# VALUATION AND SENSITIVITY OF SOCIO-ECONOMIC ACTIVITIES ALONG THE FRENCH MEDITERRANEAN COAST

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## ABSTRACT

The valuation of services linked to the coastal environment can provide useful information for decision-makers and, therefore, contribute to costal management strategies. By focussing on services in terms of uses, this case study particularly aims at evaluating the socio-economic activities along the French Mediterranean coast and the corresponding sensitivity to a major pollution event. The assessment comprises a large spectrum of coastal activities (market and non market) that are directly or indirectly linked to seawater quality. To estimate their values (monetary and nonmonetary), quantitative and semi-quantitative measures were used. These values, translated into indexes and presented in their geographical context, allow a socio-economic sensitivity mapping of the French Mediterranean coastal zones as a tool for spatial planning for decision-makers. The resulting maps help to identify and characterize coastal zones that are particularly sensitive to anthropogenic impacts such as marine pollution.

*Keywords: Accidental marine pollution, coastal services, decision management tool, economic valuation, Mediterranean Sea, sensitivity mapping.*

## 1 INTRODUCTION

Coastal environments deliver a wide range of services [1–3]. These not only maintain their well-functioning but also influence social life within the coastal communities and considerably sustain economic activities. At the same time, pressures and risks make this environment vulnerable. To balance environmental and anthropogenic issues, coastal management strategies are needed. They include decision-making processes to guarantee conservation needs, to solve conflicting interests or to face impacts often linked to human activities.

So as to contribute to the management strategies and to inform decision-makers, approaches are made to determine the values of coastal services [4–8]. Such 'service-based approaches' may be discussed controversially and may even be subject to disapproval [9,10]; however, different valuation methods can be applied to determine the values generated by the various services [11]. The concept of the 'total economic value' [12], for example, specifies use and nonuse values. It breaks down into subgroups the variety of components of coastal environment which afford benefits deriving from the use of consumptive goods or benefits attach to them even when not used.

While assigning values, i.e. intending to quantitatively measure, monetary valuation is widely considered as a useful technique. It provides a unit 'that is universally understood' [6] to measure values (use and non use), to compare them with other economic sectors as well as to depict possible consequences of impacts including socio-economic effects. It is, therefore, not only used in *ex ante* assessments as in the context of the designation of marine protected areas [13] but also applied to determine, *ex post*, damages and losses, e.g. provoked by accidental marine pollution [14,15].

The present case study attempts an *ex ante* assessment focussing on socio-economic activities in terms of direct uses on the French Mediterranean coast. It aims at assessing coastal activities (market and nonmarket) that are directly or indirectly linked to seawater quality with the objective to attribute monetary values to these activities whenever possible. The monetary values, therefore, are

used and combined and, together with a nonmonetary evaluation (semi-quantitative) of complementary activities, lead to a socio-economic valuation.

The proposed valuation process examines issues to be considered in coastal management and decision making. It mainly addresses the following question: where are located the coastal zones with the highest economic value considered as the most sensitive ones in case of accidental marine pollution?

## 2 PRECEDINGS, REMARKS AND DEFINITION

The present case study focuses on coastal services in terms of uses. The study includes activities (directly or indirectly linked to seawater quality) that are market activities, i.e. activities for which the outcome is traded on a market like for commercial fisheries. It also includes nonmarket activities like beach activities for which individuals do not usually pay directly for using coastal services.

In this way valuation, whenever possible in monetary terms, helps to determine sensitive coastal zones. The sensitivity is based on the assumption that coastal zones with high values are particularly sensitive to impacts. Exposed to a risk factor such as maritime traffic, the coastal zones become 'vulnerable' [16,17]. Accidental pollution (e.g. hydrocarbons) is nowadays considered as one of the major risks impacting the coastal environment [18], and pollution from operational ship activities has become a major risk in the Mediterranean region [19]. The present study is thus particularly oriented towards this type of impact scenario (short-term, meaning from a few days up to one year).

Pollution of course not only impacts socio-economic activities but also the coastal environment itself. While all the consequences are not further discussed here, marine pollution may imply considerable constraints for many coastal activities and even a prohibition of the activities that are directly linked to seawater quality.

## 3 METHODS

### 3.1 Study area

Situated in the north-western part of the Mediterranean, the study area (Fig. 1) embraces the whole French Mediterranean coast that represents ca. 1800 km of coastline. It is structured in three administrative regions (from west to east): Languedoc-Roussillon (LR), Provence-Alpes-Côte d'Azur (PACA) and Corsica. These divisions also correspond to environmental and socio-economic differences. For LR region: wide sandy and low-lying coast with condominiums and camping for summer mass tourism, fishing grounds and shellfish culture. For PACA: rocky shores, steep underwater slopes, mild climate favouring throughout the year-round tourism (French Riviera) and large urban areas (Marseille, Toulon, Nice). And for Corsica, mostly well preserved and protected coastline, agriculture and middle-class summer tourism.

For the assessment and to elaborate sensitivity maps, the study area has been divided into zones. This division is based on the outline for the implementation of the Water Management Plan, which includes coastal waters. Based on the appropriate size for local management, 32 different coastal zones have been established (Fig. 1). Since the outline includes zones for coastal lagoons, which are not part of the present study, coastal zone numbers are not continuous here. On the seaward side, the coastal zones are delimited either by four miles and/or the 50-m depth isobath, taking the most offshore of the two limits. On the landward side, all 189 coastal municipalities have been considered.
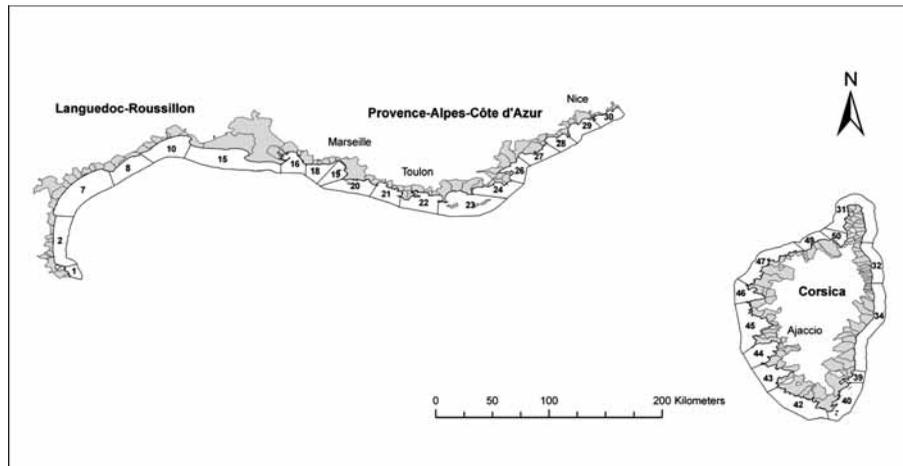
Figure 1: Study area. Municipalities (189) bordering the Mediterranean Sea are indicated in grey shading (landward side). Also displayed, the study area has been divided in marine zones (32, seaward side) with their reference numbers.

## 3.2 Coastal activities

The socio-economic activities selected are only those possibly impacted significantly by the implicit accidental scenario. The assessment comprises a large spectrum of coastal activities (Table 1) that are directly or indirectly linked to seawater quality. Market and (partly) nonmarket activities are distinguished corresponding to the following main sectors: (1) commercial fisheries and aquaculture, (2) coastal tourism, sports and recreational activities (e.g. lodging, restaurants, yachting, recreational fishing, water sports and beach activities), (3) seawater pumping (for salt production, aquaria, sportive and therapeutic uses), (4) efforts of maintenance, (5) marine research and educational activities, and (6) cultural attractiveness and maritime heritage. Furthermore, it is indicated whether the valuation has been monetary or nonmonetary.

## 3.3 Analyses

Different valuation techniques were utilized for the various coastal activities. The economic analyses (i.e. monetary valuation) mainly consider direct uses. Semi-quantitative analyses (nonmonetary valuation) cover other socio-economic activities characteristic of the coastal zones for which available data for monetary valuation were incomplete.

Requested data were never directly accessible at the required spatial scale. Therefore, data have been collected and processed to estimate values for each activity in each of the coastal zones. Whenever possible, and in particular for tourist and recreational activities, summer (April to September) and winter (October to March) season have been differentiated. The results in absolute values were transferred to relative values and transposed into maps in order to compare coastal zones as their socio-economic sensitivity (Fig. 2).

### 3.3.1 Data
The data collection, validation and processing methods have been previously described in detail [20] and are only summarized here. Data were derived from, among other sources, national data bases

Table 1: Coastal activities assessed in this study that are directly (grey shading) or indirectly linked to seawater quality.

| Activities | Directly linked to seawater quality | | Indirectly linked to seawater quality | |
| | Monetary valuation | Nonmonetary valuation | Monetary valuation | Nonmonetary valuation |
|---|---|---|---|---|
| Market | Commercial fisheries Aquaculture Yachting | Whale watching | Lodging restaurants | Cruises Transformation and sale of sea products |
| ⇕ | Scuba diving Sea-watching | Seawater pumping Water sports Link lagoon-sea | | Sportive events |
| Nonmarket | Beach activities Recreational fisheries | Surfing Efforts of maintenance | | Research and educational activities Cultural attractiveness Maritime heritage |
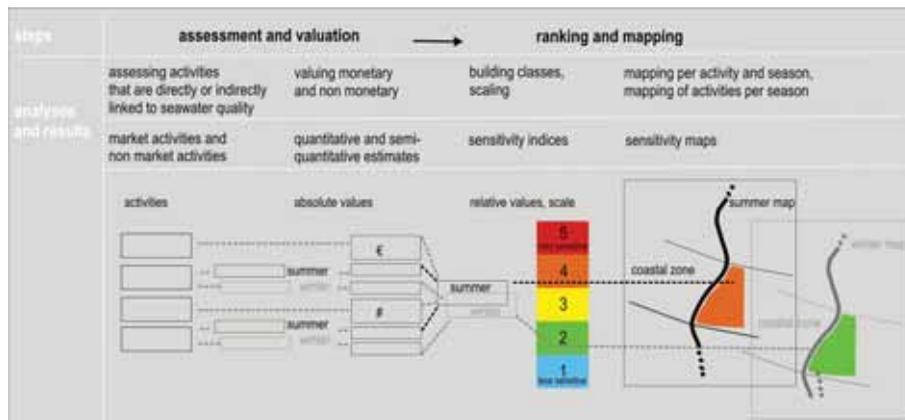


Figure 2:  Conceptual scheme of the methodological approach within the valuation process.

(such as the French National Institute of Statistics and Economic Studies, INSEE), internet, questionnaires and interviews, guides, reports and peer-reviewed journals. Most recent data accessible have been collected. Given the scope of the present study, the wide range of data and its sources as well as their accuracy, the authors refrain from using discounting factors to update on a base year.

Whenever possible, data have been collected on municipality level (189 municipalities border the French Mediterranean Sea) and then compiled to match to the 32 coastal zone units (attributed to the seaward side, the 'marine sector'). In case a municipality is shared by two coastal zones and depending on the activity, data might have been shifted to the appropriate zone (e.g. a municipality is bordered by two coastal zones of which only one has a marina and consequently yachting activity).

### 3.3.2  Assessment and valuation

The monetary assessment comprises coastal activities (Table 1) that are directly linked to seawater quality and includes estimations (quantitative) for market (commercial fisheries, aquaculture, yachting) and nonmarket activities (beach activities and recreational fisheries). For market activities, the monetary assessment is expressed as Gross Annual Revenue. For nonmarket activities, the monetary assessment uses estimated expenses out of a national survey (recreational fisheries [21]) or comes through Willingness To Pay for beach activities in a similar tourist area [22].  Concerning activities that are indirectly linked to seawater quality, only market activities (lodging and restaurants) have been evaluated. The (absolute) values are given in Euros.

Other coastal activities that are directly linked to seawater quality, i.e. market activities (whale watching), partly market/nonmarket (seawater pumping, water sports and link lagoon-sea) and nonmarket (surfing and effort of maintenance) activities, have been evaluated in a nonmonetary (Table 1), semi-quantitative way. In these cases, their presence (or absence) has been counted and sum up for each coastal zone. This evaluation type has also been used for activities that are indirectly linked to seawater quality; for market (cruises, transformation and sale of seafood products), partly market/nonmarket (sportive events) and nonmarket (research and educational activities, cultural attractiveness and maritime heritage) activities.

### 3.3.3  Ranking and mapping

For the purpose to rank the valuation results of the activities within the coastal zones and to build classes, natural breaks have been used (Jenks' method). For each activity, valued five classes have been determined and indexes attributed on a scale of 1 (less sensitive) to 5 (more sensitive). If no value could be determined for a coastal zone (either due to lack of data or because the respective activity was not found at the moment), the sensitivity index '1' (less sensitive) has been attributed  to take into account a potential unspecified activity.

A Geographic Information System (GIS; ArcGIS9 ESRI) has been used for homogenization and treatment of spatial data as well as for mapping the sensitivity indexes.

## 4  RESULTS AND DISCUSSION

Selected results of the different steps within the valuation process (Fig. 2) are presented here. While generally regarding all coastal activities that have been considered in this study, we paid particular attention to the monetary valuation of market and nonmarket activities in the summer season.

### 4.1  Monetary valuation of coastal activities for the French Mediterranean coast

The sum of monetary valuation of coastal activities (market and some nonmarket) for the 32 coastal zones is shown in Table 2. This represents, to our knowledge, the first estimate of monetary valuation of coastal activities for the French Mediterranean coastal zone (11,300 km$^2$). The total annual amount of sea-driven activities lies over 10 billion € (2009), representing around 15% of the GDP for coastal municipalities (all economic activities) estimated to 70 billions € [23]. This proportion is important when considering that coastal municipalities include large industrial and urban sectors like the cities of Fos, Marseille, Toulon and Nice with a highly diversified economy. Coastal tourism (lodging and catering) represents the major part of the annual total (83%) pointing out the importance of this field in coastal economy. A recent survey [24] performed for the Mediterranean Basin estimates the annual revenue of coastal tourism for the French coast to 8.8 billions €, which fairly matches with our figures. Table 2 also shows that summer activities accounts for 77% of the annual total. The economic impact of a major pollution event will be then much more deleterious

Table 2:  Sum of monetary valuation of coastal activities along the French Mediterranean coast.

|  |  | Summer (M€) | Winter (M€) | Annual (M€) |
|---|---|---|---|---|
| Indirectly linked to seawater quality | Restaurants | 3313,5 | 1104,5 | 4418,0 |
|  | Lodging | 3276,5 | 1073,8 | 4350,2 |
|  | Beach activities | 993,8 |  | 993,8 |
|  | Yachting | 144,5 | 121,9 | 266,4 |
| Directly linked to seawater quality | Rec. fisheries | 238,3 | 25,9 | 264,2 |
|  | Comm. fisheries | 72,1 | 24,0 | 96,2 |
|  | Scuba diving | 28,8 | 9,6 | 38,3 |
|  | Aquaculture | 23,6 | 7,9 | 31,4 |
|  | Snorkeling | 0,5 | 0,2 | 0,7 |
|  | ***Total*** | ***8091,5*** | ***2367,7*** | ***10459,2*** |

at the beginning of the summer season. The monetary value of the commercial fisheries is probably underestimated due to lack of reliable data on catches from the Fisheries Information System [25] and under declaration of landing by fishermen. The addition of monetary values obtained through different valuation lines (gross production revenue, declared/revealed expenses or Willingness to Pay) can raise some debate in the light of economic science standards but its appears as a good way to emphasize the weight of nonmarket activities within the approach of the Total Economic Value [26]. Very few similar studies are found for the Mediterranean region and the one addressing the nonmarket valuation of ecosystem services along the Catalan coast of Spain [8] estimates a mean value of 100,000 € ha$^{-1}$ y$^{-1}$ to be compared to our estimate of market and nonmarket use of about 10,000 € ha$^{-1}$ y$^{-1}$.

### 4.2  Monetary valuation for each coastal zone

The monetary valuation results for summer season in each zone are summarized in Table 3. The highest economic value is found in the dense French Riviera (zones 28 and 29), followed by the LR region (zones 2–10), high place of mass tourism. The lowest values are found in the most preserved sectors (15 and 20) and in Corsica, where the tourist capacity is reduced. However, in Corsica, although low in absolute value, the coastal economy is strategic for the region, representing 35% of the GDP [23].

### 4.3  Nonmonetary valuation for each coastal zone

The results for nonmonetary valuation of the most significant costal activities are presented in Table 4. When possible the number of sites concerned by each activity has been counted and normalized into the 1–5 range value, otherwise only the presence/absence is collected. The totals on the right column show that the core of the PACA region (zones 22–29) with a large resident population and massive summer tourism offers much diverse recreational and cultural activities.

Table 3: Monetary valuation of each coastal zone of the French Mediterranean for the summer season.

| Zone | Activities directly linked to seawater quality | | | | | | | Activities indirectly linked to seawater quality | | Total per zone (M€) | Summer sensitivity |
| | Market activities | | | | | Nonmarket activities | | Market activities | | | |
| | Commercial fishing (K€) | Aquaculture (K€) | Yachting (K€) | Scuba-diving (K€) | Snorkeling (K€) | Beach activities (M€) | Recreational fishing (M€) | Lodging (M€) | Restaurants (M€) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 6897,2 | 32,1 | 635,6 | 341,3 | 144,0 | 3,4 | 4,0 | 47,1 | 12,4 | **74,9** | **2** |
| **2** | 4926,6 | 32,1 | 8837,5 | 1535,6 | | 124,2 | 25,0 | 344,7 | 227,8 | **737,1** | **5** |
| **7** | 10592,1 | 3150,0 | 5799,3 | 981,1 | | 109,7 | 24,4 | 246,3 | 109,9 | **510,8** | **4** |
| **8** | 11823,8 | 4500,0 | 2451,4 | 895,8 | 55,8 | 16,0 | 13,1 | 225,8 | 104,8 | **379,5** | **4** |
| **10** | 14779,7 | 1350,0 | 10198,8 | 895,8 | | 65,5 | 20,1 | 253,2 | 209,6 | **575,7** | **5** |
| **15** | 2832,9 | | 4147,4 | 128,0 | | 28,0 | 2,7 | 28,6 | 36,8 | **103,2** | **2** |
| **16** | 2832,9 | 4500,0 | 4270,0 | 554,5 | | 11,0 | 7,6 | 15,2 | 53,6 | **99,7** | **2** |
| **18** | 2832,9 | | 1537,1 | 1066,4 | 7,0 | 2,9 | 3,7 | 15,6 | 36,9 | **64,6** | **2** |
| **19** | 2832,9 | 384,8 | 7744,8 | 4180,3 | | 7,3 | 6,2 | 67,0 | 241,5 | **337,2** | **4** |
| **20** | 1861,6 | | 3266,0 | 511,9 | 17,0 | 2,2 | 1,8 | 13,2 | 56,4 | **79,3** | **2** |
| **21** | 1780,7 | | 7360,7 | 938,4 | 27,0 | 30,1 | 12,0 | 192,6 | 167,3 | **412,0** | **4** |
| **22** | 364,2 | 1597,5 | 4977,9 | 2346,1 | 14,0 | 35,3 | 5,8 | 66,6 | 257,6 | **374,6** | **4** |
| **23** | 526,1 | | 9650,2 | 1109,1 | 119,0 | 29,2 | 8,1 | 93,0 | 64,5 | **206,3** | **3** |
| **24** | 364,2 | | 4608,7 | 981,1 | 38,0 | 33,7 | 6,6 | 109,8 | 179,3 | **335,3** | **4** |
| **26** | 809,4 | | 13679,0 | 1023,8 | | 58,6 | 10,0 | 173,6 | 122,3 | **379,9** | **4** |
| **27** | 809,4 | 1667,3 | 6087,7 | 895,8 | | 17,7 | 12,7 | 219,1 | 105,4 | **364,3** | **4** |
| **28** | 809,4 | 3001,1 | 22391,5 | 1407,7 | 15,0 | 63,9 | 14,8 | 275,0 | 352,1 | **733,5** | **5** |
| **29** | 566,6 | 2000,7 | 9518,6 | 2858,0 | 7,0 | 93,5 | 28,1 | 453,9 | 447,4 | **1037,8** | **5** |
| **30** | 323,8 | | 5970,6 | 469,2 | | 30,4 | 10,5 | 145,7 | 117,6 | **310,9** | **4** |
| **31** | 346,0 | | 1531,2 | 255,9 | | 8,6 | 0,6 | 9,4 | 27,6 | **48,3** | **1** |
| **32** | 404,6 | | 846,6 | 426,6 | | 38,4 | 3,4 | 28,5 | 77,1 | **149,0** | **3** |
| **34** | 248,3 | | 1329,6 | 426,6 | | 50,6 | 3,6 | 30,2 | 43,5 | **130,0** | **2** |
| **39** | 209,2 | | 782,5 | 341,3 | | 19,7 | 1,6 | 22,9 | 44,4 | **89,9** | **2** |

(*Continued*)

Table 3: (*Continued*)

| Zone | Activities directly linked to seawater quality | | | | | Nonmarket activities | | Activities indirectly linked to seawater quality | | Total per zone (M€) | Summer sensitivity |
| | Market activities | | | | | | | market activities | | | |
| | Commercial fishing (K€) | Aquaculture (K€) | Yachting (K€) | Scuba-diving (K€) | Snorkeling (K€) | Beach activities (M€) | Recreational fishing (M€) | Lodging (M€) | Restaurants (M€) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **44** | 556,0 | 256,5 | 945,1 | 682,5 | | 21,6 | 1,9 | 31,3 | 75,4 | **132,6** | **3** |
| **45** | 165,2 | 256,5 | 1201,8 | 938,4 | | 19,6 | 0,9 | 15,9 | 17,1 | **56,0** | **1** |
| **46** | 132,8 | | 157,4 | 170,6 | | 1,9 | 0,9 | 15,9 | 11,1 | **30,3** | **1** |
| **47** | 377,6 | 64,1 | 1653,8 | 1109,1 | 7,9 | 14,0 | 2,5 | 42,6 | 53,8 | **116,1** | **3** |
| **49** | | | 0,0 | 0,0 | | 4,7 | 0,6 | 9,4 | 3,2 | **17,9** | **1** |
| **50** | 40,4 | | 1194,8 | 0,0 | | 6,4 | 0,6 | 9,4 | 3,0 | **20,6** | **1** |

Table 4: Nonmonetary valuation of each coastal zone (annual estimate).

| Zone | Market activities | Activities directly linked to seawater quality | | | | Market activities | | | Activities indirectly linked to seawater quality | | | | Sea connection | All activities | |
| | | Nonmarket activities | | | | | | | | Nonmarket activities | | | | | |
| | | <> | | | | | | | <> | | | | <> | | |
| | Whale watching | Seawater pumping | Water sports | Surfing | Beach mainte-nance | Cruises | Seafood process | Fish sale | Sportive events | Research and educat. | Cultural attractive-ness | Maritime heritage | Link lagoon-sea | Total (#) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 4 | 1 | 1 | 2 | a | 1 | p | a | 2 | 2 | 3 | a | 17 | 3 |
| 2 | 1 | 5 | 3 | 3 | 5 | a | 3 | p | p | 1 | 2 | 4 | p | 27 | 5 |
| 7 | 1 | 4 | 4 | 3 | 4 | a | 3 | p | p | 2 | 2 | 3 | p | 26 | 4 |
| 8 | 1 | 2 | 2 | 2 | 2 | p | 3 | p | p | 3 | 2 | 3 | p | 20 | 4 |
| 10 | 1 | 5 | 5 | 3 | 4 | p | 3 | p | a | 2 | 3 | 4 | p | 30 | 5 |
| 15 | 1 | 5 | 2 | 3 | 2 | p | 1 | p | a | 2 | 2 | 2 | p | 20 | 4 |
| 16 | 1 | 3 | 2 | 3 | 3 | a | 3 | p | p | 2 | 1 | 4 | p | 22 | 4 |
| 18 | 3 | 1 | 2 | 3 | 1 | a | 1 | a | a | 4 | 5 | 3 | a | 23 | 4 |
| 19 | 3 | 2 | 5 | 3 | 1 | p | 2 | a | p | 2 | 2 | 2 | a | 22 | 4 |
| 20 | 2 | 1 | 2 | 2 | 2 | a | 2 | a | a | 2 | 4 | 3 | a | 20 | 3 |
| 21 | 4 | 4 | 3 | 3 | 3 | a | 1 | a | a | 3 | 4 | 4 | a | 29 | 4 |
| 22 | 5 | 4 | 5 | 5 | 3 | p | 3 | a | p | 5 | 3 | 5 | a | 38 | 5 |
| 23 | 4 | 3 | 2 | 3 | 3 | a | 1 | a | a | 2 | 4 | 2 | a | 24 | 4 |
| 24 | 1 | 1 | 2 | 3 | 3 | a | 1 | a | p | 3 | 4 | 3 | a | 21 | 4 |
| 26 | 3 | 3 | 3 | 3 | 3 | a | 1 | a | p | 2 | 5 | 2 | a | 25 | 4 |
| 27 | 3 | 3 | 2 | 3 | 2 | a | 1 | a | p | 2 | 4 | 2 | a | 22 | 4 |
| 28 | 4 | 2 | 4 | 2 | 3 | p | 4 | a | p | 3 | 4 | 3 | a | 29 | 5 |
| 29 | 5 | 2 | 4 | 3 | 2 | p | 3 | a | p | 4 | 4 | 4 | a | 31 | 5 |
| 30 | 3 | 2 | 2 | 2 | 3 | a | 1 | a | p | 2 | 5 | 2 | a | 22 | 4 |
| 31 | 1 | 1 | 1 | 2 | 1 | a | 1 | a | a | 1 | 1 | 2 | a | 11 | 1 |
| 32 | 1 | 1 | 2 | 1 | 1 | a | 1 | a | a | 3 | 1 | 1 | p | 12 | 2 |
| 34 | 1 | 2 | 1 | 1 | 3 | a | 1 | a | p | 1 | 1 | 2 | a | 13 | 2 |

*(Continued)*

Table 4: (*Continued*)

| | Activities directly linked to seawater quality | | | | | Activities indireclty linked to seawater quality | | | | | | | Sea connection | All activities | |
| | Market activities < > | < > | | Nonmarket activities | | Market activities < > | | | < > | non market activities | | | < > | | |
| Zone | Whale watching | Seawater pumping | Water sports | Surfing | Beach mainte-nance | Cruises | Seafood process | Fish sale | Sportive events | Research and educat. | Cultural attractive-ness | Maritime heritage | Link lagoon-sea | Total (#) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **43** | 1 | 1 | 1 | 2 | 1 | a | 1 | a | a | 1 | 2 | 1 | a | 11 | 1 |
| **44** | 3 | 3 | 1 | 1 | 1 | p | 2 | a | p | 1 | 2 | 1 | a | 15 | 3 |
| **45** | 3 | 1 | 2 | 1 | 1 | p | 2 | a | p | 1 | 2 | 1 | a | 14 | 3 |
| **46** | 1 | 2 | 1 | 1 | 1 | a | 1 | a | a | 1 | 2 | 1 | a | 11 | 1 |
| **47** | 1 | 2 | 1 | 3 | 1 | a | 1 | a | a | 3 | 2 | 2 | a | 16 | 3 |
| **49** | 1 | 1 | 1 | 1 | 1 | a | 1 | a | a | 1 | 2 | 1 | a | 10 | 1 |
| **50** | 1 | 1 | 1 | 1 | 1 | a | 1 | a | a | 1 | 2 | 1 | a | 10 | 1 |

4.4 Ranking and mapping economical sensitivity

After ranking and attribution of indexes, maps have been generated to display the sensitivity indexes in their geographical context. These resulting maps, the final product of the valuation process, intend to show the relative importance from one coastal zone to another as a easy-to-read tool for coastal managers and decision-makers. For coherence with other sensitivity factors (not presented here: ecological and geo-morphological), monetary valuation for each zone has been reduced to the surface of each marine area, expressing some 'density' of economical value.

Selected ranking results and sensitivity maps based on monetary valuation are displayed in Figs. 3 and 4.
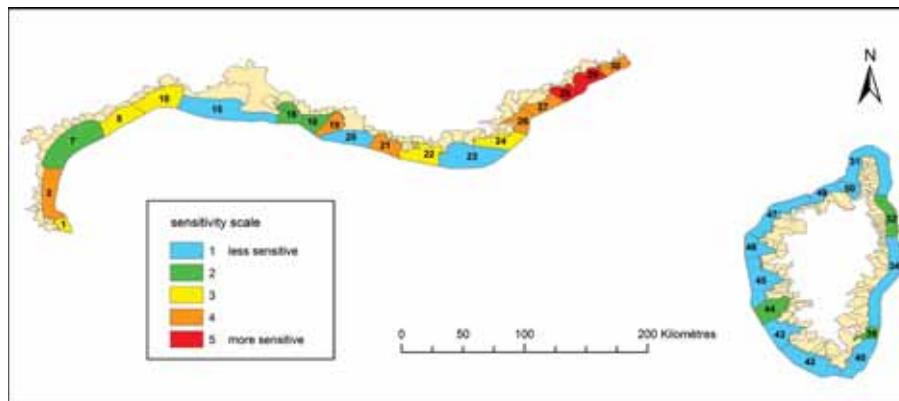


Figure 3: Economic sensitivity of the French Mediterranean coast in summer (monetary valuation of coastal activities related to the surface of each marine zone).
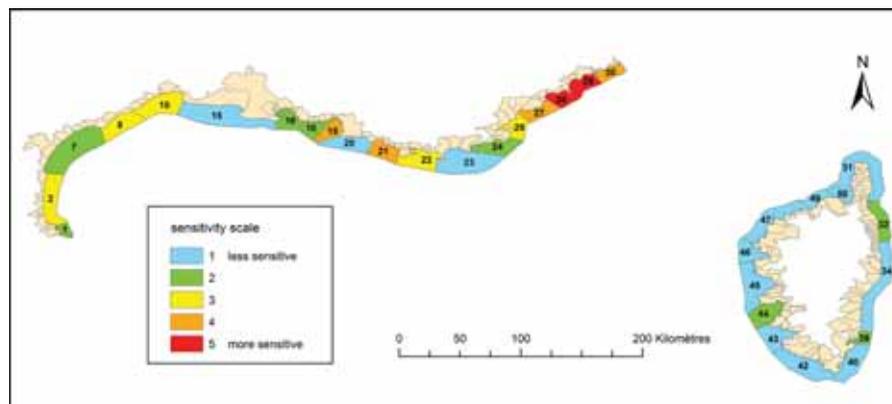


Figure 4: Economic sensitivity of the French Mediterranean coast in winter (monetary valuation of coastal activities related to the surface of each marine zone).

Summer colour map shows clearly that the highest sensitive areas appear on the eastern part of the Provence region (the so-called 'French Riviera') followed by the areas of Marseille (19) and Toulon (21 and 22) with dense population and associated economic activities. The distribution of economic sensitivity is rather similar for the winter season (Fig. 4), meaning that the main zones at risk will be about the same as in summer, only the level of economical impact should be less in winter considering the monetary valuation shown in Table 2.

## 4.5 Detailed sensitivity information

From monetary valuation included in Table 3, sensitivity ranking into 1–5 indexes has been computed and gathered in Table 5. The associated colour expression allows rapid access for each zone to the contribution of each activity to the aggregated sensitivity value displayed in Fig. 3. This detailed information completes data available for decision-makers and managers in case of emergency situation. These two levels of information (seasonal maps and detailed zone data) have been implemented in a GIS dedicated application.

## 5 CONCLUSION

The predefinition of the coastal zones is based on an existing management outline and on administrative units. Their limits and size are thought to be appropriated for the Integrated Coastal Zone Management by various authorities. In our study, this zoning scale was found well adapted to the reliable collection of geo-referenced data and to display sensitivity indexes. However, such division may seem arbitrary and artificial for water masses that are essentially moving and spatial limits should be understood as dotted lines. On the other hand, most activities related to seawater quality operate from a land base with a restricted range (fishing, aquaculture, scuba-diving and beach going).

To our knowledge, except for a case study on Corsica [27], no prior 'in depth' assessment has been carried out along the French Mediterranean coastal zone. Sensitivity indexes here describe intrinsic values and it is assumed that coastal zones in which activities generate high values are relatively more sensitive. This working hypothesis simplifies the classic cost–benefit analysis as no damage costs of an accidental scenario are estimated. The translation of valuation results into sensitivity indexes 'smoothen' potential misestimating of absolute values and allow to compare economic sensitivity of one coastal zone to another for management issues. The sensitivity maps give this overview and can be overlaid or merged with other geo-referenced data and/or with modelling results to facilitate the decision-making process.

Table 5: Economical sensitivity of French Mediterranean coastal zones in summer detailed by activity (monetary valuation).

| zone | activities directly linked to seawater quality | | | | | | | activities indirectly linked to water quality | |
| | market activities | | | | | non-market activities | | market activities | |
| | commercial fishing | aquaculture | yachting | scuba-diving | snorkeling | beach activity | recreational fishing | lodging | restaurants |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 2 | 1 | 1 | 5 | 1 | 2 | 2 | 1 |
| 2 | 4 | 2 | 3 | 3 | 1 | 5 | 5 | 5 | 4 |
| 7 | 5 | 5 | 3 | 2 | 1 | 5 | 5 | 4 | 3 |
| 8 | 5 | 5 | 2 | 2 | 4 | 2 | 4 | 4 | 3 |
| 10 | 5 | 4 | 4 | 2 | 1 | 4 | 5 | 5 | 4 |
| 15 | 3 | 1 | 2 | 1 | 1 | 3 | 2 | 2 | 1 |
| 16 | 3 | 5 | 2 | 2 | 1 | 2 | 3 | 1 | 2 |
| 18 | 3 | 1 | 2 | 3 | 2 | 1 | 2 | 2 | 1 |
| 19 | 3 | 3 | 3 | 5 | 1 | 2 | 3 | 1 | 4 |
| 20 | 3 | 1 | 2 | 2 | 3 | 1 | 1 | 1 | 2 |
| 21 | 3 | 1 | 3 | 2 | 4 | 3 | 4 | 4 | 4 |
| 22 | 2 | 4 | 2 | 4 | 3 | 3 | 3 | 2 | 2 |
| 23 | 2 | 1 | 3 | 3 | 5 | 3 | 3 | 3 | 4 |
| 24 | 2 | 1 | 2 | 2 | 4 | 3 | 3 | 3 | 3 |
| 26 | 2 | 1 | 4 | 3 | 1 | 4 | 4 | 4 | 3 |
| 27 | 2 | 4 | 3 | 2 | 1 | 2 | 4 | 5 | 5 |
| 28 | 2 | 5 | 5 | 3 | 3 | 4 | 5 | 5 | 5 |
| 29 | 2 | 4 | 3 | 4 | 2 | 5 | 5 | 5 | 5 |
| 30 | 2 | 1 | 3 | 1 | 1 | 3 | 4 | 3 | 3 |
| 31 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 1 |
| 32 | 2 | 1 | 1 | 1 | 1 | 3 | 2 | 2 | 2 |
| 34 | 1 | 1 | 2 | 1 | 1 | 4 | 1 | 1 | 1 |
| 39 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| 40 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| 42 | 2 | 3 | 1 | 2 | 1 | 2 | 1 | 2 | 2 |
| 43 | 1 | 3 | 1 | 2 | 2 | 2 | 1 | 2 | 1 |
| 44 | 2 | 3 | 1 | 2 | 1 | 3 | 1 | 1 | 2 |
| 45 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 |
| 46 | 1 | 2 | 1 | 3 | 2 | 2 | 2 | 2 | 2 |
| 47 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 |
| 49 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| 50 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 |

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