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Environmental Sensitivity Indexes in oil hydrocarbons: Its application in SIROCO

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ABSTRACT

In this study, the Environmental Sensitivity Indexes (ESI) are analyzed through SIROCO (Island Response Systems and Operations against ocean pollutants), which allow us to determine the behavior of the substrates that constitute the coastal littoral in front of the polluting action originated by hypothetical accidental spills of hydrocarbons that may affect the islands of Lanzarote and Fuerteventura.

1. Introduction

The location of the Canary Islands as an area of obligatory passage for a multitude of ships in their crossing through the Atlantic, their location just 100 kilometers from the African coast in its easternmost slope, their more than 1,500 linear kilometers of coastline, their uniqueness and the ecological wealth of their coasts, together with an economy based on the tourist sector and the growing interest on oil exploitation justify the need to have a characterization of the coastline according to its sensitivity.

One of the most relevant epigraphs within the Island Response Systems and Operations against ocean pollutants is the concerning to the coastal sensitivity analysis. The characterization of the coast constitutes a fundamental tool to manage the protocols of action of the equipment of fight against the pollution according to the behavior of the substrata that constitute the coastal littoral against the polluting action originated by accidental spills of hydrocarbons or other substances with similar behavior.

The classification of the littoral of the Canary Islands has been based according to its Environmental Sensitivity Index (ISA) in the international standard proposed by the NOAA (2002) for the elaboration of the Environmental Sensitivity Indexes (ESI). The adoption of this standard responds to the need for standardization in terms of response functions and the location of the most sensitive coastal resources that may be affected (SOCIB, 2010). This index is based on the longevity of the hydrocarbons in a certain geomorphological environment, so that the greater its value, the greater the damage that can be caused and the greater the priority of its protection and the priority of the intervention. These indexes should serve as guidelines for establishing vulnerability maps of the coasts, which in turn will allow, in case of being invaded by a spill, prioritize the protection against contamination of the most vulnerable areas (higher index) and the cleaning and restoration intervention, and / or to choose properly the cleaning methods appropriate to each specific case (Bergueiro, 2001).

2. Methodology

In order to determine the coastal sensitivity, the following factors should be considered:

- Coastal type (substrate, grain size, tidal height, origin).

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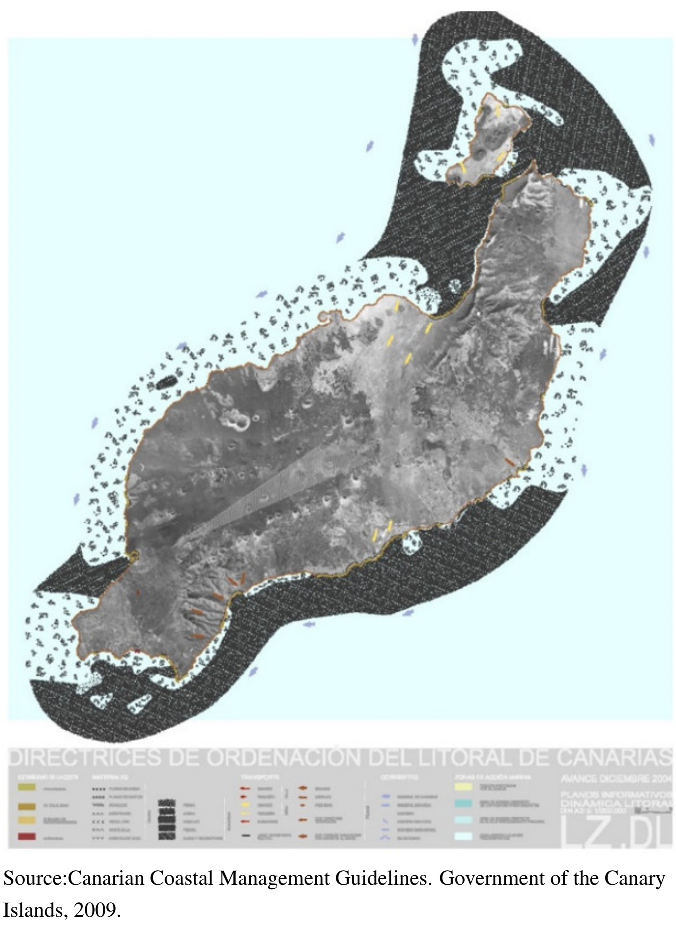
- Waves and tides exposure.
- Productivity and biological sensitivity.
- The easy of cleaning.

The prediction of behavior and persistence of oil in intertidal habitats is based on an understanding of the dynamics of coastal environments and not only on the characterization of the substrate type. The exposure of the coast to the waves and sea currents directly affects the persistence of hydrocarbons. The prioritization of the tasks of cleaning the coast is determined, in part, on the basis of the natural processes of elimination of hydrocarbons. The potential for biological damage and the ease of cleaning spilled hydrocarbons are also important factors in the classification of the environmental sensitivity index. In general terms, areas exposed to high levels of physical energy, such as the action of waves and tidal currents, as well as low biotic activity, occupy a low range on the scale, while protected areas with high biological activity have the highest ranking.

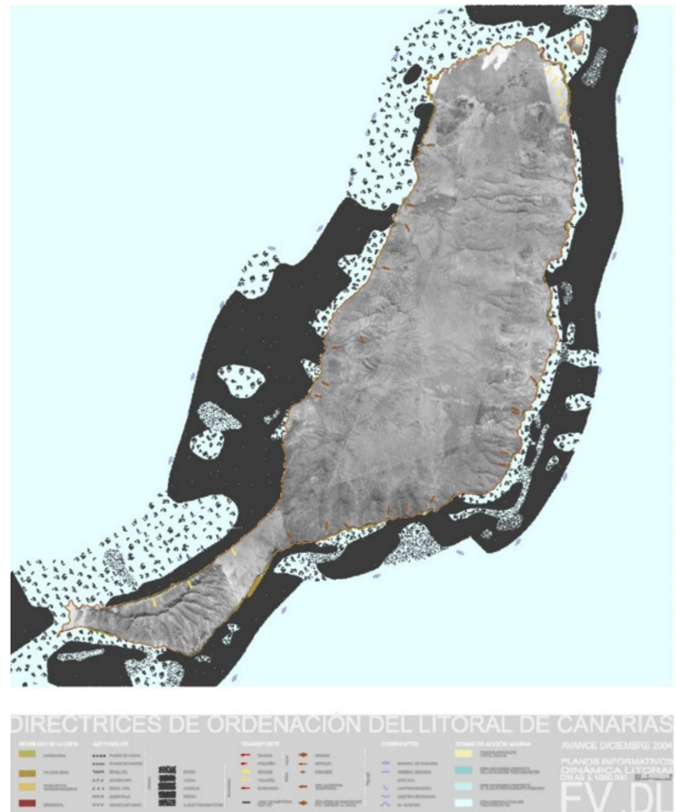
Figure 1: Information Plan on Coastal Dynamics (Lanzarote).



Source:Canarian Coastal Management Guidelines. Government of the Canary Islands, 2009.

In the case of the Canary Islands and specifically in the study of Lanzarote, Fuerteventura and eastern islets, the classification parameters proposed by the NOAA (2002) have been applied to the local coast types.

Figure 2: Information Plan on Coastal Dynamics (Fuerteventura).



Source: Canarian Coastal Management Guidelines. Government of the Canary Islands, 2009.

For the characterization of the substrates present in the littoral, the data of the document of Canary Coastal Management Guidelines (Government of the Canary Islands, November 2009) (Figure 1 and Figure 2) have been used.

Likewise, the studies of geomorphological classification included in the REGIONAL PLAN OF ORDINATION OF AQUACULTURE OF THE CANARY ISLANDS (PROAC) (Government of the Canary Islands, 2013) are taken into account.

The levels of Environmental Sensitivity Index (ESI) are color-coded (RGB), ranging from colder to warmer, indicating an increase in the index.

Each color corresponds to a particular type of coast, allowing the identification of the type and its environmental sensitivity against a hydrocarbon spill (Table 1).

Table 1: ESI Range. According to type of coast and its corresponding color code in RGB.

ESI	RGB color	Shoreline Types
1: Exposed, Impermeable Vertical Substrates		
1A	119/38/105	Exposed rocky shores
1B		Exposed, artificial solid structures
1C		Exposed rocky cliffs with boulder talus base
2: Exposed, Impermeable Substrates, Non-Vertical		
2A	174/153/191	Exposed wave-cut platforms in bedrock
2B		Exposed scarps and steep slopes in clay
3: Semi-Permeable Substrate, Low Potential for Oil Penetration and Burial; infauna present not usually abundant		
3A	0/151/212	Fine- to medium-grained sand beaches
3B		Scarps and steep slopes in sand
4: Medium Permeability, Moderate Potential for Oil Penetration and Burial; infauna presen not usually abundant		
4	146/209/241	Coarse-grained sand beaches
5: Medium-to-High Permeability, High Potential for Oil Penetration and Burial; infauna pr but not usually abundant		
5	152/206/201	Mixed sand and gravel beaches
6: High Permeability, High Potential for Oil Penetration and Burial		
6A	0/149/32	Gravel beaches
6B		Loose rock dikes (breakwater / RIP-RAP)
7: Exposed, Flat, Permeable Substrate; infauna usually abundant		
7	214/186/0	Exposed tidal flats
8: Sheltered Impermeable Substrate, Hard; epibiota usually abundant		
8A	255/232/0	Sheltered rocky shores (impermeable) and sheltered scarps in bedrock
8B		Sheltered, solid man-made structures, and sheltered rocky shores
8C		Sheltered RIP-RAP
8D		Sheltered rocky rubble shores
8E		Peat shorelines
9: Sheltered, Flat, Semi-Permeable Substrate, Soft; infauna usually abundant		
9A	248/163/0	Sheltered tidal flats
9B		Vegetated low banks
10: Vegetated Emergent Wetlands		
10A	214/0/24	Salt- and brackish-water marshes
10B		Freshwater marshes
10C		Swamps
10D		Scrub-shrub wetland

Source: Commission on the Protection of the Black Sea Against Pollution. Authors elaboration.

The different coastal habitats that can be found in the Canaries are detailed below. These are based on considerations of NOAA and IPIECA, increasingly ordered according to the sensitivity to oil.

- Exposed rocky shores (1A) (Figure 3)
- Exposed, artificial solid structures (breakwaters, coverings, docks and port facilities, etc.) (1B)
- Exposed wave-cut platforms in bedrock (2A) (Figure 4)
- Fine- to medium-grained sand beaches (3A) (Figure 5)
- Coarse-grained sand beaches (4) (Figure 6)
- Mixed sand and gravel beaches (5) (Figure 7)
- Gravel beaches (6A)
- Loose rock dikes (breakwater / RIP-RAP) (6B) (Figure 8)
- Sheltered rocky shores (impermeable) and sheltered scarps in bedrock (8A)
- Sheltered, solid man-made structures, and sheltered rocky shores (8B) (Figure 9)
- Sheltered RIP-RAP (8C)
- Sheltered rocky rubble shores (8D)

Each of the coastal habitats is detailed in the following lines in terms of their physical description, predicting the behavior of oil and the considerations of response to an emergency (Ezcurra, 2012).

2.1. *Exposed, Vertical and Waterproof Substrates (Exposed rocky shores (ESI 1A) / Exposed, artificial solid structures ESI 1B)*

Due to their nature and predominant hydrodynamic conditions are the zones that have a lower environmental sensitivity index.

These are regions exposed to waves, which tend to keep oil on the high seas by reflecting effect of the waves on the coast.

The substrate is impermeable, so that the oil stays on the surface where the natural processes eliminate it in several weeks. Although cleanliness is generally not required or recommended, Table 2 and Table 3 compare the relative environmental impact of each response method on the habitat and specific environment.

Table 2: Environmental Considerations for Marine Oil Spill Response ESI 1A (I - Gasoline products, II - Diesel-like products and light crudes, III - Medium grade crudes and intermediate products, IV - Heavy crudes and residual products, V - Non-floating oil products. A = The least adverse habitat impact, B = Some adverse habitat impact, C = Significant adverse habitat impact, D = The most adverse habitat impact, I = Insufficient information - impact or effectiveness of the method could not be evaluated, - = Not applicable.).

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	A	A	A	A
Barriers/Berms	-	-	-	-	-
Manual Oil Removal/Cleaning	-	-	B	B	B
Mechanical Oil Removal	-	-	-	-	-
Sorbents	-	B	A	A	A
Vacuum	-	A	A	A	A
Debris Removal	-	A	A	A	A
Sediment Reworking	-	-	-	-	-
Vegetation Removal	-	-	-	-	-
Flooding	-	-	-	-	-
Low-Pressure, Ambient-Water Flushing	-	A	A	B	B
High-Pressure, Ambient-Water Flushing	-	B	B	B	B
Low-Pressure, Hot-Water Flushing	-	-	C	C	C
High-Pressure, Hot-Water Flushing	-	-	C	C	C
Steam Cleaning	-	-	D	D	D
Sand Blasting Cleaning	-	-	D	D	D
Solidifiers	-	-	-	-	-
Shoreline Cleaning Agents	-	-	C	C	C
Nutrient Enrichment	-	-	-	-	-
Natural Microbe Seeding	-	-	-	-	-
In-Situ Burning	-	-	-	-	-

Source: NOAA, (2001).

Table 3: Environmental Considerations for Marine Oil Spill Response ESI 1B.

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	A	A	A	A
Barriers/Berms	-	-	-	-	-
Manual Oil Removal/Cleaning	-	-	B	B	B
Mechanical Oil Removal	-	-	-	-	-
Sorbents	-	B	A	A	A
Vacuum	-	-	-	-	-
Debris Removal	-	-	-	-	-
Sediment Reworking	-	-	-	-	-
Vegetation Removal	-	-	-	-	-
Flooding	-	-	-	-	-
Low-Pressure, Ambient-Water Flushing	-	A	A	B	B
High-Pressure, Ambient-Water Flushing	-	B	B	B	B
Low-Pressure, Hot-Water Flushing	-	-	C	C	C
High-Pressure, Hot-Water Flushing	-	-	C	C	C
Steam Cleaning	-	-	D	D	D
Sand Blasting Cleaning	-	-	D	D	D
Solidifiers	-	-	-	-	-
Shoreline Cleaning Agents	-	-	B	B	B
Nutrient Enrichment	-	-	-	-	-
Natural Microbe Seeding	-	-	-	-	-
In-Situ Burning	-	-	-	-	-

Source: NOOA, (2001).

Figure 3: ESI 1A. Los Hervideros (Yaiza-Lanzarote)

Source: Google Image Database.

2.2. *Exposed, Non-Vertical and Waterproof Substrates (Exposed wave-cut platforms in bedrock ESI 2A*

These coasts are low rated, since these are exposed to high wave energy. However, they have a flatter intertidal zone, sometimes with small accumulations of sediment in the high tide line, where oil may persist for several weeks or months. Biological impacts can be immediate and serious, especially if oil from recent spills covers the depressions of the rocky platforms where biological communities are deposited. However, oil is usually quickly withdrawn from the platform by the action of the waves. The oil will not stick to the moist surface of the rock, but could penetrate the cracks and surface layers of the sediments. Cleaning is not necessary with the exception of the removal of oily wastes and oil deposits at the high tide line, in areas of high recreational use or to protect a near-beach resource such as seabirds. Table 4 compares the relative environmental impact of each response method in the specific habitat and environment.

Table 4: Environmental Considerations for Marine Oil Spill Response ESI 2.

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	A	A	A	A
Barriers/Berms	-	-	-	-	-
Manual Oil Removal/Cleaning	-	B	B	B	B
Mechanical Oil Removal	-	-	-	-	-
Sorbents	-	B	A	A	A
Vacuum	-	A	A	A	A
Debris Removal	-	A	A	A	A
Sediment Reworking	-	-	-	-	-
Vegetation Removal	-	-	-	-	-
Flooding	-	A	A	B	B
Low-Pressure, Ambient-Water Flushing	-	A	A	B	B
High-Pressure, Ambient-Water Flushing	-	B	B	B	B
Low-Pressure, Hot-Water Flushing	-	D	C	C	C
High-Pressure, Hot-Water Flushing	-	D	C	C	C
Steam Cleaning	-	-	D	D	D
Sand Blasting Cleaning	-	-	D	D	D
Solidifiers	-	C	C	-	-
Shoreline Cleaning Agents	-	-	C	C	C
Nutrient Enrichment	-				
Natural Microbe Seeding	-	I	I	I	I
In-Situ Burning	-	D	D	D	-

Source: NOOA, (2001).

Figure 4: ESI 2A. La Santa (Tinajo-Lanzarote).

Source: Google Earth (Panoramio).

2.3. *Semipermeable Substrate (Fine- to medium-grained sand beaches ESI 3A)*

This category includes exposed sandy beaches on offshore coasts, sheltered sand beaches along bays and steep sandy beaches. These beaches are flat or moderately sloping and relatively compact, which inhibit oil penetration, minimizing the amount of contaminated sediment for disposal. On exposed beaches, if the spill oil reaches the coast following erosion caused by a storm or at the beginning of a deposition period, the oil can be buried in a contaminated layer up to one meter deep. In protected sand beaches, this phenomenon is not usually worrying due to the low energy of the waves.

These beaches are one of the easiest to clean littoral types, concentrating on removing oil and its remains from the upper intertidal zone once most of the oil has reached the shore. Manual cleaning is advised instead of cleaning using bulldozers or excavators to minimize the volume of sand extracted from the coast and to avoid mixing of oil deeper into the sediment. Table 5 compares the relative environmental impact of each response method in the habitat and specific environment.

Table 5: Environmental Considerations for Marine Oil Spill Response ESI 3.

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	B	B	C	D
Barriers/Berms	B	B	B	B	B
Manual Oil Removal/Cleaning	D	B	A	A	A
Mechanical Oil Removal	D	B	B	B	B
Sorbents	-	B	A	A	B
Vacuum	-	-	B	A	A
Debris Removal	-	A	A	A	A
Sediment Reworking	D	B	B	B	B
Vegetation Removal	-	C	C	C	C
Flooding	A	A	A	B	C
Low-Pressure, Ambient-Water Flushing	B	B	B	B	C
High-Pressure, Ambient-Water Flushing	-	-	-	-	-
Low-Pressure, Hot-Water Flushing	-	-	C	C	C
High-Pressure, Hot-Water Flushing	-	-	-	-	-
Steam Cleaning	-	-	-	-	-
Sand Blasting Cleaning	-	-	-	-	-
Solidifiers	-	-	B	-	-
Shoreline Cleaning Agents	-	-	C	C	C
Nutrient Enrichment	-	A	A	B	C
Natural Microbe Seeding	-	I	I	I	I
In-Situ Burning	-	-	C	C	C

Source: NOOA, (2001).

Figure 5: ESI 3A. Parque Natural de Jandía (Fuerteventura).

Source: Google Earth (Panoramio).

2.4. *Substrate with Medium Permeability (Coarse-grained sand beaches ESI 4)*

The coarse-grained sand beaches are classified with a higher degree of environmental sensitivity, due to the greater possibility of oil penetration into the substrate that can reach up to one meter deep. These beaches can undergo very rapid depositional and erosive cycles, with a high burial potential, even after a single tidal cycle. Cleaning is more difficult because the sediments are loose and must be processed for cleaning. The relative environmental impact of each response method practically coincides with the recommendations described in ESI 3.

Figure 6: ESI 4. Charco los Clicos (Lanzarote).

Source: Google Earth (Panoramio).

2.5. *Substrate with Medium to High Permeability (Mixed sand and gravel beaches ESI 5)*

Because of the mixed sediment sizes on these moderately inclined beaches, there may be areas of pure sand, pebbles, or gravel.

Table 6: Environmental Considerations for Marine Oil Spill Response ESI 5.

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	B	B	C	C
Barriers/Berms	C	C	C	B	B
Manual Oil Removal/Cleaning	D	C	B	A	A
Mechanical Oil Removal	D	C	B	B	B
Sorbents	-	A	A	B	B
Vacuum	-	-	B	B	B
Debris Removal	-	A	A	A	A
Sediment Reworking	D	B	B	B	B
Vegetation Removal	-	C	C	C	C
Flooding	A	A	B	C	C
Low-Pressure, Ambient-Water Flushing	B	A	A	B	C
High-Pressure, Ambient-Water Flushing	-	-	C	D	D
Low-Pressure, Hot-Water Flushing	-	-	C	C	C
High-Pressure, Hot-Water Flushing	-	-	D	D	D
Steam Cleaning	-	-	D	D	D
Sand Blasting Cleaning	-	-	-	-	-
Solidifiers	-	-	B	-	-
Shoreline Cleaning Agents	-	-	C	C	C
Nutrient Enrichment	-	A	A	B	C
Natural Microbe Seeding	-	I	I	I	I
In-Situ Burning	-	-	C	C	C

Source: NOOA, (2001).

Due to the greater permeability, the oil tends to penetrate deeply making it difficult to remove contaminated sediments without causing erosion and problems associated with the disposal of these sediments. These beaches may experience seasonal variations in wave energy and, therefore, vary the pattern of sediment distribution. Large accumulations of soaked oil should be rapidly removed from the upper beach area, limiting the removal of sediments to the maximum. low-high-pressure washing can be effective if all the released oil is recovered by collectors or sorbent material. Table 6 compares the relative environmental impact of each response method in the habitat and specific environment.

Figure 7: ESI 5. Playa La Arena (Lanzarote).

Source: Google Earth (Panoramio).

2.6. Substrate with High Permeability (Gravel beaches ESI 6A / Loose rock dikes (breakwater / RIP-RAP) ESI 6B)

The gravel beaches are classified with high ESI, due to the deep penetration of the oil and its slow removal of the subsoil due to the low natural rates of removal. Cleaning the gravel beaches is difficult.

Table 7: Environmental Considerations for Marine Oil Spill Response ESI 6A.

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	A	B	B	B
Barriers/Berms	-	B	B	B	B
Manual Oil Removal/Cleaning	D	C	B	B	A
Mechanical Oil Removal	D	D	C	C	C
Sorbents	-	A	A	B	B
Vacuum	-	-	B	B	B
Debris Removal	-	A	A	A	A
Sediment Reworking	D	B	B	B	B
Vegetation Removal	-	-	-	-	-
Flooding	A	A	B	C	C
Low-Pressure, Ambient-Water Flushing	A	A	A	B	C
High-Pressure, Ambient-Water Flushing	-	-	B	B	B
Low-Pressure, Hot-Water Flushing	-	-	C	B	B
High-Pressure, Hot-Water Flushing	-	-	C	C	C
Steam Cleaning	-	-	D	D	D
Sand Blasting Cleaning	-	-	-	-	-
Solidifiers	-	-	B	-	-
Shoreline Cleaning Agents	-	-	B	B	B
Nutrient Enrichment	-	A	A	B	B
Natural Microbe Seeding	-	I	I	I	I
In-Situ Burning	-	-	C	C	C

Source: NOOA, (2001).

For these beaches, the action of waves must be sufficiently energetic to cause the modification of sediments to a depth equal to that of oil penetration, only occurs every few years, generating the long-term persistence of oil from the subsoil. Table 6 compares the relative environmental impact of each response method in the habitat and specific environment.

Table 8: Environmental Considerations for Marine Oil Spill Response ESI 6B.

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	A	B	B	B
Barriers/Berms	-	-	-	-	-
Manual Oil Removal/Cleaning	-	A	A	A	A
Mechanical Oil Removal	-	-	B	C	C
Sorbents	-	A	A	B	B
Vacuum	-	-	A	A	A
Debris Removal	-	A	A	A	A
Sediment Reworking	-	-	-	-	-
Vegetation Removal	-	-	-	-	-
Flooding	A	A	B	C	C
Low-Pressure, Ambient-Water Flushing	A	A	B	C	C
High-Pressure, Ambient-Water Flushing	A	A	B	B	C
Low-Pressure, Hot-Water Flushing	-	C	C	C	C
High-Pressure, Hot-Water Flushing	-	C	C	C	C
Steam Cleaning	-	-	D	D	D
Sand Blasting Cleaning	-	-	D	D	D
Solidifiers	-	B	B	-	-
Shoreline Cleaning Agents	-	-	B	B	B
Nutrient Enrichment	-	A	A	B	B
Natural Microbe Seeding	-	I	I	I	I
In-Situ Burning	-	-	D	D	-

Source: NOOA, (2001).

Within the typology of ESI 6B we find the riprap structures that are composed of blocks of granite, concrete, limestone or other materials, ranging in size from rocks to crags. Riprap structures are used as coverings and breakwaters for the protection of the shore or edge of beach, and as breakwaters and channeling dikes around nipples and recreational ports. Table 7 compares the relative environmental impact of each response method in the specific habitat and environment.

Figure 8: ESI 5. ESI 6B. Caleta de Fuste (Fuerteventura).

Source: Google Earth (Panoramio).

2.7. *Protected Waterproof Substrate (Sheltered rocky shores (impermeable) and sheltered scarps in bedrock ESI 8A / Sheltered, solid man-made structures, and sheltered rocky shores ESI 8B / Sheltered RIP-RAP ESI 8C / Sheltered rocky rubble shores ESI 8D)*

In these coastal regions, the oil tends to cover the porous surfaces of the rocks in a persistent way because these are areas of low energy. Behavior and persistence patterns relative to oil are similar in regions designated with ESI 8. Cleanliness is necessary because natural elimination rates are often slow. However, the cleaning tasks are often difficult and through intrusive techniques. Table 8 and Table 9 compares the relative environmental impact of each response method in the habitat and specific environment.

Table 9: Environmental Considerations for Marine Oil Spill Response ESI 8A.

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	A	B	B	B
Barriers/Berms	-	-	-	-	-
Manual Oil Removal/Cleaning	-	C	B	C	C
Mechanical Oil Removal	-	-	-	-	-
Sorbents	A	A	B	C	C
Vacuum	-	B	B	B	C
Debris Removal	-	A	A	A	A
Sediment Reworking	-	-	-	-	-
Vegetation Removal	-	-	D	D	D
Flooding	-	A	A	B	C
Low-Pressure, Ambient-Water Flushing	-	A	A	B	C
High-Pressure, Ambient-Water Flushing	-	C	B	B	C
Low-Pressure, Hot-Water Flushing	-	-	D	D	D
High-Pressure, Hot-Water Flushing	-	-	D	D	D
Steam Cleaning	-	-	D	D	D
Sand Blasting Cleaning	-	-	D	D	D
Solidifiers	-	C	C	-	-
Shoreline Cleaning Agents	-	-	B	B	B
Nutrient Enrichment	-	A	B	C	C
Natural Microbe Seeding	-	I	I	I	I
In-Situ Burning	-	D	C	C	C

Source: NOOA, (2001).

Table 10: Environmental Considerations for Marine Oil Spill Response ESI 8B.

RESPONSE METHODS	I	II	III	IV	V
Natural Recovery	A	A	B	B	B
Barriers/Berms	-	-	-	-	-
Manual Oil Removal/Cleaning	-	B	B	B	B
Mechanical Oil Removal	-	-	-	-	-
Sorbents	-	A	A	B	B
Vacuum	-	-	-	-	-
Debris Removal	-	A	A	A	A
Sediment Reworking	-	-	-	-	-
Vegetation Removal	-	-	-	-	-
Flooding	-	-	-	-	-
Low-Pressure, Ambient-Water Flushing	-	A	B	C	C
High-Pressure, Ambient-Water Flushing	-	B	B	C	C
Low-Pressure, Hot-Water Flushing	-	-	C	C	C
High-Pressure, Hot-Water Flushing	-	-	C	C	C
Steam Cleaning	-	-	D	D	D
Sand Blasting Cleaning	-	-	D	D	D
Solidifiers	-	-	-	-	-
Shoreline Cleaning Agents	-	-	B	B	B
Nutrient Enrichment	-	I	I	I	I
Natural Microbe Seeding	-	I	I	I	I
In-Situ Burning	-	-	-	-	-

Source: NOOA, (2001).

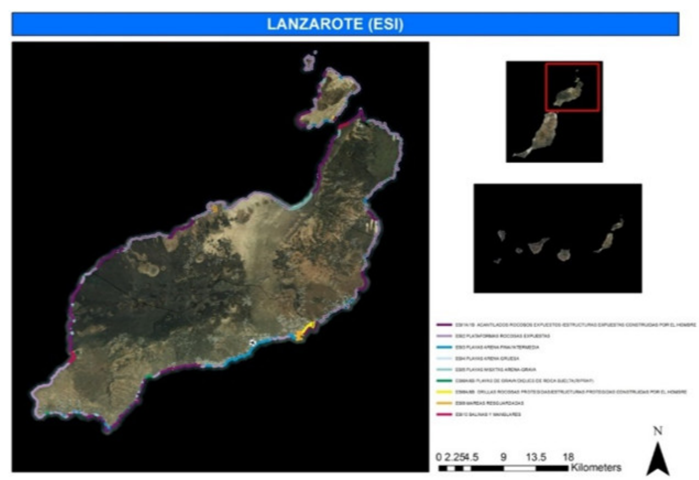
Figure 9: ESI 5. ESI 8B. Caleta de Fuste (Fuerteventura).

Source: Google Earth (Panoramio).

Results and Conclusions

Depending on the parameters described in the previous lines, a series of ESI maps have been generated for the islands of Lanzarote and Fuerteventura (Figure 10 and Figure 11).

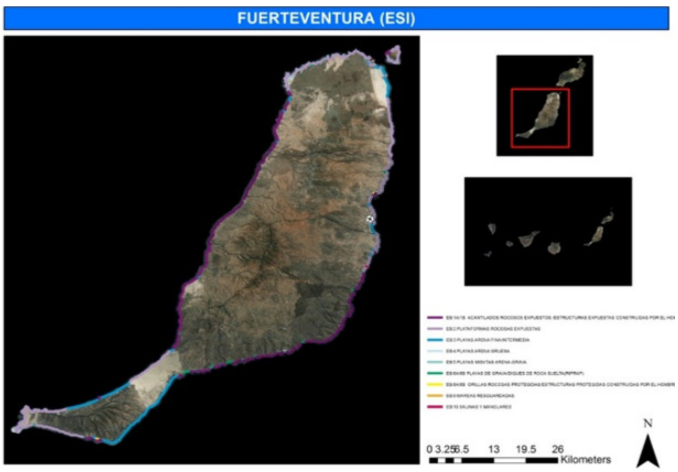
Figure 10: ESI Map of Lanzarote (Canary Islands).



Source: Authors.

In any contingency plan for a spill of hydrocarbons spilled into the sea, it is necessary to always take into account the location of all coastal environments and especially those with a special sensitivity to hydrocarbons. To minimize the impact of a hydrocarbon spill, it is necessary to manage the available environmental information in the most operational way possible. The cleanliness of coastal areas is considerably more difficult and requires more time than the containment and recovery of the oil in the water. It should be borne in mind that the physical separation of crude oil from some types of coast can cause more physical and ecological damage than would occur if a natural process were to be followed. The decision to commence clean-up and restoration of contaminated areas of crude oil must be based on a careful assessment of socio-economic or aesthetic ecological factors. The criteria to take into account to take this important decision are the behavior of crude oil in coastal areas, the protection of the coasts, the own coastal sensitivity to the cleaning methods and the own restoration methods.

Figure 11: ESI Map of Fuerteventura (Canary Islands).



Source: Authors.

The crude oil that reaches the coast affects it to some extent; however, the impact of crude oil and cleaning operations is greater in biologically active areas from the point of view of the environment. In order to assess the desirability of undertaking the cleaning of a coastal area, it is also necessary to consider the probable speed of the natural processes of dispersion and degradation under local climatic conditions and the sensitivity of the contaminated areas. Depending on the various factors and the characteristics of the different zones, these can be ordered according to the priority of their cleaning when they are affected by crude oil. Thus, areas where natural oil separation may be relatively rapid or those that are not ecologically sensitive may be classified as low priority; by contrast, in those in which oil may remain for years and those in which biological sources may be seriously affected, would be classified as high priority. To these considerations we should add others such as the effectiveness of the cleaning and restoration equipment and available technology, the steepness of the coast and its composition (sand, pebbles, rocks?). The development of the ESI maps of the islands of Fuerteventura and Lanzarote and their integration into SIROCO allow us to characterize the coastal zones most likely to suffer the impact of a hypothetical hydrocarbon spill in waters near the coast of the eastern islands of Canary Islands.

References

Bergueiro, J.R. et al. (2001). La Gestión de los Derrames de Hidrocarburos en el Mar. Palma de Mallorca: Ref. I.S.B.N.: 84-699-60571.

Ezcurra. (2012). Estudio de Impacto Ambiental y Social Previo a la Prospección Sismica Costa Afuera. Panamerican energy LLC. Ezcurra & Schmidt S.A.

NOAA. (2002). Jill PETERSEN. Environmental Sensitivity Index Guidelines.Hazardous Materials Response Division. Office of Response and Restoration. NOAA Ocean Service.

SOCIB. (2010). Sensibilidad Ambiental de la Costa (métodos). ICTS SOCIB. Sistema d?observació i predicció costaner de les Illes Balears.

SOCIB. (2010). Sistema d?observació i predicció costaner de les Illes Balears. Ministerio de Ciencia e Innovación y Gobierno de las Islas Baleares.