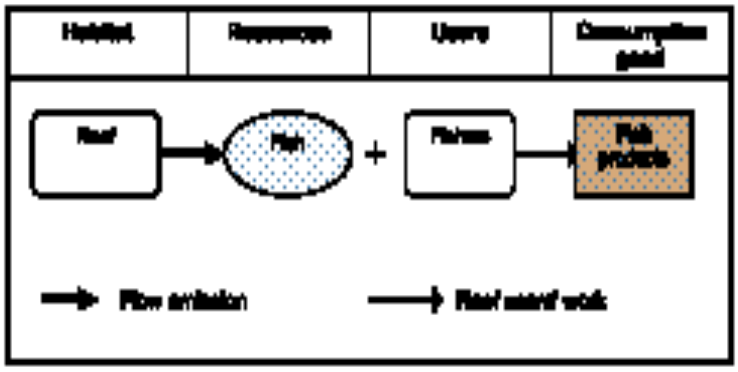


Figure 4 – From the reef to the market : the Reef fish processing into consumption goods

b) Flows of microscopic size living matter, constituting potential energy for the reef's animal species cropped by its users or a resource for future potential users. Once it has reached its macroscopic size, this living matter will turn into, either a resource to be cropped by reef users, or into feed for the coastal waters halieutic resources, that will be cropped by other users than the reef's. Thus a major share of the reef's exported larvae will be consumed within deep sea habitat via a food chain whose higher links made up of great deep-sea fish such as tunas or jacks, both target species for high sea fishing. Some among those small pelagics (sardines, silversides...) as intermediate links within this chain, will return to the coast, where they will, for a few weeks, act as target species to reef fishermen practising hand cast net or gill net fishing. As for Trochus, mother-of pearl shells, as for many crustaceans, larvae or juveniles must leave their pelagic stage and go back to the reef habitat in order to reach adulthood. At that stage, they will then bear the pressure from reef cropping fishermen (figure 5).

[8] Different from a direct consumer good, the indirect consumer good requires the intervention of man labour in order to be made available to consumers.

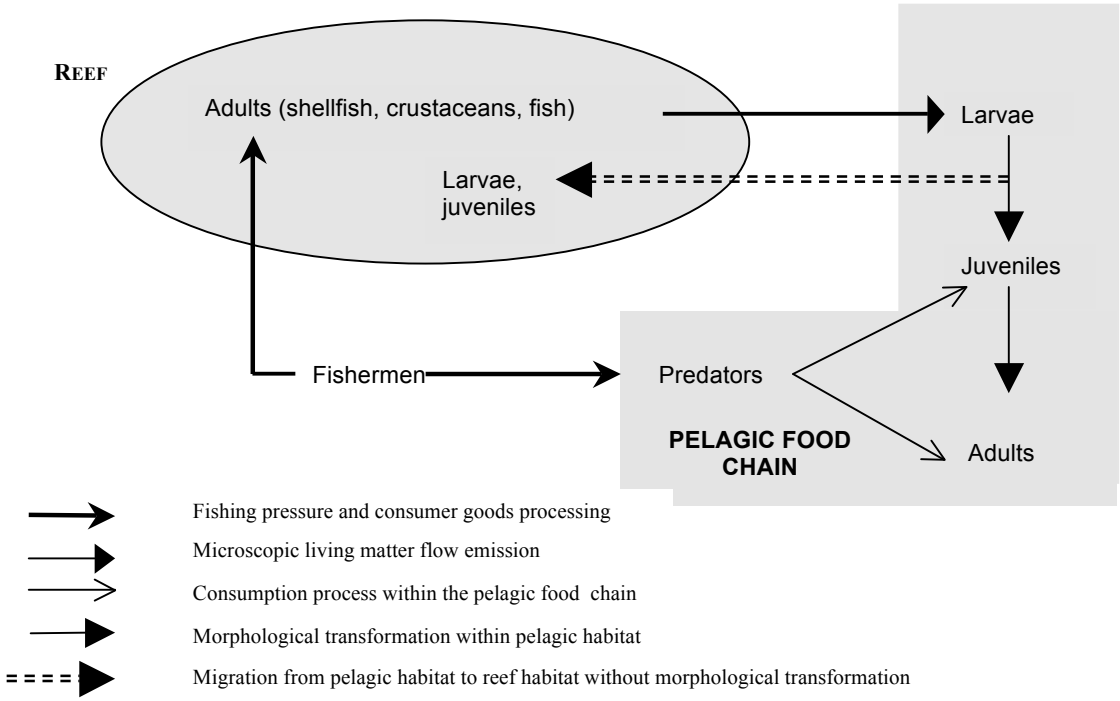


Figure 5 – The microscopic living matter flows from the reef as potential energy for future inner or outer reef fishing

c) A constant image flow that permeates reef users' perception in the shape of a landscape. This comes under an information flows domain, harder to grasp under an economical angle than matter flows: thus, depending upon the user type, images may be assimilated either to a direct consumption good or to a resource.

Images are deemed *direct consumption good* whenever the consumer is the user, physically present on the reef. Owing to the access cost gap between submarine and aerial environments, a distinction will occur between, on one hand, the reef's emerging portion, and on the other hand, the submarine landscape, that can only be perceived while snorkelling or scuba diving. It is important to stress that the mental setup processing information flows issued by the reef into a landscape doesn't require any specific energy input, this not representing any labour, these flows cannot in any way be related to as a resource. The only presence of a user turns them into an images flow, a direct and instant consumption good that the user will store in his memory as recollections after having consumed it in its present state. On the other hand, should the user not be physically on the reef or upon its submarine portion, a presence materialised through an access cost, this mental construction cannot be achieved. The information flow emitted by the reef will not be converted into images; putting it another way, those Reef capital generated interests will not convert to consumption goods. (figure 6).

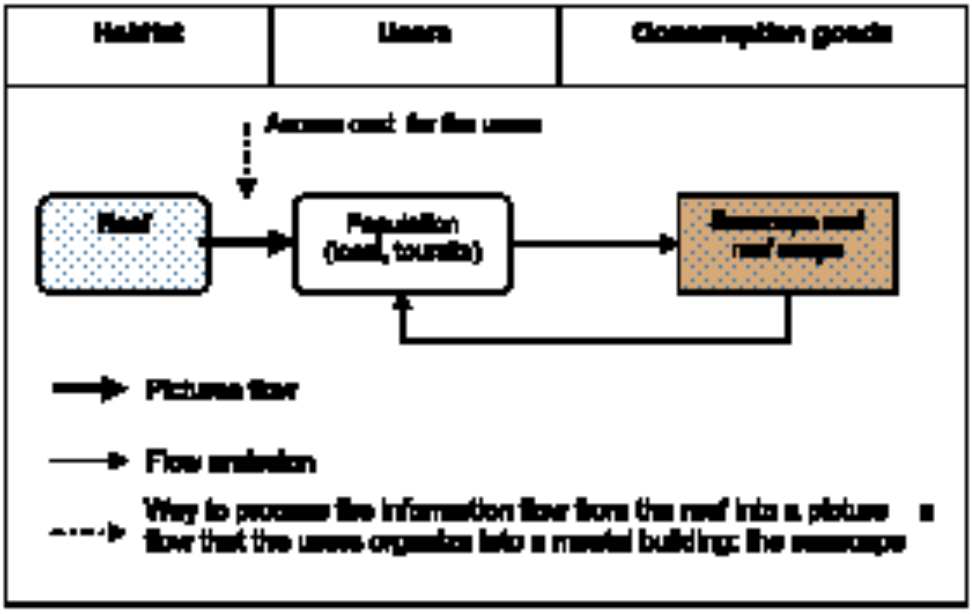


Figure 6 – The reef as an information flow transmitter and the reef scape as a direct consumption good

The reef emitted image flow being meant for private use and not subject to any transaction, it evades all market values ; however this so-called « reef view » image flow, is not without economic influence .

On one hand it allows real estate agents and hotel managers to increase prices over the goods they put up for consumption in comparison with normal market prices (a so called « hedonic" price). On the other hand it represents a decision making tool that may turn out as critical in a real estate property purchase or in the extension of holidays. However, the view, such as accepted herein, an instant images flow perceived by the reef user, is not a factor in holiday location choice. Indeed, the decision is made prior to the user's arrival upon the reef. The only exception corresponds to a second stay over the same holiday location. The decision is then triggered by a previous stay's memories, among which those relating to the reefscape.

In one case (majoration of a property selling price) as in the other (inducement to this good's consumption) the reef view being assimilated to an annuity (Figure 7), in economist terms, this refers to "any payment granted to a production factor on top of the minimum compulsory payment required to maintain this factor on the market" (Baumol *et al.*, 1986, p. 447).

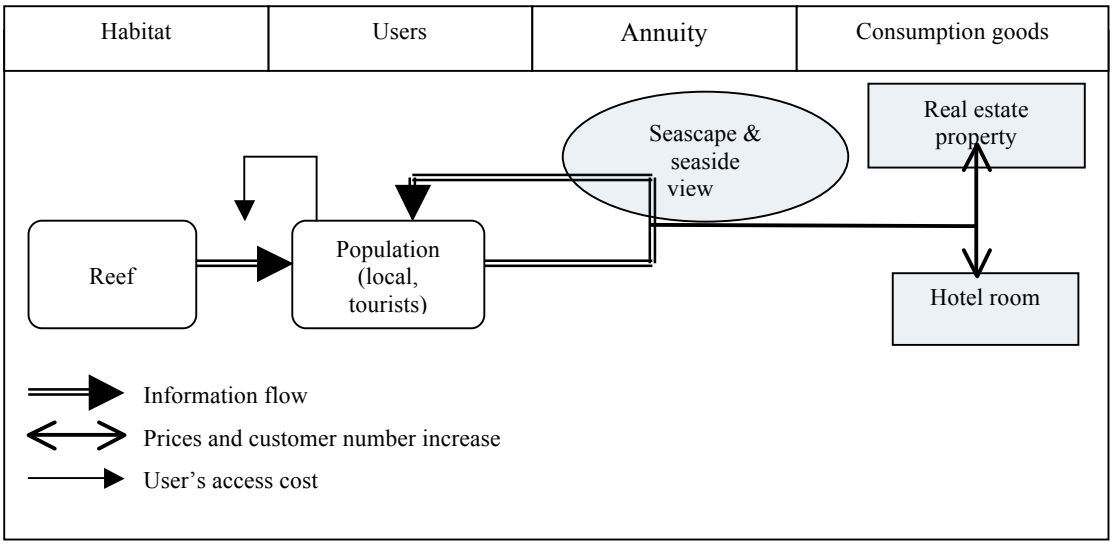


Figure 7 – The reef as an annuity transmitter and the reefside view as an information flow changing the access and the price of consumption goods

The images only become resource and consumer goods after their transformation through user's labour, i.e. the photographer, the film maker or the video sound mixer, thus maintaining a long term image flow that turns into an instant landscape, whose analog or digital depiction can be duplicated. The user's reef access cost is then integrated to the consumer good's overall production cost. The consumer good resulting from this labour can also be meant for private use, as it is then the case with souvenir films or photos (figure 8); it may also be meant for commercial use, as with slide shows, video films, postcards or local dissemination or national or international broadcasting photo reports.
Three consumer types may be identified:
- tourists and other reef users staged within commercial use images ; who, through postcards, videos and slide shows, attempt at making durable their snorkelling or scuba diving souvenirs, or simply their strolling upon the flat ;
- users of reefs other than the one staged upon commercial images, and who, through those videos , books or advertising leaflets, are attempting to get information about reef environment, either to increase their general knowledge, to identify a holiday destination, or to select a future real estate property purchase ;
- reef's non-users, who, through images they will come to watch (films, videos, books or leaflets) will be enticed to come and visit the reef environment, leave nearby, or simply to cast a different eye upon this environment. Documentaries shot by the Cousteau team and broadcasted worldwide according to the very model of this type of images meant for a large layman audience. As commercial consumer goods, these images will be appropriated by part of this audience and integrated to their dreaming. Should the image be enticing enough and the consumer responsive enough, the dream, in which he stages himself in touch with the reef, will be striking enough to entice him to an attempt at really living in this holiday environment. The reef images consumer thus becomes a new user of this environment (figure 8).

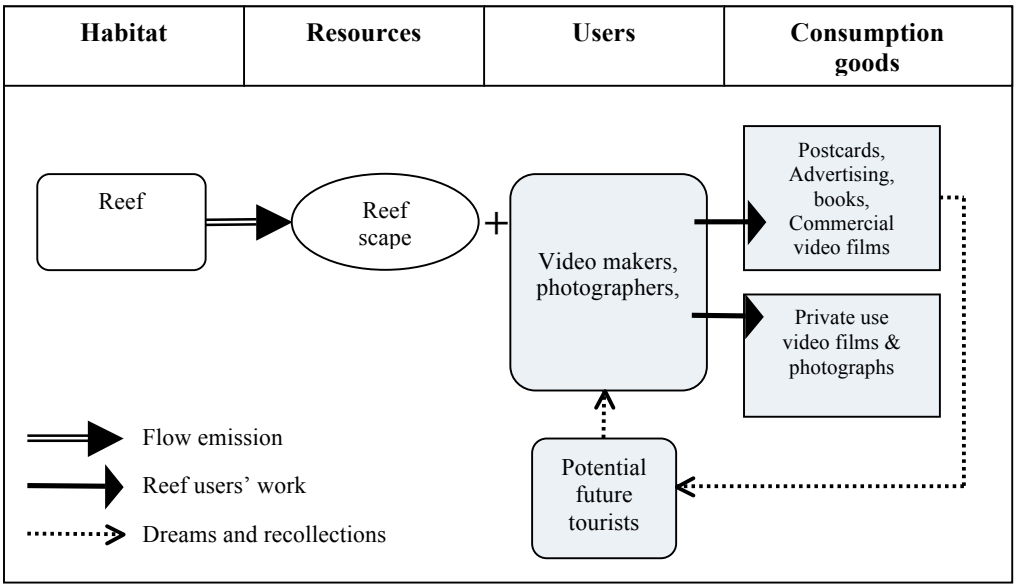


Figure 8 – The reef as a resources transmitter processed by the users' work into consumption goods promoting the property and tourism markets

Images are also a resource that scientists frequently include within production of new scientific knowledge, assimilated to consumer goods. This production requires for the image resource to be associated to another resource: the scientists' reef knowledge, then it should be coupled to field data, their collection being assimilated to a job. Popular science requires an additional stage: that the new knowledge be subject to a specific labour of sorting and rephrasing for this knowledge (figure 9).

Depending upon regions, the reef can also be of a considerable special social and cultural dimension for the resident local communities who, over generations, have peopled it with geo-symbols[9] such as shipwreck, battles, coastal landing of the first craft contributing to an island's peopling.
The reef's notable geographical landmarks used in rituals or known as the dwelling of spirits are also deeply structuring geo-symbols. From an economic point of view those geo-symbols may be assimilated to a cultural consumer good, the result of the implementation of a labour historical event or ritual) over a resource: the part of the reef environment affected by this labour.

[9] J. Bonnemaison (1981, 1986) defines geo-symbols as places and itineraries appropriated by men along generations and in which and through which their culture is rooted in. Those are either physical, as the significant landmarks of the landscape, or historical: the place is then related to an event. Geo-symbols thus punctuate a familiar space, never far away from the place of dwelling.

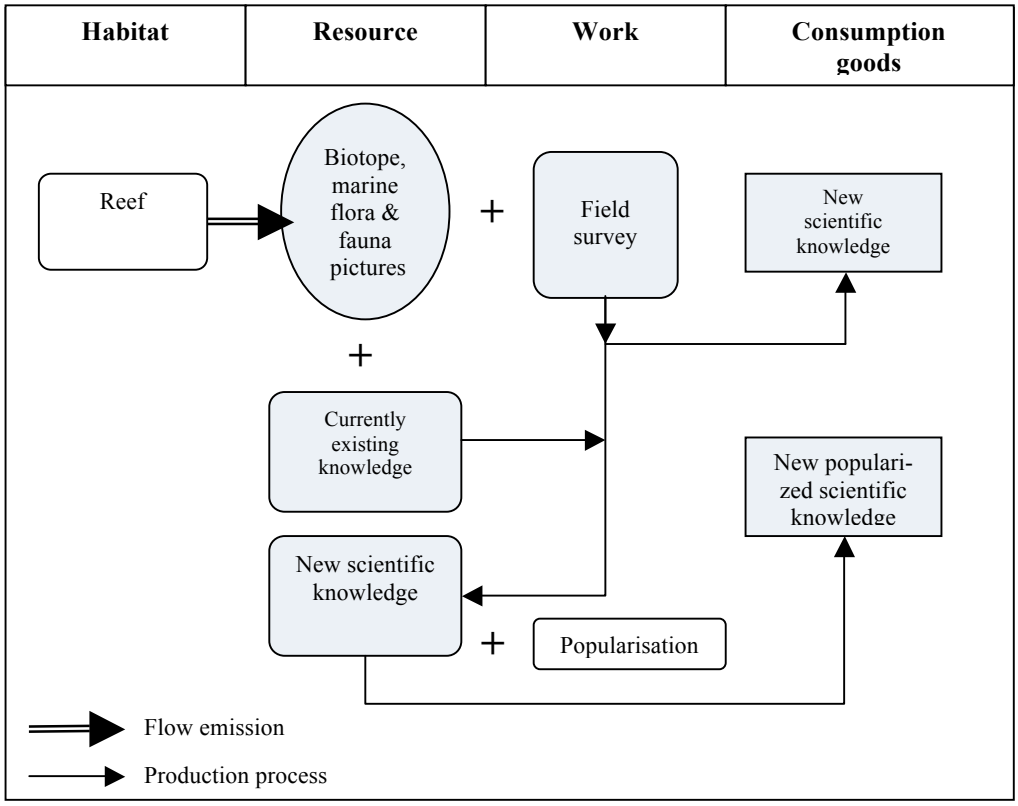


Figure 9 – The reef as a resources transmitter processed by scientists and popularisers into new consumption goods

The reef's geo-symbols sometimes occupy a significant place within the culture of resident local communities of whom they are an essential component of cultural identity, who in turn contributes to the group's social cohesion. Within this pattern, the geo-symbol is no longer a consumer good but a resource used for the production of a good : the group's social cohesion (figure 10). Could the latter be assimilated to a consumer good? Not quite. On one hand it is a collective property, ranked by classical economics postulates as outside of the consumption field, and organised along individual preferences. Moreover, generally speaking, consumption generally pertains to flows, while social cohesion rather pertains to a frame of mind. Thus social cohesion is not marketable. On the other hand it gets constructed through the setting of geo-symbols. This construction is very time consuming; in economic terms we could thus consider it quite costly, for a not always long lasting result. In fact social cohesion is a rather fragile state and its operational costs (would it be economical or political) are high.

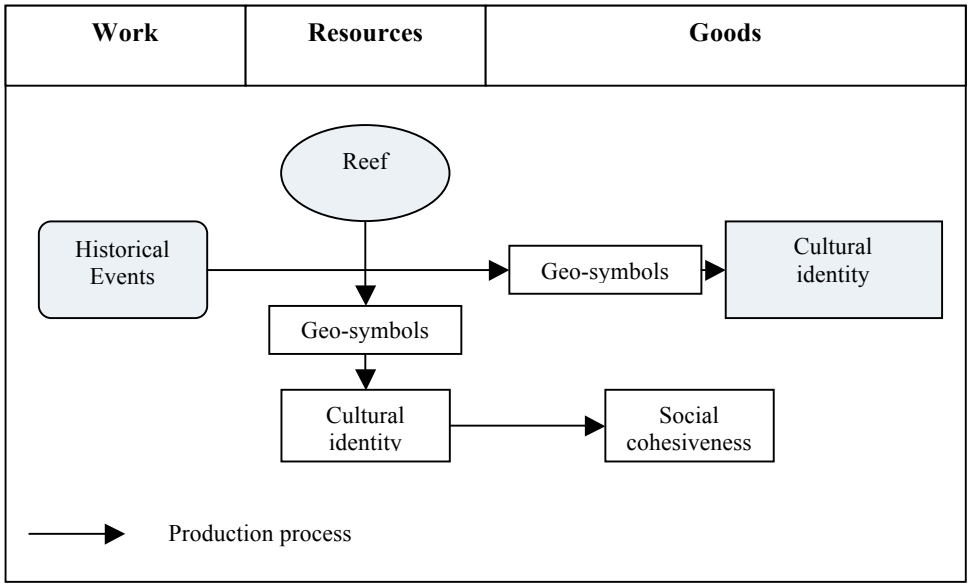


Figure 10 – The reef as a resource producing geo-symbols and social cohesiveness

Apart from the flows (interests) it generates, the reef has its own economic value as a capital through the services it provides. There are six of those, linked to three categories: tourist services, other economical services relating to aquaculture and ecological services[10].

➥ From a tourist point of view, the reef may be assimilated to a recreational space, would it be with the beaches and the lagoon providing a tract of water for bathing and water leisure, with the reef slope, the pinacles often visited by scuba and apnoea divers as well as by yacht fishing (table 1).

➥ In terms of aquaculture, the reef is at the same time **a)** a physical aid for cage fish aquaculture and **b)** a physical and biological aid for algae and seashells aquaculture, mainly oysters, Trochus and green mussels.

In terms of ecological services, the reef's role is threefold **a)** protection against coastal erosion, **b)** biological and physical aid for a large share of marine biodiversity, **c)** biological and physical aid for coastal marine species visiting the reef by intermission (feeding, reproduction, nurseries).

As illustrated in figure 1, a reef total economic value is made up of three sets: the use value, the option value, the existence value and the bequest value. This value will now be reviewed. The stress will be put upon the first one, as it is the one raising the greatest number of methodological questions whose answers will be even more relevant as they will call for crossed disciplinary points of view, relating to biology and economics, but also to geography and anthropology.

[10] Those services are studied in section dedicated to the indirect use values.

3. REEF USE VALUE

3.1. ESTIMATE OF THE USE VALUE

A first estimate of the reef value is given by the total value of the yearly productions, which can be assimilated to the interests of the Reef capital over a year. This method, thus, boils down to estimate the capital according to the interests perceived over a year, which is not very satisfying. How getting from the estimate of the interests to the estimate of the capital? We will consider, in the case of sustainable management of the reef uses, that the capital value can be met by the sum of the interests serviced on a long period, which is its capitalization value. Considering the necessity to associate the notions of Reef capital and Reef heritage, we will set this period to the time needed for human generation renewal, at 30 years. The term of generation remains a key word of the sustainable development definition given by the Brundtland commission « development that enables to satisfy current needs without compromising the opportunity for the next generation to satisfy those same needs ». The value of the Reef capital can then be estimated by adding all the interests serviced by the reef over 30 years, to which we apply an actualization rate to reflect the effect of time. According to the chosen rate, the value can significantly vary. Thus, on a 20 years time frame, the value of lagoon fishing in Fiji almost doubles when the actualization rate changes from 15% to 5% (O'Garra, 2007). But, the time problem in the reef use value estimate should not be limited to the actualization rate. More methodological issues remain.

How to estimate the potential production of a commercial good provided by the reef over 30 years, knowing that the actual production can greatly fluctuate over the years, and that the causes of this variability more often come from economical, social or cultural considerations concerning the reef users than the ecosystem productivity? The ideal would be to choose a reference production matching the annual average over 30 years and multiply it by 30. The problem is that without a long statistic series, it is not possible to know if the production data relative of the year t of the study are representative of the previous years, which inter-annual variability is supposed to provide information on the future state of the production, formulating the simplistic hypothesis that future productions would be the extension of the passed ones. Yet, the simple demographic growth of Oceania coastal populations leads to undermine this hypothesis. If the number of reef users grows, the probability for reef uses intensification and reef productions increase is high, until the stage of over-exploitation of the resources is reached. In the case of methodological issues, most of the authors chooses simplicity and considers with a lot of optimism that the collected data are representative of this future.

Because the direct use value is measured by the added value of the produced or consumed good, another question arises: how to take into account the time variations of the production costs, on one hand, and the market sale price on the other, knowing that both are independent of the reef ecosystem productivity but submitted to several factors likely to evolve greatly in the future. Thus, the production costs should increase with the over-fishing threatening the reef and the increase in fuel cost. As for the reef productions prices, they depend partially, in most Oceania countries, on the price of substitute products available on the international market. For instance, tinned mackerel or tuna is an alternative to reef fish consumption.

All those unsolved problems in the creation of an « effective » use value, based on actual reef productions and real production costs, bring us to propose a) another method allowing to estimate the

value of the capital according to the annual interests serviced by the latter and consequently b) another kind of use value, that we'll call « potential ». Instead of leaning upon effective productions that are costly to estimate and show a large inter-annual variability, we will consider that, on one hand, in the case of optimal functioning of the coral reef ecosystem, the Reef capital can be assimilated to the Reef heritage and remains constant over time and that, on the other hand, the interests serviced every year are maxima. Those interests are assimilated to the reef carrying capacity or to the maximum balanced collect (MBC) extracted from the reef, which is the maximum production that can be realized every year without compromising the renewal of animal and vegetal populations composing the coral reef ecosystem. This MBC is often higher that the effective production. For instance in Moorea, the actual lagoon fishing production (10 to 22kg/ha/yr) is more than ten times higher than the potential production estimated at 230 kg/ha/yr (Mahé, 2005). Over the 30 years reference time frame, the value of the Reef capital will thus be estimated by multiplying by 30 the reef carrying capacity or the maximum sustainable yield (MSY) extracted from the reef. This valuation method leads to a (potential) use value far superior to the (effective) use value estimated according to the usual method. Based on a vision of the Reef capital as a heritage, it partly integrates the option of a future reef use set within the limits defined by the MSY. This option equates to a surplus in production available for the future user compared to the effective production he benefits from today. However, because it is linked to the potential of the Reef capital without being revealed by the users' willingness to pay, this option doesn't belong to the option value but to the use value.

Although attractive, this method has a major inconvenient. It does not take into account damages following natural disturbances, like coral bleaching, or due to human activities, like pollution or terrigenous flows coming from upstream watersheds, that even optimally managed, can affect the reef. The drops in MSY and carrying capacity following any damage lead to a reduced final reef value, except when the latter shows exceptional resiliency.

In addition, whether it is about effective use value or potential use value, the actualization rate issue remains. This rate is unable to reflect the possible value distortions generated by inflation over a 30 years period.

Another issue, this one concerning all the valuation methods, is the choice of the geographic area used for the economic valuation of a reef. In general, it is the country and the venal value applied to the reefs uses is defined according to the national market. For instance, two reefs, one located in Florida and the other in Madagascar, with the exact same surface area, the same morphology, the same floristic and faunistic communities and providing similar goods and services to the local populations, would have two different value based on the fact that the two countries have different GDP. This difference in value, caused by factors external to the reef, is conformed to the neoclassic economy principles, as long as the externality represented in the environment is internalized. On the contrary, in a multidisciplinary approach putting the accent on the functioning of the reef natural capital, such difference is a problem. Yet, can we formulate the hypothesis that all the reefs worldwide with the same surface area, same morphology, same floristic and faunistic communities and providing the same goods and services to the local populations, would have the same economic value? And in case of a yes, how should we calculate this value, according to the highest GDP amongst the countries sheltering coral reefs?

The answer to the first question appears in the rare articles presenting the ecological services provided by the reef. Moberg and Folke (1999), for example, mention three types of services that cannot be translated into a monetary value, in which case it doesn't make sense to give them a difference in value based on GDP:

- services associated to coral reef biocenosis, whether it is intra-ecosystems or inter-ecosystems services, like juvenile nurseries or breeding areas;
- services of a biochemical nature, like carbon fixing into calcium carbonate;
- services relative to the knowledge of past climates, for instance via a sort of dendochronology applied to the massive coral specimen like the porites.

This perspective brings to consider that some services provided by the reef cannot be integrated to the market economy. According to a similar pattern, services relative to the society and culture can be assimilated to wellbeing « providers ». When an equivalent wellbeing is provided to a population in Vanuatu and a population in Hawaii, is it logical to give different values to those goods and services based only on the fact that the two countries have different GDP? Or, should we consider, that equal services deserve a unique value wherever the reefs are geographically localized? This kind of questions are completely forgotten by the neo-classic environment economists, but definitely deserve to be asked, even though they lead to methodological difficulties in estimating the value of those services.

3.2 DIRECT USE VALUE OF COMMERCIAL CONSUMPTION GOODS

3.2.1. FISHERIES

In terms of the reef monetary value, a first distinction should be made between the activities linked to commercial trade and the activities linked to recreation or subsistence. Another differentiation, within the commercial activities, between activities from the informal sector and the others, which are usually supervised by public authorities, complements the picture. Generally, the estimate of a MSY for such multi-specific populations, like coral reef environment populations, is not an easy task. The models used in temperate areas are not operational, so the simplest way remains to use the Schaeffer model summing up all the catches in a unique group no matter what species. A similar operation is done for the fishing effort, expressed into a simple standard unit: the fishing trip. Net timing or hook fishing timing is a far better appreciator but is usable only if the hourly output of all the used devices is known, data that is sometime a challenge to get.

a) Commercial fishing or harvesting within the structured industry

We will make a distinction between the fishing output destined to the feeding of aquarium fish and the collected shells destined to be sold to the tourists.

Fishing for alimentary purpose

The total value of this fishing activity will be determined by allocating to the maximum reef production over 30 years, equals to thirty folds the annual maximum sustained yield (MSY), the average value of a kg of fish bought to fishermen over the last year for the commercial species the closest from the self-consumed ones.

Fishing and harvesting for non-alimentary purpose

Generally, shells collected to be sold to tourists being different than the ones harvested for humans consumption, the MSY can be used to assess the maximum quantity of shell available for a non-alimentary purpose.

This MSY will be given a value equal to the average purchase price of shells to the fishermen in order to assess the maximum interests bankable on the reef. The value of the Reef capital will be equal to the total of those interests over 30 years.

Concerning the aquarium fish, it seems more relevant to talk in terms of effective production and not in terms of MSY, because it takes into account the high mortality rate in this field. If all the fish survived, it is very likely that retail sale prices will decrease, a drop impossible to assess though. Thus, it seems preferable to assess the reef value in the aquarium trade by allocating to the whole annual production the local fishermen average purchase value, multiplied by 30. It is to be noted, that deep changes are currently happening on this sector of activity. Aquaculture experiments, using larvae very common nearby reefs, are currently underway. Most of those larvae are « meant » to feed the little predators occupying the reef environment or occasionally visiting it to feed. This larvae flow represents only a small energy intake for those predators and has no damageable consequences for the ecosystem. On the contrary, breeding those larvae and raising them to be sold once adult to the aquarium aficionados prevents harvesting in the natural environment and thus, constitute an important step towards the good functioning of reef biocenosis, lately particularly threatened by the aquarium craze.

b) Commercial fishing and harvesting within the informal sector

The method enabling to assess the value of this type of fishing is the same as the previous one, but two kind of issues must be solve beforehand:

the valuation of the fishing effort and of the catches requires heavy field surveys considering the geographic scattering of the sites of production landing and selling off.

the same target species can be caught in the formal or informal sectors. The effort and production estimations of the informal sector relative to those specific species will, thus, have to be added to the estimates of the structured sector in order to calculate the MSY. Nevertheless, a Maximum sustainable yield specific to the target species exclusively caught in the case of informal fishing will be established.

c) Subsistence or recreational fishing

The estimates of the efforts parameters and of the catches require even more complex surveys than the previous case. Surveys on landing sites and with questionnaires will have to be used in complement in order to estimate the effort, moreover the production, of the previous week. A questionnaire on fishing integrated to the population census, enabling to identify fishing devices and count frequency of fishing trips, is a precious tool to prepare the survey protocol and the sampling plan.

Part of the catches, caught within the subsistence and recreational sectors, are also targets for the commercial formal or informal sectors. The MSY calculation should, thus, exclusively concerns the specific target species of those two non-commercial sectors. In fact, the species are mixed up during a fishing trip and it is extremely difficult to make this distinction and to allocate a specific effort to the species that would only be captured within the recreational or subsistence fishing contexts.

Another problem arises when trying to set a monetary value to those catches specific to the subsistence and recreational sectors, because they elude the commercial sector; the heterogeneity of those catches, composed of fish, shellfish and crustaceans, add an extra issue. Two solutions are possible:

- in the first one, we do allocate to each type of catch the monetary value given on the informal market. The idea behind it is that subsistence and recreational fishing replace fish purchases that could have happened if the buyers had a sufficient income or if the sale had been sufficiently spread out over a territory to touch a whole population.
- in the case where the fresh fish trade is sufficiently structured to supply the whole country, we will consider that in the areas outside the fresh fish trade zone, subsistence fishing replaces the purchases of tinned animal proteins, that can be found in any little coastal food store.

Because it is impossible to give the same monetary value to a tinned kg of tuna, a kg of fresh fish, a kg of shellfish or a kg of crabs, it is necessary to create a standard unit for fishing output, a unit that remains constant whatever product is considered. This unit is the gram of protein. Diagrams realized by the FAO or the South Pacific Commission give the protein content of the main fishing products. The quantity of proteins corresponding to the subsistence and recreational fishing MSY will be given the same monetary value than the matching protein quantity in tinned tuna can, the latter being widely available on the planet.

d) Global estimation of reef fisheries

In short, the monetary value of the reef from a fisheries point of view can be estimated with the following formula:

30 x ((MSYsfrf x valsfrf) + (MSYicf x valicf) + (MSYscf x valscf))

Or:

MSYsfrf = Maximum Sustainable Yield of the species exclusively caught within subsistence and recreational fisheries.

MSYicf = Maximum Sustainable Yield of the species exclusively caught within informal commercial fisheries.

MSYscf = Maximum Sustainable Yield of the species caught within the structured commercial fisheries.

valsfrf = monetary value of species exclusively caught within subsistence and recreational fisheries

valicf = monetary value of species exclusively caught within the informal commercial fisheries.

valscf = monetary value of species caught within the structured commercial fisheries.

3.2.2 Near-shore dredging and production of building material

In the islands where no volcanic rocks to be crushed is available, the coral reef is often the main, sometime the sole, source of sand supply. Lal (2004) reports that in Tonga, the need for public works and construction sector ranges every year between 10,000 to 20,000 tons. In this field, the reef economic value is easy to assess. It represents the total quantity (in tons) extracted over the last ten

years multiplied by 3, with the average purchase price paid to the producer on the last year. Anyhow near-shore dredging is not an optimum use of the Reef capital and is actually a problem for other uses: like tourism, for example, for whom Sand is an important element, or like fishing, because important sand removal causes large sediments flows potentially damaging for the habitat of the species targeted by fishermen. Aggregate dredging can greatly modify the shape of the coast by facilitating waves erosion. Thus, in the global climate change and its resulting ocean rising level context, the search for substitute materials replacing coral reef sand constitutes a priority to reduce coastal erosion. Even worse than near-shore dredging, is the use of coral reef blocks to produce lime, because it often uses living material. And even though, it is not very interesting economically, it remains a very common activity in Papua New-Guinea and the Solomon Islands where the habit to chew Betel nut always pairs up with lime consumption[11].

3.2.3. MEDICAL USE OF THE REEF

The medical use of the reef is a sector of activity still under-developed but with great potential. Already, coral structure is being used for bone graft, while sponges and sea fans enter into the composition of medicines. Generally, natural marine substances are promised to a bright future in the medicine production of tomorrow. In this context, the reef economic value cannot properly being estimated, because we're essentially talking about production yet to come. Hence, the reef is not only a capital but a heritage too, defined by resources « able to establish a bridge between the past, the present and the future with the services provided or possibly provided ». Besides, those resources « might keep in the future the ability to adapt to uses unforeseeable in the present » (Comolet, 1994, p.30 et 31). The Indo-pacific zone sheltering the richest reef biodiversity of the planet, offers potentially a maximum of opportunities in terms of medical use of the reef.

3.2.4. DIRECT USE VALUE OF NON–COMMERCIAL GOODS

We will make a distinction here between the educative value and the social and cultural values of the reef.

How assessing the contribution of the reef theme within a school curriculum or general public information? A solution is to use the contingency valuation method, using a questionnaire to the effective users or potential users (we will choose here the students patents) to assess:

the amount they are willing to pay for the reef to be studied,

the compensations they hope to receive if this theme disappears from the curriculum.

This method might lead to underrate the educative value of the reef though. Hence, it would be possible to replace it by an accounting method assimilating the reef value to the overall time spent by the teachers on this theme, multiplied by their average hourly wages. This result is then being added to the elaboration and manufacturing cost of the pages dedicated to the reef in the educational material available to teachers in a specific geographic area. To be completely thorough, we might add

[11] In the South-West Pacific countries, mainly the Solomon Islands and Papua New-Guinea, coral powder (lime) is used as an excipient for the consumption of Betel nuts. Its basic properties are meant to cancel the acidity of the nut.

to this total, the elaboration and manufacturing cost of the pages dedicated to the reef of the considered area in the educational material available to students outside this geographical zone.

Concerning the reef social and cultural values, two economic valuation methods can be implemented: the contingency method or the replacement cost method relative to the cultural and recreational services provided by the reef. Hence, the « swimming » service provided by a depression behind the reef can be provided by a swimming pool, which size will be calculated according to the number of beneficiaries of this service, estimated by direct visual observation during school holidays. The reef value, relative to this service, will thus be matching the construction cost of the pool.

3.3. INDIRECT USE VALUE

3.3.1. ECONOMIC SERVICES

a) Tourist services

In the Pacific Islands, tourism is essentially seaside tourism. Why do Europeans bother going to Moorea, Bora Bora, or Fiji Islands when they could spend their holidays on the Algarve or Andalusia coasts at much cheaper cost? According to us, the key to the answer is to be looked for beyond economic realities, into the subconscious level. Compare to Southern Europe, Pacific destinations carry an image of virginity due to the island and coral reef isolation. This virginity haunts the collective unconscious of the Northern hemisphere populations, from Bougainville with his new Cythere to J.Y. Cousteau, who has been associating in his movies the inter-tropical islands and reef to the Eden, a virgin and pure world in which everybody could reconnect with an original state. In this sense, the reef is a major element of the islands tourist success and a big part of the tourists' expenses can be related to the reef, not even mentioning the marine reservations fees that are a direct measure of the tourists' interest for the reef.

Hence, the monetary value of the tourist services provided by the reef, which will be noted MVTSR, covers three components. Each one is expressed differently but the sum of the three is necessary to estimate total monetary value of the tourist services.

When the visited reef has a marine protected area (MPA) status, the simplest method to assess the tourist impact of this reef is to multiply the annual number of visitors by the entrance fee, such as :

MVTSR1 = NbVAC x PAF

or:

MVTSR1: monetary value of the tourist services provided by the reef within the marine protected areas context.

NbVAC : total number of visitors of the marine protected areas of the country.

PAF : marine protected areas entrance fee.

➥ A second valuation method is based on the expenses relative to international transportation. According to this travel cost method, the number of visitors in a country depends on the distance to be travelled or the cost of the trip; tourists seek preferably the cheapest destinations in

terms of travel cost (for an equivalent service). Thus, for any tourist destination, there is a logical number of tourists determined by such factors as distance and travel cost; the income level of the populations living in the tourist spot, and the total inhabitants number of the country the tourists originate from, play also a role. Thus, any extra tourist can be considered reflecting the attraction of the country itself, which value is estimated by multiplying the number of extra visitors by their spending on international travel.

How much of this attraction should be credited to the reef? To answer this question, a questionnaire is distributed to the tourists to list the criteria influencing their choice of destination. The reef attraction is estimated with a percentage k of the total attraction. The impact of this attraction on the tourist spending in terms on international travel will be expressed with the following formula:

MVTSR2 = k x Nbxvi x Expintrav

with k = Atref/Atot
or :
MVTSR2: monetary value of the tourist services provided by the reef according to the travel cost method.
Nbxvi: number of extra visitors.
ombre de visiteurs supplémentaires
Expintra: expenses in terms of international travel.
Atref : attraction sparked by the reef.
Atot : total attraction of/for the tourist destination.

Allocating the percentage k to the extra visitors group leads to make a distinction between two virtual sub-groups: the extra tourists which visit is solely motivated by the presence of the reef and those who can't care less.

➥ A third valuation method of the tourist services provided by the reef is given by the local expenses in housing, food and transportation of the tourist population.
➥ In accord with the previous method, only extra visitors will be taken into account and the total of the local expenses will be allocated the percentage k, such as :

MVTSR3 = k x Nbxvi x Loexp

or
MVTSR3: monetary value of tourist services provided by the reef according to the local expenses method.
Nbxvi: number of extra visitors.
Loexp: local expenses (housing, food, transportation)

The parameters **MVTSR1**, **MVTSR2** and **MVTSR3** represent the interests generated by the Reef capital in terms of tourism. Like in the previous paragraphs, we will assess the value of this capital to

30 fold the value of the annual interests. In total, before any application of the actualization rate, the monetary value of the tourist services provided by the reef can be formulated as follow:

MVTSR = *30 (MVTSR1 + MVTSR2 + MVTSR3)*

= *30 ((NbVAC x PAF) + (k x Nbxvi x Expintra x Loexp))*

or

NbVAC: total number of visitors of the marine protected areas of the country.

PAF : marine protected areas entrance fee.

Nbxvi: number of extra visitors.

Expintra: expenses in terms of international travel.

Loexp: local expenses (housing, food, transportation)

b) Economic services for aqua-culture

The reef ecosystem and the adjoining column of water are physical supports for fish (cages), shellfish and algae aquaculture. The value of the service reflects the total value of the aqua-cultural production provided by the reef resources sites over 30 years. Arbitrary, we will make do with multiplying by 30 the last year aqua-cultural production value. The example of pearl-farming in French Polynesia shows that aquaculture can significantly increase the GDP of many Oceania islands and archipelagos. When a local market exists or when the international markets are easily accessible, breeding high value fish like some groupers offers interesting prospects. Tropical fish have the advantage to keep a good organoleptic quality for 3 to 4 weeks if they are properly killed (electric shock or encephalon destruction with a pin –the Japanese ikishime technique-) and preserved at low temperature (2 to 4° C). Besides food or mother-of-pearl production, the aquarium trade represents a promising market for the aquaculture in coral reef environment. For now, the emphasis is put on shellfish production ponds, such as giant clams, or coral culture « in situ » on manufactured supports. In a near future, aqua-farms working on larvae flows captured on reef and raised to reach commercial sizes should multiply.

3.3.2. ENVIRONMENT SERVICES

a) Protection against coastal erosion

That's one of the main role played by the reef. This protection happens in two ways: with the reef mass itself which is dispersing the energy of the waves and with the production of rubble then coral sand that are fattening the beach and largely contributes to limit the erosion of the coastline. Although recognized by all actors, this function provokes sometime heated exchanges between the environmentalists and the tourism developers for whom several centimeters of coral rubble on the beach is a nuisance; tourists seek the image of the perfect white sand beaches. In a case like that, when the beach is being used for the benefit of the tourists, this rubble is being picked off the ground. Inevitably ensues the slimming down of the beach and a regression of the coastline, possibly threatening the tourist equipment and buildings built by the water.

Estimating the monetary value of this protection function is not easy. The simplest method is to consider the replacement cost of the natural environment by human artifacts to provide the same functions. A good example is already given with the implementation of expensive anti-erosion

measures due to the slimming down of beaches. In the case of the disappearing of a coral reef, those measures would only be complementary and relatively secondary compared to the set up of tetrapods a few dozens or hundreds meters from the coastline. Those tetrapods are the sole artificial structure able to reproduce the reef protection function. Late 80's a kilometer of tetrapods was estimated a million US dollars (Mc Allister, 1988 quoted by Spurgeon, 1992). The cost of this type of equipment has doubled since. In 2004, in Western Samoa, the seashore protection cost was estimated between 1.6 to 3.3 millions US dollars per km, an average value of 2.5 millions, for a life span ranging from 25 to 50 years. Those differences are imputable to the different degrees of exposure to the dominant swell depending on the sites. The sea level rise should translate into 30% extra cost (Spurgeon *et al*., 2004) but this cannot be assimilated to an increase of the reef value. Numerous scientists consider that coral growth won't be sufficient to compensate the extra erosive hazard caused by the ocean level rise. The value associated to the reef protection function will then have reached a maximum threshold corresponding, more or less, to the reef maximum charge capacity, in terms of swells and waves mechanic energy, and to the erosive hazard resorption linked to it.

b) Physical and biological supports to biodiversity

A coral reef is the biological support of numerous species that either come to breed (reproduction function), develop up to the juvenile stage (nursery function), or hunt (feeding function). A reef also provides to the coastal waters fish used as food bank by pelagic species such as trevallies, barracudas, mahi-mahi or tunas.

Two methods enable the economic valuation of those services:

- the replacement cost of the reef by artificial structures (building of aqua-culture ponds on land) providing an equivalent production.
- changes in productivity of the environment or the activity (fisheries, aquaculture) caused by reef damages. This kind of method has been initiated by marc Allister in the 80's in the Philippines,

When the reef production is known, which is rarely the case because of the difficulty of such an exercise, the first method is preferable. But generally, those two methods are difficult to apply because they are stumble on our insufficient knowledge on ecosystems and the difficulty to extrapolate results obtained on a large scale (on a little study field) to a much smaller scale (a space a thousand to a hundred fold larger). Of the three functions, feeding, nursery and reproduction, the first one is easier to ensure with artificial structures. On the contrary, the mastering of coral fish reproduction still remains utopian and a few specialists involved into aquarium fish aquaculture are happy so far to extract larvae into the natural environment and put them into culture.

4. EXISTENCE, BEQUEST AND OPTION VALUE OF THE REEF

4.1 EXISTENCE VALUE

If the existence value is the value that an individual gives to the reef, without using it in the facts, it is necessary to remind the difficulty to find such a population to be surveyed. In facts, in most of the Oceanian islands the coastal population uses the reef for food or recreational purposes. To consider only the non-users, means focusing the study of the existence value on the sole tourists.

Amongst the latter, the ideal would be to distinguish the ones who never had anything to do with the reef from the ones who had and thus must be overlooked for the study. It is best to survey the target population just arriving in the country: either at the airport or the harbor –in case they're cruisers-, and making a distinction between the persons coming for the fist time in the country and the persons who already have an experience as users of the local coral reef. The main challenge of such a study is the little time the interviewed persons can offer in those circumstances.

When, for practical reasons, tourists are interviewed at their accommodation or activity site, we will consider that their reef experience is too short to be considered as users. As a consequence, there might be a bias compared to the previous method, but because of the heterogeneity of the interviewed persons it won't necessary affect the results. Every one of them answers according to its perception and representations of the local reality filtered by its past experiences and personal motivations. Within a population of tourists from diverse nationalities, socio-professional categories and age groups, important gaps in the answers can be expected compared to the average; hence, a variable that won't always be very relevant.

In the islands where tourism is under-developed, the estimate of the reef existence value can not be limited to the sole tourist population. The coastal population must be integrated, even though it is mainly composed of reef users. That's what has been done in the American Samoa (Spurgeon et al.,2004). In the end, is it really the existence value that is measured? Let's be provocative. Is it so important to dissociate the reef existence and its use? Does being a reef user prevent from perceiving the environment existence concept? No. Hence, we choose a pragmatic view, linked to the valuation method. It is the willingness-to-pay that gives a measure of the existence value. Even if this willingness-to-pay is biased by the fact that the coastal population benefits from the reef, it would not be logical to assign it to the estimate of the use value. The latter is exclusively measured with objective values, whether they come from a transaction on a goods and services market, extra travel cost to reach a holiday resort by the reef, or extra real state cost to live near a reef. At any rate, a willingness-to-pay never reflects the value of a present use.

When the island economy is mostly a subsistence economy and the money supply circulating is limited, paying to preserve the reef is a process too foreign to the local culture to consider the contingency valuation relevant. The willingness-to-pay must be replaced by the willingness-to-work, which means a certain number of hours per year, month or week. Each hour dedicated to reef conservation is then given an hourly rate, as close as possible to the effective skills of the considered

person. Hence, in Fiji, the amount defined in the Navakaku area, is the sum earned by basic workers as shown by the 1996 census and corrected according to the inflation between the reference period (1994) and the time of the study, 2005 (O'Garra, 2006).

Rather than a reference hourly wage calculated at a national level and meaningless for the surveyed populations, it can seem smarter, although more complicated, to offer different type of work (for instance : reef fishing, clearing for subsistence cultures or garden maintenance) and to link the duration of the actual work to the value of its output. Hence, knowing that producing a kg of yams requires x days of s work, the wilingness-to-work can be estimated at Z dollars (or euros) ; a sum corresponding to the negotiated value (on the local market) of the Y kg of yams produce during the working days dedicated to reef conservation.

4.2 BEQUEST VALUE

This value being the projection into the future of the existence value, the same methods will be used to define it; meaning that all the difficulties previously met in terms of representativeness of the sampled population will remain. Yet, what would be the periodicity of the willingness-to-pay or to-work to be taken into account in order to transmit the Reef capital with all its functionalities to the next generation, in 30 years time. Most authors just estimate the bequest value according to the willingness-to-pay or to-work on the year 1. But are we sure that the money or the offered work will suffice to preserve the reef? In case of a no, it would make more sense to estimate the willingness-to-pay or to-work every year, knowing that this amount would have to be multiplied by 30 to know the bequest value.

4.3 OPTION VALUE

If the option value is what an individual is willing to pay to keep an option on a future use of the environment, and the bequest value is what an individual is willing to pay to transmit to his children a natural capital generating goods and services equivalent to what he has known, then those two notions are close. Hence, bequest value and option value can be joined under the generic name "Heritage value". Besides the potential willingness-to-pay or to-work, two other methods help estimate the heritage value of a natural asset such as the reef.

In the first place, comes the public funding allocated to studies and researches on reef knowledge, its management and the means to preserve it in the years to come. On this sole ground, reef environment value has been valuated to 308,917 euros/sq km in La Reunion Island (Mirault, 2007). The total public spending allocated to those studies have exceeded 3.7 millions euros over the last 10 years, a considerable amount, showing the authorities' will to protect the coral reef ecosystem, even though this case is characterized by its small size (the reef covers only 12 sq m) and a strong anthropogenic pressure.

In second place, comes the willingness to sanction the wrongdoers caught effectively or potentially damaging the reef environment. This method has been used in La Reunion Island within the context of

a marine protected area (MPA). The interviewed public (students parents geographically spread out over the different regions of the island) had to play the role of a judge sanctioning illegal practices in a MPA sanctuary zones, in a case of first offence and then a second one a month later. Refusing to sanction or a symbolic sanction has been interpreted as a preference for the present use of the reef environment versus its preservation for future generations. On the contrary, sanctioning the offenders meant the recognition of the reef as a heritage which value justifies the suspension of its uses in order to bequeath it in a good state, even if it is at the expense of the current users (Thomassin *et al*., 2007).

CONCLUSION: ESTIMATE OF THE SOCIO-ECONOMIC VALUE OF A NATURAL ENVIRONMENT, A COMMUNICATION TOOL

Nowadays, 10% of the reefs are irreparably damaged worldwide, 30% are threatened on the short or medium run (Wilkinson, 1998). Because of an inadequacy between the scientific argumentation, focused on the biodiversity and ecological wealth of natural environments, and the stakeholders' rationality, scientists have failed to stop the deterioration process. Giving a monetary value to the reef enables to integrate ecology into the economic field and to speak to the stakeholders in a language they do understand. That's why, despite the methodological challenges and the scarce knowledge on the functioning of this environment, contingency valuations must be overlooked to aim towards an environment total value, summing up use, option, existence and bequest value of the reef. The most difficult part remains the estimate of the use value, which is supposed to sum up all the uses this environment provides. Only a multidisciplinary effort, associating marine biologists and socio-economists, will succeed. Considering reefs both as heritage and natural capital is a key step.

The definition most commonly used in French literature for natural heritage is J.L. Weber's definition (1986, p. 39) encompassing « ecological systems where species reproduce, including the physical support to those systems ». Reefs concentrating more than a quarter of marine biodiversity (Moberg and Rönnback, 2003) and playing an essential role in the trapping of the carbon worldwide are indubitably natural heritage. This naturalist analysis of natural heritage is not enough though. A cultural analysis is also needed. The heritage will be better protected if the users integrate it to their territory. An economic analysis is as much interesting. It is the tool enabling to understand that natural environment conservation and development are not antagonistic terms. The « natural » heritage is assimilated to a whole of goods who, belonging to the eco-sphere, present a collective nature. Hence, the natural heritage eludes private property and provides its services simultaneously and indiscriminately to all (Comolet, 1994). This concept of service is the bridge between the heritage concept and the natural capital concept. Hence, the reef is a recreational space for tourism, the support for maritime companies geo-symbols, a source of inspiration for tales and myths, a protection against coastal erosion, a physical and biological support for a) cage fish, mother-of-pearl shells and algae aqua-culture, b) a large part of tropical marine biodiversity, c) a feed and breeding ground for numerous coastal species occasionally visiting the reef environment. Furthermore, this Reef capital permanently generates interests in the form of living matter (algae, larvae, fish), mineral matter (sand, coral blocks) and information (images). Its monetary value will then correspond to the value of all the

services provided, to whom is added the sum of the interests serviced over 30 years, time necessary for the renewal f a human generation.

If the reef, as a heritage, provides the same services as the Reef capital, can we mix up the natural capital and natural heritage concepts? Logically, the answer is no. The fundamental difference between those two concepts comes from the management style and the inheritable nature of the heritage. As written by A. Comolet (1994, p.30), *« […] the heritage is what our ancestors leave to us as inheritance ». It is also what we will transmit of this inheritance to our offspring. Heritage creates, matter-of-factly, solidarity between successive generations and hence, should be managed with the perspective of its reproduction and transmission to future generations ».* This management stresses the accent on the integral transmission of a stock of opportunities and on the ability to create new opportunities when capital management has for sole objective to increase itself or generate maximum interests.

Nevertheless, even if the natural capital and natural heritage notions are distinct, both can apply to the same geographical object; it is the case for both the reefs natural heritage and natural capital. De facto, estimating the socio-economical value of this natural heritage is the same as estimating the socio-economic value of the Reef capital. This double nature enables to assign a clear objective to the natural environment management, whatever the pace considered: the consistency of the capital and the constant production of maximum interests, without the environment renewal capacities, or the resources it shelters being affected. To offer quality economic services, natural heritage and capital such as the reefs, need to be preserved of major deterioration. But all human intervention is far from being banished. Hence, fish populations will present a more important intra-specific abundance in the context of sustainable fisheries compared to a context of non-existing fisheries, ecosystems maturity being synonymous of a lesser productivity (Frontier *et al*., 2004). Presented under this economic angle, conservation of the reef heritage-capital is absolutely not antagonistic to development. On the contrary, it is perfectly integrated into the logic of a long-lasting development aiming an optimum and sustainable use of the nature productive potential.

BIBLIOGRAPHICAL REFERENCES

- ALQUIER, C. (1987). *Economie politique*. Paris, Economica, 601 p.
- BARBIER, E.B. (ed.) (1993). *Economics an ecology : new frontiers and sustainable development. London*, Chapman & Hall, 205 p.
- BARBIER, E.B., BURGESS, J.C. FLOKE, C. (ed.) (1994). *Paradise lost ? Theecological economics of biodiversity*. London, Earthscan, 267 p..
- BAUMOL,, W.J; BLINDER, A.S.; SCARTH, W.M. (1986). L'économique, principes et politiques –micro-économie. Quebec, ed. Etudes vivantes, 579 p.
- BELWOOD, D.R, HUGHES, T.P, FOLKE, C., NYSTRÖM, M. (2004). Confronting the coral reef crisis. *Nature*, n°429, pp. 827-833.

- BERTRAND, G. (1972). Ecologie d'un espace géographique : les géosystèmes du Valle de Prioro. L'Espace géographique, n°2, pp. 113-128.
- BLANQUET, P. (2008). Document de synthèse sur les récifs coralliens. Paris, Ministère de l'Ecologie, du Developpement et de l'Aménagement Durables, 27 p.
- BONNEMAISON, J. (1981). " Voyage autour du territoire ", *L'Espace Géographique,* n°4, pp. 249-262.
- BONNEMAISON, J. (1986). « L'arbre et la pirogue ». *Les fondements d'une identité : territoire, histoire et société dans l'archipel de Vanuatu (Mélanésie)*. Paris : Orstom, Coll. Travaux et Documents n° 201, vol. 1, 540 p.
- BRANDER, L.M., VAN BEUKERING, P.V., CESAR, H. (2007). The recreational value of coral reef : a meta analysis.Ecological Economics, n° 63, pp. 209-218.
- CESAR, H. (1996). Economic analysis of Indonesian coral reefs. Washington DC., World bank, Division CDIII, East Asia and Pacific Region, Environment Department, 86 p.
- CESAR, H. J.S. (1999). "Socio-economic aspects of the 1998 coral bleaching event in the Indian OCEAN". IN LINDEN, O., SPORRONG, N. (1999). *Coral Reef Degradation in the Indian Ocean. Status reports and project presentations 1999*. Stockholm : SIDA/FRN/MISTRA/World Bank/WWF, pp. 82-85.
- CESAR, H.S.J. (Ed). (2000). *Collected Essays on the Economics of Coral Reefs*. Kalmar : CORDIO/ Kalmar University, 250 p.
- CESAR, H.J.S., PET-SOEDE, L., WESTMACOTT, S., MANGI, S., AISH, A. (2002). "*Economic Analysis of Coral Bleaching in the Indian Ocean* – Phase II". ", Report prepared for the World Bank in support of the Coral Reef Degradation in the Indian Ocean (CORDIO) Programme. Washington DC : World Bank, 147 p.
- CESAR, H. ; BURKE, L. ; POET-SOEDE, L., (2003). *The economics of world wide coral reef degradation*. Cesar Environmental Consulting, ICRAN/WWF, 23 p.
- CILLAUREN, E. (1987). La pêche à la traîne autour des dispositifs de concentration de poissons mouillés à Vanuatu : un exemple dans le Pacifique sud-ouest. Brest, Université de Bretagne Occidentale, Thèse de 3^{e} cycle de biologie marine, 205 p.
- CHARLES, M. (2005). Functions and socio-economic importance of coral reefs and lagoons and implications for sustainable management, vase study of Moorea, French Polynesia. Wageningen, Wageningen university, Master thesis, 147 p.
- COMOLET, A. (1994) *L'évaluation et la comptabilisation du patrimoine naturel : définitions, méthodes et pratiques*. Paris, Eds. L'Harmattan, 258p.
- CONSTANZA, R, D'ARGE, R., DE GROOT, R., FARBER, S., GRASSO, M., HANONNON, B., LIMBURG, K., NAEEM, S., O'NEILL, R., V., PARUELO, J., RASKIN, R.G., & SUTTON, P., (1997) « The value of the world's ecosystem services and natural capital », *Nature*, n°387, pp. 253-260.
- CORLAY, J.P. (1998). « L'analyse intégrée des zones côtières : place et démarche du chercheur ». *In* MIOSSEC, A. et PERON, F. (dir.). *Analyse et gestion intégrée des zones côtières*. Séminaire de l'UMR 6554, Nantes 24 avril 1998. Nantes : IGARUN/CNRS, pp. 12-17.
- CROPPER, M. OATES, W. (1992). Environnemental Economics : a survey. *Journal of Economic literature*, n°30, pp. 675-740.
- DALY, H-E. (1968). On economics as a life science. *The Journal of political economy*, vol. 76, pp. 392-406.
- DIXON, J.A; SCURA, L.F.; CARPENTER, R.A ; SHERMAN P.B. (1997). *Economic analysis of environmental impacts*. London, Earthcan Publications Ltd.

- EMERTON, L. (1999). *Economic tools for the management of marine protected areas in Easter Africa*. Nairobi, IUCN Eastern Africa Porgramme, 22 p.
- EHRLICH, P; MOONEY, H.A.. (1983). Extinction, substitution and ecosystem services. *Bioscience* n°33, pp. 248-254.
- FAUCHEUX, S. et NOËL, J.F. (1995). *Economie des ressources naturelles et de l'environnement* . Paris : Armand Collin, Coll. U Economie, 370 p.
- FAUCHEUX, S. et O'CONNOR, M. (1999). Un concept contreversé : le capital naturel. Saint-Quentin-en-Yvelines : Université de Versailles/Saint-Quentin-en-Yvelines, Cahiers du C3ED, n° 99-01, 49 p.
- FRONTIER, S., PICHOT-VIALE, D., LEPRETRE, A., DAVOULT, D., LUCZAK, C. (2004). Ecosystèmes : structure, fonctionnement, évolution. Paris : Dunod, 549 p.
- GARRABE, M. (1994) *Ingénierie de l'évaluation économique*. Paris, Eds. Ellipses, 255p.
- GRICULAS,T.A. ; CONGAR, R. (eds). (1995). Environmental economics for integrated coastal area management. : valuation methods and policy instruments. Nairobi, UNEP, *Regional Seas Reports and Studies*, n°164, Xp.
- GUEDEZ, A. (2003) Valeurs. *in* LEVY, J. et LUSSAULT, M. *Dictionnaire de la géographie et de l'espace des sociétés*. Paris, eds. Belin, pp.975-976.
- GUNDERSON L.H. (2000). Ecological resilience –in theory and application. Annal review of ecology and systematics n°31, pp. 425-439.
- GUSTAVSON, K. (1998). Values associated with the local use of the Montego Bay Marine Park. Washington, D.C., World Bank, Report Prepared for the Environmentally and Socially Sustainable Development Sector Department, Latin America and the Caribbean Region (LCSES) of the World Bank
- HAROU, P.A et STENGER, A. (2005). Les grands courants actuels de la pensée en économie de l'environnement. *Liaison Energie-Francophonie*, n°66-67, pp. 9-17.
- HUMBER, G. et LEFEUVRE, J.C. (1992). A chacun son patrimoine ou patrimoine commun. *In* JOLLIVET, M. (ed.) *Sciences de la nature, sciences de la société : les passeurs de frontière*. Paris, CNRS, pp. 287-294.
- HUNDLOE, T. (1990). Measuring the value of the Great Barrier Reef. Australian Parks and Recreation 26(3), pp.11-15.
- IUCN/WCPA, (1998*). Economical values of protected areas:guidelines for protected area managers. WPCA Task foirce on econoic benefits of protected areas within the IUCN Econcomic service unit*. Gland.Cambridge, 52 p.
- IUCN/TNC/World Bank (2004). *How much is an ecosystem worth ? Assessing the economic value of conservation*. Washington, The World bank, 33 p.
- LAL, P. (2004).Coral reef use and management –the need, role, and prospects of economic valuation in the Pacific. *In* AHMED, M., CHONG, C.K., CESAR, H. (eds.).Economic valuation and policy priorities for the sustainable management of coral reefs. Penang, Wolrd Fish Center, World Fish Centre conference proceedings, n°70, 222 p.
- LEBLIC, I (1999). Pêcheurs kanak et politiques de développement de la pêche en Nouvelle-Caléonie. *in* BLANCHET, G. (ed.) *Les petites activités de pêche dans le Pacifique Sud*. Paris, IRD, pp. 119-141.
- LEMOS, R. (1995) *The nature of values, axiological investigations*. Gainesville University Press of Florida, 220p.
- LESCUYER, G. (2005) La valeur économique de la biodiversité : fondements, méthodes et usages. *Liaison Energie-Francophonie*, n°66-67, pp. 60-68.

- MC ALLISTER, D.C. (1988). Environmental, economic and social costs of coral reef destruction in the Philipinnes. *Galaxea* n°7, pp. 161-178.
- MC ALLISTER, D.E, (1991). What is the status of the world's reef fishes? *Sea wind*, n°5, pp. 14-18.
- Millenium Ecosystem Assessment, 2003. Ecosystems and Human Well-being: A Framework for Assessment. Chapter 2: Ecosystems and Their Services. Washington, Island press.
- MIRAULT, E. (2007). Les fonctions et enjeux socio-économiques des écosystèmes récifaux : une approche géographique des valeurs de l'environnement appliquée à l'île de la Réunion. Paris, Université de Paris X, thèse de géographie, 712 p.
- MOBERG, F., FOLKE, C. (1999). Ecological goods and services of coral reef ecosystems. *Ecological economics*, n°29, pp. 215-233.
- MOBERG, F (2001). Human use and abuse of coral reefs, managing for ecosystem services and resilience. Stockolm university, Department of systems ecology. Docotral thesis in *Natural ressources management*, 31 p. + annexes.
- MOBERG F., FOLKE, C. (1999). Ecological goods and services of coral reef ecosystems. *Ecological Economics*, n°29, pp. 215-233.
- MOBERG, F ; RÖNNBÄCK, R. (2003). Ecosystems services of the tropical seascape : interactions; substitutions and restoration. *Ocean and Coastal Management*, n°46, pp. 27-46.
- MUNASINGHE, M. (1993). Environmental economics and sustainable development. Washington, DC, World Bank, World Bank Environment Paper No. 3.
- O'GARRA, T. (2007). Estimating the total economic value of the Navakavu LMMA : final report. Suva, University of the South Pacific/CRISP, 131 p.
- PEARCE, D.W. (1990). Environmental sustainability and cost-benefice analysis. *Environmment and Planning*, n°22, pp. 1259-1266.
- PEARCE, D.W. (2002). An intellectual history of environmental economics. Annual Review of Energy and the Environment, n°27, pp. 57-81.
- PINCHEMEL, PH. et PINCHEMEL, G. (1997) *La face de la terre*. Paris, Eds. A. Colin, 5ème édition,517p.
- REVERET, J.P; WEBER, J. (2005). Introduction au numéro, *Liaison Energie-Francophonie*, n°6-67, pp. 5-8.
- ROUGERIE, G, et N BEROUTCHACHVILI, (1991) *Géosystèmes et paysages.* Paris Armand Colin.
- RUITENBEECK, H.J. AND C.M. CARTIER (1999). Issues in applied coral reef biodiversity valuation: Results for Montego Bay, Jamaica. Washington D.C., World Bank, Research Committee Project RPO#682-22 Final Report.
- SALVAT, B. (ed.) (1987). Human impacts on coral reefs : facts and recommendations. Morréa : E.P.H.E., 253 p.
- SEENPRACHAWONG, U. (2004). An economic analysis of coral reefs in the Andaman Sea of Thailand. In Ahmed, M., Chong, C.K., Cesar, H. (eds.).Economic valuation and policy priorities for the sustainable management of coral reefs. Penang, Wolrd Fish Center, World Fish Centre conference proceedings, n°70, pp. 79-83.
- SPURGEON, J.P.G. (1992) .« The economic valuation of coral reefs », *Marine Pollution Bulletin*, vol.24, n° 11, pp. 529-536.
- SPURGEON, J.P.G.; ROXBURGH, T.; O'GORMAN, S.; LINDLEY, R.; RAMSEY, D.; POLUNIN, N. (2004). Economic valuation of coral reefs and adjacent habitats in American Samoa, Final Report. Jacobs Pago-Pago, 163 p.

- TACHEIX, T. (2005). Le cadre de l'économie néoclassique de l'environnement. *Liaison Energie-Francophonie*, n°66-67, pp. 18-23.
- TOMASSIN ; A. ; DAVID, G.; WHITE, C. (2007). Evaluation of MPA social acceptability: the case of Reunion Island, 5th WIOMSA Scientific Symposium, Durban, 22-27 october 2007, 13 p.
- TURNER, K. ; PAVAOLA, J. ; COOPER, P. ; FABER, S. ; JESSAMY, V. ; GEORGIOU, S. (2003). Valuing nature : lessons learned and future research directions. Ecological Economics, n°46, pp. 493-510.
- VAN BEUKERING, P.J.H., HAIDER, W., WOLFS, E., YI LIU, LEEUW, K. VAN DER, LONGLAND, M., SABLAN, J., BEARDMORE, B., PRIMA, S. DI, MASSEY, E., CESAR, H.S.J., HAUSFATHER, Z. & GOURLEY, J. (2006). The Economic Value of the Coral Reefs of Saipan, Commonwealth of the Northern Mariana Islands. CEEC report, 153 pp.
- VIVIEN, F.D. (1994). *Economie et écologie.* Paris, la découverte, 125 p.
- WEBER, (dir.) (1986). Les comptes du patrimoine naturel. Paris, INSEE, *Série C*, n°137-138.
- WILKINSON, C. (ed.), (1998). *Status of coral reefs of the world : 1998.* Townsville : Australian Institute of Marine Science, 184 p.
- WILLINGER, (1996). La méthode d'évaluation contingente : de l'observation à la construction des valeurs de préservation. *Natures Sciences Sociétés*, vol.°4, n°1, pp. 6-22.