Indices to Rate the Degree of Oiling on Shorelines

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Abstract

Shoreline oiling conditions documented by SCAT surveys include data on length and width of oiled area, surface distribution or coverage, and thickness. These data may be combined and used in a variety of ways to support the planning process, the cleanup operations and public information team.

One of the most useful compilations is a rating of the degree of surface oiling in each segment. Detailed field observations are summarized into a simple index, typically described as Trace, Very Light, Light, Moderate, or Heavy. The use of such indices allows a single-value, site-to-site relative comparison that provides a perspective to describe and compare multiple areas or long sections of oiled coast in an easily understandable manner. The indices are a basic data used in setting cleanup priorities and selection of tactics.
A rating scheme for marine tidal environments based on templates from Owens and Sergy 2004, has been used extensively worldwide. The original criteria for the tidal environment rating are explained and variations on this basic concept are described for rating the degree of oiling in non-tidal environments (predominantly freshwater lakes and rivers) and in vegetated marshes.

Introduction

During an oil spill, Shoreline Cleanup Assessment Technique (SCAT) teams survey the affected area to provide geo-referenced documentation on oil and shoreline conditions in a rapid, accurate and systematic process, using standardized methods and terminology. The repeatable methodology provides for consistent data collection and thus allows a comparison of data and observations between different sites, between different observers, and between the same sites over time.

The data and information generated by the SCAT surveys are the basis of spill planning for the operational stages of the shoreline response. Individual data are analyzed and used in a variety of applications (Lamarche *et al.,* 2007). Some of the outputs are at a high level of detail and specificity. In other cases data is grouped to provide an overview or summary level output. One such summary is to provide comparative indices or ratings on the relative severity or degree of shoreline oiling. Detailed field observations are summarized into a simple index, typically described as Trace, Very Light, Light, Moderate, or Heavy.

Formalized indices to rate the degree of oiling based on systematic data, were first developed during the Exxon Valdez in 1989 (Owens and Teal, 1990) ED IS THIS THE CORRECT REFERENCE). A subsequent generic version for the marine environment was created and published by Owens and Sergy (1994, 2000, 2004). The indices are used in a range of applications and data outputs, typically taking the form of summary tables or maps that are used in detail planning, decision making, operations, monitoring progress and explaining the situation and progress to public and media. Examples from actual spills are reported in ED PROVIDE REFERENCE and their derivation generically described in "The SCAT Data Management Manual" (Lamarche *et al*., 2007). Some examples of outputs include (a) Setting priorities. All segments can be ranked according to severity of oiling. Initial priorities can be directed towards segments or groups of segments with 'heavy' oiling conditions. Likewise segments with similar physical characteristics, or shoreline type, or value, can be ranked according to severity of oiling. For example all sand beaches, or all reed beds, or all recreational beaches could be individual ranked so the first cleanup crews can be directed to those with heavy oiling conditions. The above types of groupings and rankings can be done on segments within a work area or operational division to direct the activities of the cleanup task force within than zone, (b) Representing the overall oiling condition. The severity of oiling can be summarily displayed for the entire affected area, or for specific types of shorelines. This can be done to locate them geographically on a map or provide specific information of length of shoreline oiled. This can also be done in a greater level of detail of each individual segment, (c) Monitoring progress. Changes in the oiling conditions within the affected area or a zone can be displayed to demonstrate the progressing cleanup over time.

In this paper we explain the derivation of the original marine tidal environment template. New variations on this basic concept are described for rating the degree of oiling in non-tidal environments (predominantly freshwater lakes and rivers) and in vegetated marshes. The applications of the indices and how they are used or should be used in oil spill response is presented.

Types of Data Used to Develop Indices

Indices to rate or summarize the degree of oiling are based on field data and observations of surface oiling conditions collected in accordance with SCAT methodology (see Owens and Sergy 2000, 2004). Surface oiling conditions can be described in terms of length, width, distribution, thickness, and character of the oil within a specific tidal zone, lake shore, or riverbank. This information is recorded for each segment, sub-segment, or zone within the survey area.

For sediments or bedrock, oiling conditions can be described in terms of

- Length, referring to alongshore (parallel to the shoreline) distance of the oiled area within a segment, sub-segment, or zone
- Width, referring to the average across-shore (perpendicular to shore) distance of the intertidal oil band within a segment, sub-segment, or zone
- Surface Distribution, referring to the actual percent of the surface that is covered by oil within a fixed area. The actual oil distribution measurements can also be categorized or grouped as Trace <1%, Sporadic 1–10%, Patchy 11–50%, Broken 51–90%, Continuous 91–100%
- Surface Oil Thickness, referring to the average or dominant oil thickness within the segment or zone. It is described according to the categories; Thick >1 cm, Cover >0.1 cm and <1 cm , Coat >0.01 cm and <0.1 cm, Stain <0.01 cm, Film/Sheen

For the stems of standing vegetation, oiling can be described in terms of

- Surface Distribution, referring to the percentage of individual stems that are oiled, relative to all the stems, within a fixed area
- % Stem Length Oiled, referring to the width of the oil band on the plant stem relative to the length of the stem

- Oil thickness: refers to the thickness of the oil on the stem using the same criteria as for sediments
- Stickiness: a relative indication of sticky or not sticky

Several of the above data can be combined in various ways to create indices to rate the degree of oiling or relative severity of oiling in a particular segment of shoreline. A few basic principles apply.

1. The indices should be created in the initial stages of the spill.
2. This must be done with some consideration to spill conditions to create a range of oiling categories. In other words there is little value if the categories are all calculated as 'heavy' or if they are all 'light'. There should be some distribution between categories.
3. They are a relative index and not an absolute numerical index.

That being said, it is possible to summarize the degree of oiling at most spills addressed using existing templates, or with fine tuning to adjust those templates presented below.

The Original Tidal Environment Indices

The original tidal (marine) environment indices of Owens and Sergy have been used extensively on spills in the last two decades. The indices are:

Surface Oil Cover = width x surface distribution of the oil (Table 1)

Surface Oiling Category = width x surface distribution x thickness (Table 2)

Surface oil cover (Table 1) can be calculated using estimates from aerial surveys or measurements from ground level surveys. It is often used in the initial stages of the spill. The surface oiling category (Table 2) provides more accurate representation of the severity of oiling. These data must be collected by detail ground surveys. The calculation is a two step process building on the initial categorization from Table 1.

The first index can be used by itself, or with the input of thickness data, used to calculate the second index. For purposes of Table 1 and generic standard of the SCAT manual, the width of the oiled area is categorized or grouped as Wide > 6 m, Medium > 3 m to 6 m, Narrow > 0.5 m to 3 m, Very Narrow < 0.5 m.

Table 1. Surface Oil Cover

		Width of Oiled Area			
		Wide	**Medium**	**Narrow**	**Very Narrow**
Oil Distribution	**Continuous 91 – 100%**	Heavy	Heavy	Moderate	Light
	Broken 51 – 90%	Heavy	Heavy	Moderate	Light
	Patchy 11 – 50%	Moderate	Moderate	Light	Very Light
	Sporadic 1 – 10%	Light	Light	Very Light	Very Light
	Trace < 1%	Very Light	Very Light	Very Light	Very Light

Table 2. Surface Oiling Category

		Initial Categorization of Surface Oil			
		Heavy	**Moderate**	**Light**	**Very Light**
Avera ge Thick	**Thick or Pooled > 1 cm**	Heavy	Heavy	Moderate	Light
	Cover 0.1 – 1.0 cm	Heavy	Heavy	Moderate	Light

	Coat 0.01 – 0.1 cm	Moderate	Moderate	Light	Very Light
	Stain/Film < 0.01 cm	Light	Light	Very Light	Very Light

A numerical hind casting was conducted to validate the distribution of the array ‘heavy’ through ‘very-light’ in Table 1. Calculations were made to determine the area of oil per metre length of shoreline for each of the categories. Since the input parameters of oil distribution and width both have a range of values, therefore the actual amount of oil represented by each of the boxes in the array, also represents a range of potential oil area. For example, the ‘heavy’ category at the intersection of ‘broken’ and ‘medium’ has a range of 1.5 to 2.7 m^2 of oil per metre length of shoreline depending on whether the observed oil distribution was at minimum 51% or maximum 90% value. Averaging the ranges of each of the categories in Table 1 we can summarize the amount of oil represented by the categories. This type of exercise could be performed on any index developed for a spill, if there was a need to quantify the categories.

Table 3. Overall Average and Range of the Amount of Oil Represented by the Surface Oil Cover Category (m^2 of oil per metre length of shoreline).

Category	Average	Range
Heavy	4.4	>6 to 1.5
Moderate	2.0	>3 to 0.3
Light	0.18	1.5 to 0.06
Very Light	0.05	0.3 to <0.005

A One Step Variation on the Original Tidal Environment Indices

The original tidal environment indices calculate surface oil category (Table 2) in a two step process.

width(x)distribution=oil cover category(x)thickness=surface oil category

A one step variation can also be used as illustrated in Table 4.

Table 4. An Alternate Surface Oiling Category Index

Oil Thickness and Width of Oiled Area			Oil Distribution				
			91-100%	**51-90%**	**11-50%**	**1-10%**	**<1%**
	Thick Oil >1.0 cm	**Wide**	Heavy	Heavy	Heavy	Moderate	Light
		Medium	Heavy	Heavy	Heavy	Moderate	Light
		Narrow	Heavy	Heavy	Moderate	Light	Light
		V.Narrow	Moderate	Moderate	Light	Light	Light
	Cover 0.1-1.0 cm	**Wide**	Heavy	Heavy	Heavy	Moderate	Light
		Medium	Heavy	Heavy	Heavy	Moderate	Light
		Narrow	Heavy	Heavy	Moderate	Light	Light
		V.Narrow	Moderate	Moderate	Light	Light	Light
	Coat 0.01-0.1cm	**Wide**	Moderate	Moderate	Moderate	Light	V. Light
		Medium	Moderate	Moderate	Moderate	Light	V. Light
		Narrow	Moderate	Moderate	Light	V. Light	V. Light
		V.Narrow	Light	Light	V. Light	V. Light	V. Light
	Stain <0.01	**Wide**	Light	Light	Light	V.Light	V.Light
		Medium	Light	Light	Light	V.Light	V.Light

		Narrow	Light	Light	V.Light	V.Light	V.Light
		V.Narrow	V.Light	V.Light	V.Light	V.Light	V.Light
	Film/ Sheen	n/a	Sheen	Sheen	Sheen	Sheen	Sheen

Indices for Freshwater and High and Low Tide Environments

Width of oiled area is one parameter that can be very easily adjusted according to the tidal range. For example, oiling widths of > 6m may not exist in a region of small tidal changes such as the Mediterranean, whilst in the Bay of Fundy (Canada), all oiling could exceed this width. In such cases the indices of Table 1 and 2 would skew the actual observations such that most data would be in the heavy or light categories, therefore reducing the usefulness of the index. This is easily corrected by changing the definitions of width to better represent the range of tides and width of oiling experienced in the spill. and the application of .

This simple adjust allows Tables 1 and 2 to be used in the freshwater environment where lake and river shoreline oiling is more a function of wave level and therefore substantial less than tidal environments. During the SCAT data analysis the values used for width criteria can be downsized. A typical range of width parameters that could be used for freshwater shorelines is as follows.

Wide	>100cm
Medium	>20cm to 100cm
Narrow	>2cm to 20 cm
Very Narrow	< 2cm

A Solution for Tar Balls

In spills where tar balls are the primary form of oiling, adaptations can be made to describe the severity of oiling in terms of numbers, size or weight of tar balls per unit area or per metre of length of shoreline.

In the case of the *New Carissa* Spill, the long term SCAT surveys of oiling conditions was modified to be sensitive to the predominant type of long term oiling, namely low level stranding of tar balls (Owens *et al.,* 2000). This was necessary because standard SCAT procedure reports the degree of oiling in terms of a per cent coverage, width, and thickness. Reported in these terms, the surface oiling category area was always reported as "light". Thus for the tar ball monitoring, oil distribution was represented by the frequency (number of tar balls/m^2) and volume (gal) of tar balls and normalized tar ball concentration per unit of area (gm/m^2). At the *New Carissa*, the tar ball distribution data was not actually used to produce a summary index on the severity of oiling, however, such a conversion would have been relatively simple. For example, Corbin at al., (1993) applied a simple schema for ranking tar ball oiling in Caribbean countries based on tar ball weight per m^2 as (a) negligible = 0 to 1.0 g/m, (b) low = 1.0 to 10 g/m, (c) moderate= 10 to 100 g/m, and (d) high > 100 g/m.

Sunken tar ball oiling was addressed during the 2005 Lake Wabamun spill, where Bunker C oil from a train derailment was distributed as sunken tar balls and tar patties on the lake bottom. In this case submerged oil size and distribution were documented by surveys and used to set submerged/sunken oiling category (Sergy, pers com). Those categories were assigned a 1, 2 and 3 to reflect the severity of oiling, and the priority assigned to treatment, with 1 (heavy) being the highest priority (Table 5).

Table 5. Ranking of Severity of Sunken Tar Balls during the Lake Wabamun Spill.

Oil Distribution Tar Balls per 2 m^2		Tar Ball/Tar Pattie Size (Diameter) <2cm	2-10 cm	>10 cm
Low	≤ 2	3 (light)	2 (moderate)	1 (heavy)
Moderate	3-8	2 (moderate)	1 (heavy)	1 (heavy)
High	>8	1 (heavy)	1 (heavy)	1 (heavy)

Marsh Vegetation Index

Rating the degree of oiling for marsh vegetation requires a different approach. Oil floating on the water surface contacts the plant stem and results in an oiled band on the stem. The width (i.e. vertical height) of an oil band depends on water level changes caused by waves, tides or changes in base water levels while the oil is still mobile on the water surface. Oil may or may not contact the sediment in which the same vegetation is rooted.

An index to categorize the oiling of stems of marsh vegetation was developed for the *M/V Westwood Anette* spill in Squamish, BC (Table 6). The vegetation in this case were stiff standing stems of *Carex sp., Eleocharis sp.,*and *Potentilla sp.* The index was based on estimates of the percent of individual plants oiled per square metre and the percentage of the vertical stem that was oiled within the same square metre. The concept is a variation on the approach used in Table 1.

Table 6. Surface Oil Cover Category for Marsh Vegetation.

% of Length of Stem Oiled	Distribution of Individual Plants Oiled: 91-100%	51-90%	11-50%	1-10%	<1%
91-100%	Heavy	Heavy	Moderate	Light	Very Light
51-90%	Heavy	Heavy	Moderate	Light	Very Light
11-50%	Moderate	Moderate	Moderate	Light	Very Light
1-10%	Light	Light	Light	Very Light	Trace
<1%	Very Light	Very Light	Very Light	Trace	Trace

In the case of marsh vegetation is may be useful to describe oiling in terms of the total marsh area, and small representative plots, e.g. $1m^2$. Typically each marsh is a distinct segment, sub-segment or zone within a segment. Table 6 or an adaption can be used to summarize the severity of oiling for an entire marsh, or zones of oiling within a marsh or fixed area plots.

In addition to the actual oiled vegetation, the plant roots/sediments of the marsh may be oiled and this reported and summarized separately. In freshwater lakes and rivers, the roots/sediments of deep water marshes populated by emergent reed beds such as *Scirpus sp.*, typically remain submerged. Oiling on the stems of vegetation could be reported as per Table 6 . For tidal marshes and freshwater marshes that span the shore-water interface, then sediments are exposed and oil on the plant is reported separately from oil on the sediments/roots. In this case, Table 1, 2 or 4 can be used to summarize oiling on the sediments. An adaption was developed for the *M/V Westwood Anette* spill to report oil on sediment within a fixed area, i.e. independent of the size of the oiled area (Table 7). This approach was adopted in order to pair the observations of oil on plants with oil on sediments within 1m^2 fixed areas.

Table 7. Surface Oil Category Index for Fixed Areas of Marsh Sediments oiled by the *M/V Westwood Annette* Spill.

		Oil Distribution				
		91-100%	**51-90%**	**11-50%**	**1-10%**	**<1%**
Oil Thickness	**Thick >1.0 cm**	Heavy	Heavy	Heavy	Moderate	Light
	Cover 0.1-1.0 cm	Heavy	Heavy	Moderate	Moderate	Light
	Coat 0.01-0.1cm	Moderate	Moderate	Moderate	Light	Very Light
	Stain <0.01	Light	Light	Light	Very Light	Very Light
	Film or Sheen	Sheen	Sheen	Sheen	Sheen	Sheen

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