RESULTS OF A THREE YEAR MONITORING PROGRAMME ON THE NATURAL RECOVERY OF VEGETATION AFTER THE ERIKA OIL SPILL: LESSONS FOR ADAPTING RESPONSE TECHNIQUES

Florence Poncet
Cedre
Rue Alain Colas, BP 20413
29604 Brest Cedex, France
florence.poncet@le-cedre.fr

Rémy Ragot
Cedre
Rue Alain Colas, BP 20413
29604 Brest Cedex, France
remy.ragot@le-cedre.fr

Franck Laruelle
Cedre
Rue Alain Colas, BP 20413
29604 Brest Cedex, France
franck.laruelle@le-cedre.fr

Frederic Tintilier
Cedre
Rue Alain Colas, BP 20413
29604 Brest Cedex, France
frederic.tintilier@le-cedre.fr

ABSTRACT: *The Erika oil spill and the attendant cleaning operations it required have impacted almost every type of Breton shoreline, habitats and plant communities on shingle and sandy beaches, rocky cliffs, marshlands and dunes. The French Ministry of the Environment (Ministère de l'écologie et du développement durable) launched an impact assessment in 2000 on oil spill clean-up operations and the recovery of impacted vegetation via the «Réseau de suivi des conséquences écologiques et écotoxicologiques de la marée noire résultant du naufrage de l'Erika» (Monitoring network of the ecological and ecotoxicological consequences of the Erika oil spill). The* Cedre *and the Conservatoire Botanique National de Brest are dealing with the terrestrial vegetation program. Vegetation was surveyed in sixty locations where one hundred quadrates were recorded covering all vegetation types including all the degrees of oiling and the varying amounts of damage resulting from the removal of the HFO. A few examples of the oiled areas are discussed. The three year monitoring program shows a high degree of persistence of the HFO in uncleaned quadrates of a number of habitats. The FO 6 did no really serious damage in terms of mortality, vegetation cover and species composition. The survey illustrates how gentle manual oil removal techniques can enhance vegetation recovery within the space of a few years. It also exemplifies how some techniques have a very negative impact such as HWHP washing which only serves to delay recovery.*

Introduction

The Administrative Regions of Bretagne and the Pays de la Loire in addition to the Ministry of the Environment (now called the Ministry of the Environment and Sustainable Development) have initiated a 5-year Monitoring program on the ecological and ecotoxicological consequences of the Erika oil spill (2000-2004). As part of the program the *Cedre* and the Conservatoire Botanique de Brest have set up an observation network of about sixty stations in which 100 representative permanent quadrates have been set up to exemplify the diversity of the habitats, species, degrees of oiling and the clean-up techniques involved. Standard field investigation techniques are being used : phytosociological surveys (total plant cover for each species, abundance-dominance coefficients per species, minimum, maximum and average plant height and phenology), contact points, individual counting and photographic monitoring. The findings reported here are not final and are the result of a three year monitoring program.

The context

The Erika broke up and sank off the south coast of Finistère on 12 December 1999 generating a spill of 20,000 tonnes of FO 6. The oil drifted and weathered for 12 days before it beached after sustaining very rough seas that broke the slick up and heavily emulsified the oil before it reached the shoreline. When the slicks reach the shore with these storm conditions combined to very high spring tides, the oil was sprayed very high into the upper level of the intertidal zone and as far as the supratidal zone which is normally only affected by sea spray. Consequently, the oil covered lichens and land vegetation. In fact, every single type of vegetation present along the south Britain and Pays de la Loire coastline was oiled, namely the saltmarshes, sand or shingle beaches pioneer communities in addition to dunes, rocky cliffs or sommital aerohaline grasses.

Pollution features and extent

This oil spill stretched from the northern end of the bay of Audierne as far as the northern tip of the island of Oléron (just short of 400 kilometers all told). The oiling was very patchy, and involved very small tarballs and sizeable oil-cakes (10 - 20 centimeters in diameter) spray and slicks of varying sizes (several

hundred to several thousand square meters). Plant damage was variable and involved either partial or total sommital oiling not to mention thick oil patches at the foot of the vegetation. The oil covered the ground either entirely or partially forming deposits that were several centimeters thick and made up of pure emulsion in the rocky areas or gradually mixed with sand on beaches and dune areas.

Bunker C is very viscous, hardly volatile and only slightly soluble and hardly infiltrated sediment layers which was a boon for the root systems. However as far as sand and shingle layers were concerned sedimentary displacement did bury some of the oil.

From February to March 2000, responders walked over 380 kilometers(cf.1&2) along the coastline in a bid to assess how much of the coastline was affected (maps used were 1:25,000).

During the 3 year monitoring program we managed to identify 195 species that were directly impacted by the oil (on the plant itself or in the soil), or affected by the clean-up.

Rocky habitats (plants found in cracks in the rocks or on the top of cliffs and shingle beaches)	109 kms
Sandy habitats (top end of the beach, sand dunes and stable dunes)	88 kms
Salt marshes	24 kms
Coastal marshes	22 kms

NB. There can be several habitats on the same site which explains why the total of oiled coastline is not equal to the actual stretch of the coastline that was oiled.

Figure 1. Areas with plant cover that was either slightly or heavily oiled.

The vegetation issue and clean-up

People's recollections of how seriously the vegetation was impacted by the clean-up operation in the wake of the AMOCO CADIZ brought the regional bureau of the Ministry of the Environment (DIREN) to mobilize as many environmental experts - especially botanists -as possible.

In some case, the vegetation trapped great quantities of oil, for example in the salt marshes of Loire Atlantique, and the risk of recontamination of shellfish breeding areas afford a rapid removing of the bulk of the oil. In most of the case the clean-up of area with vegetation had to be deferred.

As the removal of the the bulk of the oil involve generally Polmar teams of soldiers, Civil Defence and Fire brigade personnel who had no training in how to clean up vegetation, the fact of deferring the clean-up helped officials to organize environmental expert involvement. In addition it also sought mutual agreement on where to start clean up, the techniques to use and deciding on how far clean up operations should go (how clean is clean ?).

Botanists co-operated with *Cedre* (French organism in charge of technical aspects for oil spill cleaning operations) and were supervised by the regional environment bureau (DIREN) in their efforts to devise prior technical recommendations. These discussions include questions as, where to start clean up operations and treat polluted plant cover, what precautions would be required to minimize the impact of storage facilities and vehicle access to clean up sites, on areas where the vegetation was not oiled.

A number of solutions were advocated for cleaning up the oiled vegetation along the coastline from one «Département» (county) to another. Some botanists supervised the clean-up job done by the fire brigade in the saltmarshes in Bourgneuf Bay. Companies specialized in coastal clean-up and volunteers from environmental conservation associations also supervised the work done by unskilled responders that were employed by local

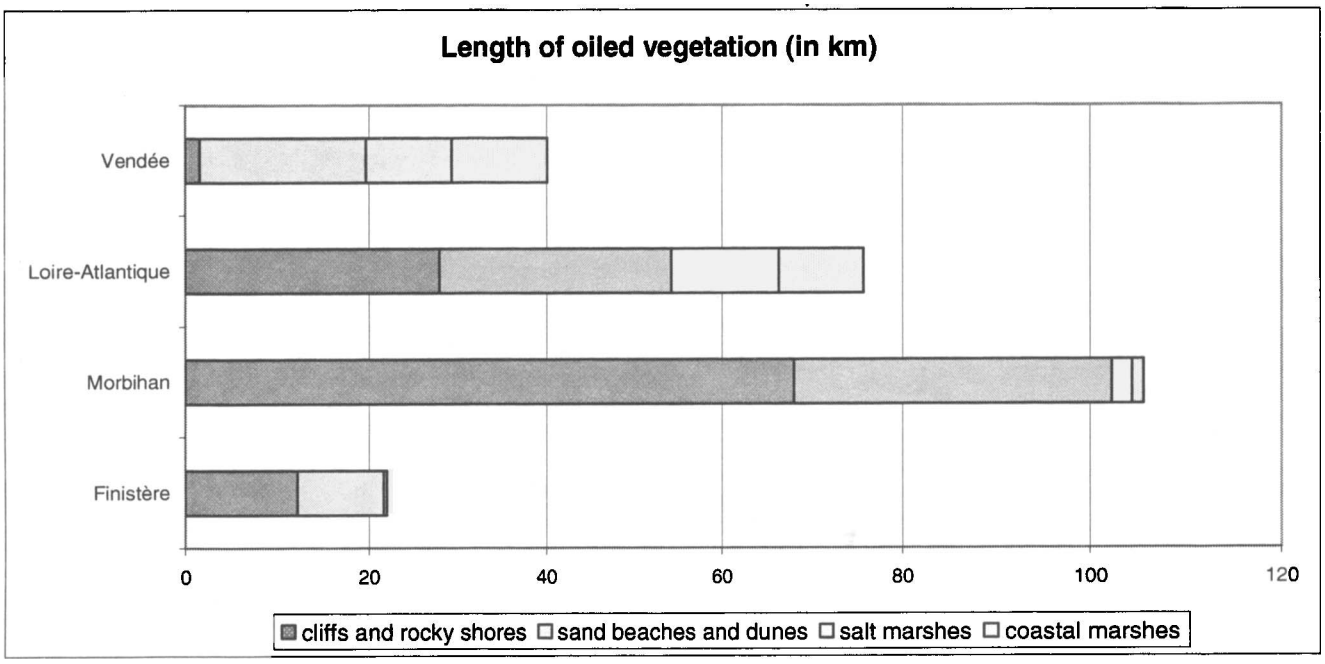

Figure 2. Length of oiled vegetation (in km).

authorities. A company specialized in pollution response, in charge of sensitive areas cleaning in islands, secured the services of a botanist in addition to hiring other dedicated response personnel. From this patchwork of solutions arose a very varied response to recommendations and how they should be applied in addition to deciding where and how far to clean up.

Techniques

The techniques were mainly manual ones based on the use of light duty equipment such as gardening, fishing or masonry tools. It consisted of cutting oiled plants when the species can afford it and/or selective and gentle scraping of oil accumulated at the foot of the plants. Manual screening techniques were used in the dunes. In all case the aim was the elimination of only a part of oil, to enhance recontamination and help the environment to restore itself.

Severely polluted shingle had to be cleaned in concrete mixers but no important plant species were involved. Vegetation transition areas were treated with varying techniques depending on the site and the personnel being employed for that purpose: annual vegetation found at the top end of beaches (as seeds since winter was about to start) were affected by beach cleaners that people used as there was apparently no vegetation to speak of at this time of year instead of cordoning the areas off and screening the beaches by hand. Pioneer vegetation on the rocky cliffs and areas covered by lichen were sometimes treated as bare rock surfaces and hosed down by HWHP washers. The monitoring network was set up purposefully to observe all of this.

Impact of pollution and of clean-up techniques

A few examples will now be chosen to illustrate the impact of pollution and clean-up on some plant communities (this article does not address issues such as indirect impact regarding access to sites and the use of site clean-up equipment).

1. A cliff-top marsh that was polluted but not cleaned.

Description: a small cliff-top marsh located along a low rocky coastline comprised a gentle slope leading down to the sea contained by a very small cliff. Plants grow on a mixture of shingle and soil and freshwater seeps naturally from the ground. High spring tides deposit seaweed and flotsam and jetsam. This little marsh is very characteristic on account of its plant diversity as fourteen plants were found there including one very rare plant, the *Triglochin palustre*.

Pollution: a film of oil was deposited on the marsh and was trapped by the vegetation. The oil coated the base of the stems and the leaves of high growing plants and covered low growing plants such as the *Glaux maritima* (hemicryptophyte).

Clean-up: only the rocky surfaces were treated with HWHP washers; the marsh is in an unvisited area and it was not treated at all.

Monitoring: each year botanists perform a phytosociological survey in the marsh and take photographs in addition to spotting oil. Samples of *Glaux maritima* were taken for analysis purposes.

Observation conclusions:

- oil still present in summer 2002, 2 to 5 centimeters thick, still sticky at the lower part of the quadrate. Elsewhere in the quadrate, plants push through the crust formation and fragment the oil crust that then mixes with shingle and plant debris. In spring each year the *Glaux maritima* buds push their way through the oil crust formation;
- plant cover is in good condition and the plant cover is still almost entirely coated with oil (95%) after three years of observation;
- no change was found in species composition;
- a slight drop in *Phragmites communis* but more *Juncus maritimus* in 2002.

Discussion: several small marshes can be found in the rocky surfaces that abound along this part of the shoreline where ecological conditions vary a lot which means there is no unpolluted benchmark. No impact of oil can be noticed. Increasingly, plants continue to push through the oil crust and fragment the oil crust that is still there three years later.

2. Bourgneuf Bay saltmarshes, highly polluted and supervised by botanists during clean-up operations.

Description and pollution: the saltmarshes at the bottom end of Bourgneuf Bay cover a 44 hectare area of which 5 hectares were severely oiled but no assessment was performed to determine the extent of fragmented pollution. The oil was trapped by the channels, at the high tide levels and especially around the edges of vegetation made up mainly of *Spartina maritima* sward, the best example of this kind of vegetation in France, elsewhere people tend to find *Spartina alterniflora* (from America) or *Spartina anglica* (a hybrid). In the center of the vegetation, experts found patches of oil cakes.

Since these communities are so important and in view of the recontamination risk to nearby shellfish breeding areas, clean-up was performed quickly and completed prior to budding and was supervised by botanists.

Clean up (Lacroix & Lachaud 2000):

- access roads and pathways were channeled, materialized and protected and the work site was organized so as to avoid trampling; itineraries used by quads for evacuating collected materials and pollutants skirted the sea-purslane *(Halimione portulacoides)* silver scrubs and the shrubby sea-blite (*Suaeda vera*) scrubs on consolidated sediment;
- vegetation was not uprooted but the polluted haulm of *Spartina maritima* was cut 5 centimeters above ground level and the heavily oiled stems of *Suaeda vera* scrubs were cut 10 centimeters above ground level;
- a small fork used for scraping mussels was used to remove the oil and bigger forks were used at high water marks in the event of heavy oiling but no sediment was removed so as to protect the root systems and leave seeds intact.
- when the work sites were started up, some were trampled and on one or two occasions pubic works equipment was used for grading so as to remove the bulk of the polluted seaweed.

Monitoring: 11 quadrates were set up in the Bay

Observation conclusions:

- annual Glasswort (*Salicornia sp.*) swards (2 quadrates): both were oiled but only one was cleaned. In the one that was not cleaned surveys showed no evidence of impact on the vegetation. Plant phenology and size did not change over the three year period. The one that was cleaned, was raked by the small mussel fork and the bigger fork. In which case, plant cover decreases gradually as does the *Salicornia sp.* Conversely, common saltmarsh-grass *(Puccinella maritima)* tends to spread. We can say that oil had no impact on the survey as the phenology and the size of the plants were not affected. The *Salicornia sp* annual swards dropped off as the channel bank was eroded which is where the quadrate was set up. In the Bay, no

significant impact was observed on the annual glassworts apart from locations trampled by vehicles. In some locations, vehicles did cross bare mudflats (in winter) that are colonized in summer by the *Salicornia.* Vehicle tracks recolonize only slightly if at all initially and we had to wait three years for recolonization to appear.

- *Spartina maritima* swards (3 quadrates): all the quadrates were located in oiled areas. Two were cleaned but the third one was not cleaned and was used as a control. In one quadrate, *Spartina* was cut to remove the oiled vegetation and after three years of monitoring, no oil effect was reported. *Spartina* was also cut in the other quadrate and oil was raked out by people using mussel forks but thick oil patches still remain in this quadrate (recurrent arrivals). The plant cover receded and the oil patches covering the area did not recolonize afterwards. In the control quadrate after two stable years, *Spartina* is lower and plant cover is slightly less. In the Bay, the cordgrass cycle was not affected, it flowered every year. *Spartina* developed every year but had a hard time to recolonize oil patches that beached and were deposited after the grass was cut and remained. One of the deposits is currently being tested and the crust has been removed on half of the quadrate so as to observe the recolonization process.
- perennial glasswort (*Arthrocnemum perenne)*mats (1 quadrate): the quadrate is in a polluted area but was not cleaned. After two years, no oil effect has been evidenced both in terms of cover and phenology, but this year cover has dropped off a lot owing to erosion along the edges of the saltmarshes grass;
- sea purslane silver scrubs (2 quadrates): two quadrates were located in polluted areas and one only was cleaned up but the markings for the quadrate disappeared. The mussel fork was used for raking the polluted quadrate and there are one or two crusts left on the *Halimione* stems and the soil. Over the three year monitoring period there was a regular drop in plant cover essentially owing to a drop in *Halimione*. Erosion has occurred at the foot of the plant where a small hollow has formed but which has had no effect on plant phenology. The fact that the scrub was oiled must have caused part of the plant to disappear thus enhancing the hollowing out effect at the foot of the plant which is detrimental to the species;
- common saltmarsh grasses *(Puccinella maritima)* (2 quadrates): both quadrates are in polluted areas and have been partially cleaned using the mussel fork. There has been no impact on either quadrate and one of them there has even been an increase in the number of species present (previously 3, now 7);
- shrubby sea-blite scrubs (1 quadrate): This quadrate is also located in a polluted area and was cleaned with the mussel fork. There has been no impact during the monitoring period. Scrubs are smaller in front of this quadrate and the *Suaeda vera* stems have been cut about 10 centimeters above ground level when oiling was severe. New branches are growing on nearly every stem;

Conclusion: The impact of the oil and clean-up in Bourgneuf Bay have not damaged vegetation too much. After a three year monitoring period, the areas have recovered well with virtually no traces of oil except in the cordgrass swards. There has been no large scale mortality of species and plant surfaces but there have been few cases of mortality. The appearance of the salt meadows has not changed and there has been no change in the distribution of plant communities.

3. Impact of HP washing of a rocky surface with heavily oiled rock samphire (*Crithmum maritimum*).

Description and pollution: this is the edge of a rocky surface with an enormous amount of cracks located just behind the beach. *Crithmum maritimum* is colonizing the cracks down at the lower end but the entire area has been severely oiled.

Response: a high pressure washer was used for cleaning the rock surface and the oil in the cracks at the foot of the *Crithmum maritimum* was removed by hand. Owing to the summer sunshine, the oil fluidized and polluted the rock once again. Tests were conducted deliberately to ascertain the resistance capability of the species and the stems and branches were cut at ground level and the washer was used *ad libitum* until all the oil had been removed.

Conclusion: when spring came, *Crithmum maritimum* shoots appeared again and by 2002 the crack was fully colonized once again.

Discussion: the resilience of this species was reported all along the shoreline. There is nonetheless an example of one quadrate where the washer was used three times in a row over a two year period. In 2001 two *Crithmum maritimum* plants disappeared out of a total of three.

In the light of these observations, the recommendation not to clean that was advocated at the outset of the spill may well be eligible for revision for this particular species when there is only one species present.

4. A heavily oiled cliff that was completely cleaned.

Description, pollution: this site is on a rocky cliff formed of schist and is about 85 square metros in size. It was heavily polluted by oil spray that caused oil to drip down the cliff face.

Response: a high pressure washer was used. The cliff is alongside an amenity beach and the rock face nearest the access to the beach was cleaned completely. No trace of oil was left on the rock face. Vegetation and soil had disappeared and the rock face was pitted. Each time we did a survey, more small blocks of stone fell from the pitted rock face.

Conclusion: during the first year and after cleaning, monitoring revealed incipient growth of a few *Crithmum maritimum* plants (cover was about 2 to 3 %) but no flowers appeared the first year. During the second year, the *Crithmum maritimum* plants were ever present alongside two new species that were not native to the habitat. During the third year *Crithmum maritimum* was still developing and small shoots started appearing (two of them) and were native to the habitat, namely Thrift (*Armeria maritima)* and rock sea-spurrey *(Spergularia rupicola).* The total plant cover was estimated at 3 %.

A control quadrate was set up on an unoiled cliff and exposed to the same weather conditions. Plant cover was dominated by red fescue (*Festuca rubra), Crithmum maritimum* and *Armeria maritima* in addition to just under a dozen vascular species, lichens and moss. Vascularia species, moss and lichen plant cover amounted to 95%, 30% for vascular vegetation alone.

Despite the presence of vegetation on a cliff and a sommital grassbed, recolonization had hardly set in three years later and soil in the cracks was still lacking. At present there are no lichens, no moss, only *Crithmum maritimum* has managed to survive. These findings have been confirmed by other quadrates in similar environments that were given the same treatment.

Conclusion: Overall appraisal of direct impact

Quite apart from induced impact, further to the implementation of worksites in unpolluted areas not reported on here, but that are part of the monitoring program, and at the end of the three year period, the following can be said:

- no massive mortality of individuals related to oil has been observed but some plants that were totally or partially coated with oil have disappeared and in some cases necrosis has set in;
- perennial species with oil at the foot of the stems or partially covering the branches and leaves that did not disappear during the first year are still present;
- there was no impact on the plants in the dune systems that were scattered with tarballs or oil cakes mixed with sand;
- there was no significant trend in plant composition in the quadrates that were polluted;
- there was no impact on plant phenology (flowering and fruit-bearing capacity) from the second year onwards;
- in the quadrates that were not cleaned at all, oil persisted a great deal in underexposed conditions and in location that did not include sediment mobility or that were in the upper portion of the intertidal zone and in the spray zone. Oil deposits fragmented to a variable degree that was commensurate with hydrodynamic conditions and/or the plants pushing up through them;
- in sandy habitats oil deposits fragmented efficiently, as thinning occurred in the sediment layers and involved oil burying when sand was blown over the area;
- species reacted diversely to clean-up operations, and the way response techniques were implemented professionally by responders. After three years in most of areas treated and supervised by botanists, there was no impact in the quadrates that were hardly or slightly polluted and slightly cleaned up. Recolonization is slower when severe oiling is followed by a great deal of scraping to remove the oil;
- severely oiled plants were cut. This turned out to be efficient and non detrimental to species for which the technique was recommended. However, this technique cannot be implemented far and wide especially with stems that are sturdy and branched such as *Limonium spp, Armeria maritima* and *Plantago maritima,* because they cannot withstand this kind of treatment;
- negative impacts were reported when HP washers were used as all the plant life was removed in addition to the soil that had accumulated in the cracks in the rocks. In this case growth has hardly started again. *Crithmum maritimum* with its very deep root system that develops in nooks and crannies in the rocks is the first to make an appearance and this often happens a few weeks after HP washing. Two years after, this is virtually the only species growing in some rocky areas that were washed thoroughly.

Having botanists supervise worksites was an original feature of this clean-up operation in France in the field of oil spill clean-up. Areas where plants were not particularly protected can show the negative impact that was finally avoided during the Erika clean-up operation whereas those areas that were supervised by botanists showed good recovery capability.

Oil persisted a great deal in some areas that were not cleaned up at all which only serves to bear out the usefulness of clean-up. The slight impact of Bunker C bears out the claims of botanists who advocated moderate clean-up and in some instance no clean-up at all of the vegetation when the techniques used were likely to generate a major undirect impact.

The continuation of observations in the medium term should afford an improvement of our knowledge of the reactions of plants to this kind of oil and the techniques used to clean it up in a bid to optimize response.

Biography

Florence Poncet is project manager of the terrestrial vegetation impact assessment programme of the Erika oil spill. PhD in Biogeography, she was environmental expert in a consulting firm involved in the Amoco-Cadiz trial for expertise on shoreline damage assessment.

Acronyms

CEDRE : Centre d'Etude et de Recherche sur la Pollution des Eaux
HFO : heavy fuel oil
FO6 : HFO
HWHP washing : hot water high pressure washing

References

1. Lacroix P. & Lachaud A.; 2000; Chanters de depletion de la Bay de Bourgneuf (Vendée) suite à la marée noire de l'Erika. Compte rendu de suivi de chantier; Conservatoire Botanique National de Brest, Plan POLMAR, Cellule environnementale.

Bibliography

1. Laruelle F.; 2002; Nettoyage des surfaces végétalisées suite à la marée noire provoquée par le naufrage de l'Erika; Colloque «Pour des mers plus sûres et plus propres» Les leçons techniques de l'Erika et des autres accidents[a]; Résumés; p. 17-18.
2. Poncet F., Lachaud A., Le Bail J., Tintilier F. & Ragot R.; 2000; Impact de la marée noire de l'Erika. Synthèse des observations sur les espèces végétales et les habitats littoraux terrestres; Conservatoire Botanique National de Brest.
3. Poncet F. & Tintilier F.; 2002; Impacts de la marée noire de l'Erika sur les espèces et communautés végétales terrestres; Colloque «Les évaluations des suites du naufrage de l'Erika»; Résumés; p. 8-9.