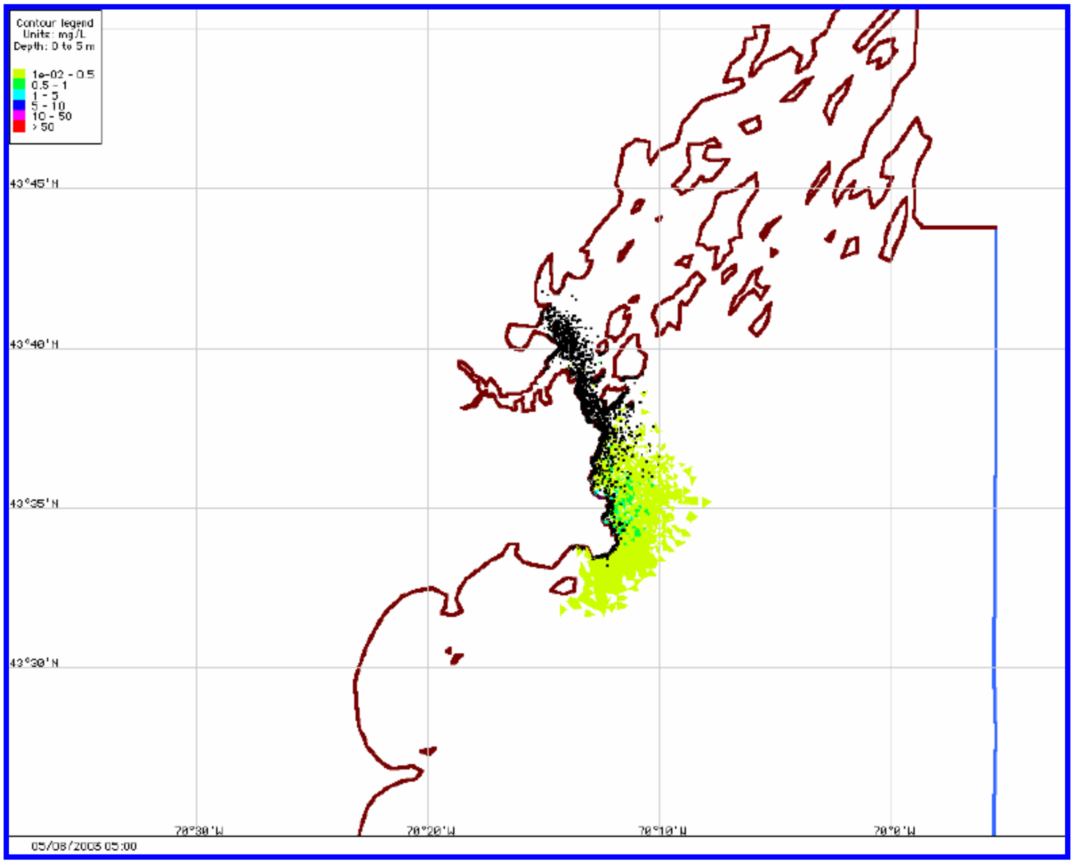
Ecological Risk Assessment: Consensus Workshop

Environmental Tradeoffs Associated With Oil Spill Response Technologies

Casco Bay, Maine



UNITED STATES COAST GUARD
1790

Ecological Risk Assessment: Consensus Workshop

Environmental Tradeoffs Associated With Oil Spill Response Technologies

Casco Bay, Maine

A Report to the Maine/New Hampshire Area Committee

Don Aurand and Laura Walko (Compilers)
Ecosystem Management & Assoc., Inc.

Ecosystem Management & Associates, Inc.
Report 03-02

REPORT AVAILABILITY

Copies of this report can be obtained from the following address:

Commandant (G-MOR-2)
United States Coast Guard
2100 Second Street, SW
Washington, DC 20593
202-267-0518

CITATION

Suggested Citation:

> Aurand, D. and L. Walko (Compilers). 2003. Ecological Risk Assessment: Consensus Workshop. Environmental Tradeoffs Associated With Oil Spill Response Technologies. Casco Bay, Maine. A report to the Maine/New Hampshire Area Committee. Ecosystem Management & Associates, Inc., Lusby, MD. 20657. Technical Report 03-02, 36 pages.

SPONSOR

This report was prepared under Purchase Order DTCGG8-03-C-MER087 for US Coast Guard Headquarters (G-MOR-2), 2100 2nd Street, SW, Washington, DC 21593.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS, SYMBOLS, AND ACRONYMS

Term	Abbreviation, Symbol, or Acronym
Area Contingency Plan	ACP
Automated Data Inquiry for Oil Spills	ADIOS
Barrels	bbls
Cubic Kilometers	Km^3
District Response Advisory Team	DRAT
Ecological Risk Assessment	ERA
Ecosystem Management & Associates, Inc.	EM&A
Environmental Protection Agency	EPA
Environmental Sensitivity Index	ESI
General NOAA Oil Modeling Environment	GNOME
Geographic Information System	GIS
Hours	hrs
In-Situ Burn	ISB
Knots	kts
Meters	m
Miles per hour	mph
National Oceanic and Atmospheric Administration	NOAA
Office of Response and Restoration (NOAA)	OR&R
Parts per million	ppm
Regional Response Team	RRT
Scientific Support Coordinator	SSC
Square Kilometers	Km^2
United States Coast Guard	USCG
United States Coast Guard, Headquarters	USCG HQ
United States Fish and Wildlife Service	USFWS

ACKNOWLEDGEMENTS

Ecosystem Management & Associates, Inc. and the sponsors of this project extend their thanks to all those who participated in the risk assessment workshops. Special recognition is extended to Mr. Scott Lundgren (USCG District 1), who served as the Assessment Coordinator, and to LT Rebecca Drew (USCG District 1), Mr. Steve Lehman (NOAA SSC), Mr. Seth Barker (Maine DMR), Barbara Parker (ME DEP), John Kenney (ME Dept. of Inland F&W), Edward Gilbert (EPA), Andrew Raddant (DOI), Wade Blake (NOAA), Allen Jarrell (EPA), Andrew Major (USFWS), and Debra Kimbrell-Anderson (USFWS), who served as the Assessment Planning Team, and to Dr. Alan Mearns (NOAA HAZMAT) for his support at the workshop and to and Mr. Glen Watabayashi (NOAA HAZMAT) for his help with oil fate modeling. Contractor support to assist in the planning and facilitation of the workshops, and in the preparation of the report was provided by the Office of Response, Headquarters, USCG (G-MOR) under Purchase Order DTCGG8-03-C-MER087. The support and guidance of the Project Manager, LCDR Mark Cunningham, and of Mr. Robert Pond of the G-MOR office is gratefully acknowledged.

Ecological Risk Assessment: Consensus Workshop

Environmental Tradeoffs Associated With Oil Spill Response Technologies

Casco Bay, Maine

Executive Summary

In June 2003, the United States Coast Guard (USCG) District 1 sponsored a workshop to evaluate the relative risk to natural resources from various oil spill response options (on-water mechanical recovery, dispersant application, and shoreline removal) compared to natural recovery. The spill scenario involved a release of approximately1,200 barrels (50,000 gallons) of Brent crude near the southern edge of Casco Bay, under conditions which threatened some interior islands and some exterior coastline. Participants examined this scenario during one accelerated, two-and-a-half day meeting during which they received briefings on the expected results of the spill with and without response options; the relative effectiveness of on-water mechanical recovery and dispersants; and the risks and benefits of these response options to the area's habitats and natural resources. Participants divided into two focus groups and developed relative risk scores for three alternatives, using standard analytical protocols outlined in the Coast Guard guidebook: *Developing Consensus Ecological Risk Assessments: Environmental Protection in Oil Spill Response Planning. A Guidebook*. Scores from each group were then compared, and a composite risk matrix developed to represent the overall consensus. At the conclusion of the workshop, participants developed lessons learned along with recommendations for the Regional Response Team (RRT) and local Area Committee to improve local response planning efforts.

1.0 Objectives of the Casco Bay Workshop

1.1 Background and Process

In 1998, the U.S. Coast Guard (USCG) began sponsoring efforts to develop a comparative risk methodology to evaluate oil spill response options. Interest in selecting response options based on a risk/benefit analysis predates the 1998 initiatives, but the current effort is different in that it emphasizes a consensus-building approach to evaluate risks and benefits.

Headquarters, USCG (G-MOR) sponsored the development of a guidebook on this process. The document, *Developing Consensus Ecological Risk Assessments: Environmental Protection in Oil Spill Response Planning. A Guidebook*, is available from G-MOR (Aurand et al., 2000). It can also be downloaded from the contractor's web site at www.ecosystem-management.net.

The process is designed to help planners compare ecological consequences of specific response options, especially in nearshore or estuarine situations. This is particularly important for consideration of dispersants and in-situ burning, which present difficult analytical issues. The process focuses on ecological "trade offs" or cross-resource comparisons. Through a structured analytical approach participants find "common ground" for evaluating impacts and they develop defensible logic to support their conclusions. The process is consistent with the U.S. Environmental Protection Agency's Ecological Risk Assessment (ERA) guidelines (US EPA, 1998), but emphasizes development of group consensus among stakeholders. The process uses a series of analytical tools specifically developed for use in a group environment. It is designed as a planning tool and should not be used during an actual event. However, knowledge gained by participants in the consensus-building process facilitates real-time decision-making.

Training usually involves two 2- or 3-day workshops lead by a facilitator. The ideal size is 25 to 30 participants, including spill response managers, natural resource managers and trustees, subject matter experts, and non-governmental organizations. The goal is to achieve consensus interpretations of potential risks and benefits associated with selected response options based on a scenario developed by local participants. Time between the two workshops is used by participants to research issues of concern before developing final conclusions. The process focuses heavily on achieving a consensus interpretation of the available technical information. Therefore, it is important to have broad stakeholder representation in the decision process; otherwise, results may not be accepted by all stakeholders involved in an actual spill event.

The workshop process includes three primary phases - **problem formulation, analysis,** and **risk characterization**. Details of the process are described in the Guidebook. In the first phase, **problem formulation**, participants develop a scenario for analysis, identify resources of concern along with associated assessment thresholds, and prepare a conceptual model to guide subsequent analysis. In the **analytical phase**, participants characterize exposure and ecological effects. The conceptual model, developed in the problem formulation phase, directs the analysis using standard templates and simple analytical tools that define and summarize the analysis for each resource of concern and each response option. Finally, participants complete a **risk characterization**. During this phase, participants interpret their results in terms of the costs and benefits of each response option to overall environmental protection as compared with natural recovery (i.e., baseline).

1.2 Sponsor's Objectives

The Casco Bay workshop was sponsored by USCG District 1 in support of oil spill response planning by the Maine/New Hampshire Area Committee. The workshop's overall purpose was to evaluate impacts of spilled oil and oil spill response operations on the ecological resources of the southern Maine coast.

The results of this ERA process are intended to improve oil spill response strategies and to enhance existing oil spill contingency planning. Exercises such as this are intended to help identify natural resources at risk during a spill as well as to address benefits and inherent tradeoffs associated with various spill response tools. As stated by the sponsor, countermeasures (dispersants and burning) hold some promise to improve on-water response capability. Unfortunately, logistics have not always followed planning for use of these tools, and approvals tend toward conservative, offshore areas. However, in this area (Maine/New Hampshire), due to depth of water and challenges in mechanical recovery, the Area Committee did take a more aggressive approach with its pre-approval for dispersant use (as close as 0.5 nm).

Considering the volume of oil transported in the area, USCG District 1 and the Area Committee expressed a strong interest in assessing one particular option – dispersants. In an effort to further assess their capabilities, and to promote knowledgeable conversation of countermeasures during the ERA workshop, USCG District 1 first sponsored a seminar on dispersant use at the Area Committee's Spring Seminar in April 2003. Participants in the dispersant seminar were informed about efforts to increase countermeasure capabilities by requiring dispersant capability of industry operating in pre-approved zones. Participants agreed that the seminar assisted them in understanding dispersant use capabilities so that they could adequately discuss and evaluate this response option during the second part of the assessment phase - the ERA workshop. Additionally, the Area Committee plans a third part to this pro-cess – deployment of a dispersal trial. This trial was originally planned for May 2003, but due to other commitments, the assisting service (US Air Force) had to postpone the project.

1.3 Participants and Responsibilities

A total of 23 individuals attended one, two, or three days of the workshop. Their names and affiliations are provided in Appendix A. Due to various other constraints, including working on the Buzzard's Bay spill, not all attendees were able to participate for all three days. Twenty of the attendees available for two days of the workshop were divided into two focus groups to assess response options for the given scenario. While three groups are recommended for the assessment process, only two focus groups were feasible due to the limited number of natural resource experts participating.

2.0 Overview of Workshop Events

This training exercise consisted of one accelerated, two-and-a-half day workshop held 4 to 6 June 2003. This is the first time that the workshop was held under such a tight schedule. The sponsors recognized that this would limit their ability to resolve some issues during the workshop, since there would be no interim period for research. At the beginning of the meeting the participants agreed that, although the two and a half day time constraint was necessary due to other obligations, it was a difficult schedule to meet.

Prior to the meeting, the Assessment Planning team had agreed on the spill scenario, the response options for consideration and the resources at risk.

Day one began with an overview of the Buzzard's Bay oil spill by Scott Lundgren of USCG District 1. The ERA workshop was postponed from its original dates of 7-9 May 2003 due to the response to the spill in Massachusetts, which involved many of the participants.

After Mr. Lundgren completed his update, Don Aurand of Ecosystem Management & Associates, Inc., disseminated notebooks containing a copy of his presentation, brief description of the scenario for Casco Bay, resources-at-risk table, and a set of fact sheets about response options and oil impacts. Dr. Aurand then presented an overview of the ERA process, followed by a discussion of the basic scenario, habitats of concern, analytical process, risk ranking matrix, and basic fate information developed for the oil if no response was initiated (the natural recovery baseline). Efficiency data estimated by the USCG for mechanical recovery was presented by LT Rebecca Drew, USCG District 1. NOAA trajectory modeling results were presented by Alan Mearns, NOAA Scientific Support Coordinator (SSC) from Seattle, WA.

After these discussions were completed, participants were divided into two focus groups in order to begin the analysis. The preferred number of groups is three because it allows for additional points of view to be developed, and aids later in the process in consensus development. However, due to the limited number of participants and availability of resource trustees, only two groups were possible. Participants concluded day one by completing the natural recovery portion of the risk matrix, in order to ensure that they understood the process.

On day two, the two groups began by comparing the results of their evaluation of the natural recovery baseline. Participants discussed differences in scoring and resolved them to the extent possible. The risk scores associated with this option formed the basis for evaluating other response options in Casco Bay (in order): on-water mechanical recovery, dispersant application, and, to a less detailed level, shoreline removal.

Upon completing the discussion about natural recovery, participants reviewed efficiency estimates for on-water mechanical recovery and dispersant application. Determining the efficiency for on-water mechanical recovery received extensive discussion, due, in part, to a figure provided by LT Drew on the first day. Use of the NOAA Mechanical Recovery calculator suggested that as much as 37% of the total volume released might be recovered via on-water mechanical methods. Many participants felt this was a very high number, based on the fact that it used very favorable assumptions and did not account for oil which stranded on the shore during the early stages of the spill. Eventually, participants settled on a 20% effectiveness rating for mechanical recovery. Due to time constraints, they accepted the 80% effectiveness rating for dispersant use with little discussion. While virtually all participants felt that it was unlikely that that much oil could be dispersed in this scenario, Gary Ott (NOAA) pointed out that it would better to use a high efficiency to evaluate water column effects.

Normally, participants are asked to completely evaluate each response option before moving on to the next. In this case it was suggested that the evaluation would be faster if they worked vertically through the risk matrix, scoring by habitat first, then by response option, e.g., scoring marshes for on-water mechanical recovery *and* dispersant use before moving on to the next habitat classification. This recommendation was accepted by all participants and they rejoined their separate groups to finish scoring. On day two they completed both on-water mechanical recovery and dispersant use.

On day three, groups conducted an abbreviated evaluation of shoreline removal and conversed about their differences in scoring. Given the time constraints, no attempt was made to resolve scoring differences between the two groups. The rest of the morning and early afternoon were devoted to evaluating workshop results, developing a list of lessons learned, and allowing agency representatives to comment on the process.

3.0 Exercise Scenario and Basic Analytical Information

3.1 Exercise Scenario

After considering a variety of options, the Assessment Team agreed to examine a release of 50,000 gallons (approximately 1,200 barrels) of Brent crude from the *Phantom Menace* while anchored in Casco Bay. Ship collisions which could cause this type of release represent a realistic threat for the area. The volume was selected to a) represent a realistic release, b) not overwhelm the potential spill response, and c) allow the maximum benefits of the ERA.

The release occurred at 0500, 7 May 2003. Based on a review of average winds for the area at the time of the spill, winds were NNW at 15 knots. The forecast was for the winds to continue from the NNW until evening, at which time they were forecasted to shift to the SSE at 10-15 knots and remain that way for a period of approximately 24 hours.

3.2 Geographic Area of Concern

The general area of concern was the coastline of southern Maine along with the internal and coastal waters of Casco Bay. Participants were asked to consider resources as either regional (coastal) or local (Casco Bay) when they were evaluating impacts.

3.3 Resources of Concern

Participants agreed to use the resource table developed by the Assessment Planning Committee as the template for risk evaluation matrix. As is the case in each ERA workshop, the participants developed a list of habitats and subhabitats which they felt included the resources which would need to be evaluated (Appendix B). For each subhabitat they examined impacts to a list of resource groups, each of which was either a taxonomic or ecological grouping. Normally, participants develop a list of example organisms for each of the resource groups, and review the list to eliminate resource groups which are not relevant to the analysis. In this case, the example organisms were identified by the Assessment Planning Committee. In addition, they eliminated as many of the resource groups as possible prior to the workshop. These suggestions were accepted by the participants at the beginning of the workshop with a few modifications, which can be seen as minor differences in the categories on the detailed risk ranking matrices. In addition, the representatives on the Assessment Planning Committee from the natural resource agencies provided references dealing with the various habitat categories. These are included in Appendix B.

3.4 Conceptual Model

During discussions about the general analytical process, the participants agreed that developing a detailed model was not necessary for their purposes. They were presented the list of seven hazards developed initially in the San Francisco Bay workshop (Pond et al., 2000), and used in all subsequent workshops, and it was suggested that these be considered for each of the proposed response options (these hazards are air pollution, aqueous exposure, physical trauma, oiling/smothering, thermal, waste and indirect). They agreed that the response options to be considered would be natural recovery (no response), on-water mechanical recovery, dispersant application, and if time was available, shoreline protection.

3.5 Modeling Results

The NOAA HAZMAT Modeling Group used the basic information in the scenario to develop a surface trajectory and a dispersed oil trajectory analysis using GNOME for the detailed risk assessment portion of the workshop. Basic weathering information was calculated using the ADIOS II program. Mass balance estimates are presented in Table 3.1.

Table 3.1 Oil Budget (in Gallons) for Undispersed and Dispersed Oil (40 and 80% Efficiency) as Predicted in the Casco Bay Scenario

Oil in the Environment, 24 Hours Post-spill			
Response	Floating	Beached	Disp/Evap
No Dispersal	13035	26185	10780
Disperse 40%	9420	20590	19990
Disperse 80%	5930	14995	29075
Oil in the Environment, 48 Hours Post-spill			
Response	Floating	Beached	Disp/Evap
No Dispersal	2445	31320	16235
Disperse 40%	1875	24200	24105
Disperse 80%	1440	16550	32010

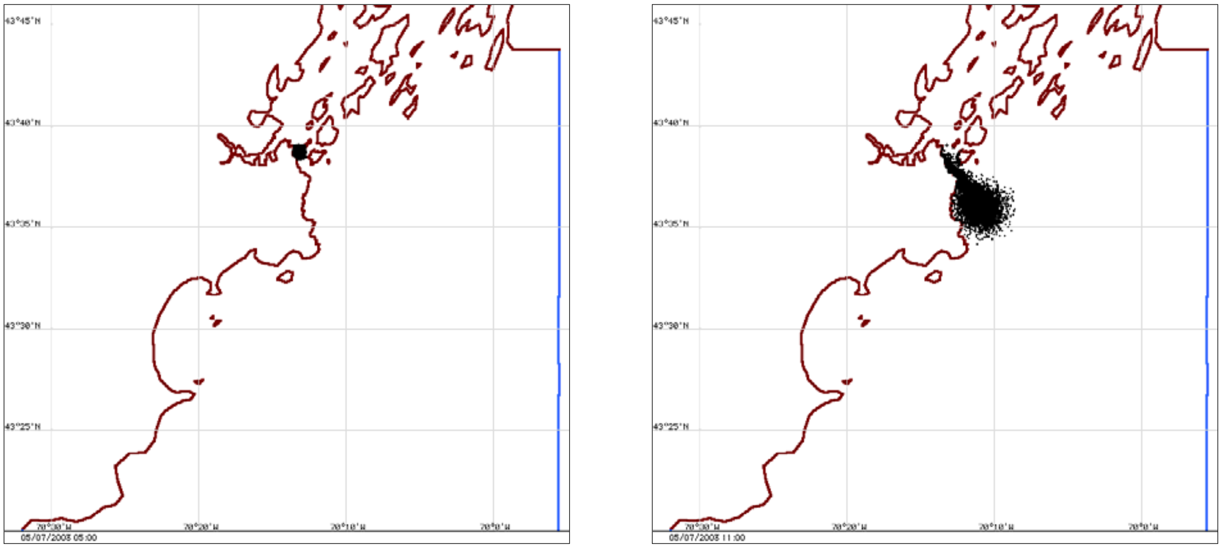
Selected snapshots from the surface oil trajectory modeling results are shown in Figure 3.1. Snapshots from the dispersed oil modeling results are shown in Figure 3.2 for 80% effectiveness with the surface slick showing, and in Figure 3.3 for 80% effectiveness showing only the sub-surface dispersed plume. Finally, the average concentration in the dispersed oil plume (Figure 3.4, at an expanded scale) is compared to toxicity threshold values for adult crustaceans (Figure 3.5) and sensitive life history stages (Figure 3.6) (see Table 5.1 and the associated discussion in Section 5 for information on development and interpretation of thresholds). Figures 3.7 and 3.8 present the same information for the maximum plume concentration.

Under prevailing winds the oil initially moves out to sea, away from the harbor. During this phase, oil is stranding all along the outer coast. Within 24 hours, the tides change and the winds shift, bringing oil back into Casco Bay and southward along the coast. Extensive shoreline contamination is expected on the Bay's islands, much of it in very rugged areas. Additionally, oil is expected to impact Crescent Beach, a nesting area for piping plovers, a federally listed species. Because of the strong currents and location, within 24 hours over 52% of the spilled oil has reached the shoreline, and within 48 hours this has increased to 63%. Under the scenario, dispersant application began at 6 hours, so it will not reduce the initial stranding along the outer shore. In the 80% effectiveness scenario, the volume impacting the shore at 24 hours is reduced to 30%. Overall, at the end of 48 hours, if dispersants are 80% effective, the model predicts that shoreline contamination would be reduced by nearly 15,000 gallons, or almost 50%.

Even assuming 80% overall efficiency with dispersants, the rate of dilution is very rapid. At the time of initial dispersion, the model predicts that the maximum concentrations averaged over 0 to 5 meters depth will be in the range of 1 to 5 ppm in the center of the plume, with most of the plume at less than 1 ppm. Within nine hours all of the predicted concentrations were below 1 ppm, and the vast majority were below 0.5 ppm. Figure 3.4 shows the average concentration in the plume (0 to 5 meters depth) over time. The average value peaks at approximately 0.65 ppm immediately after dispersion, and by 24 hours is less than 0.2 ppm

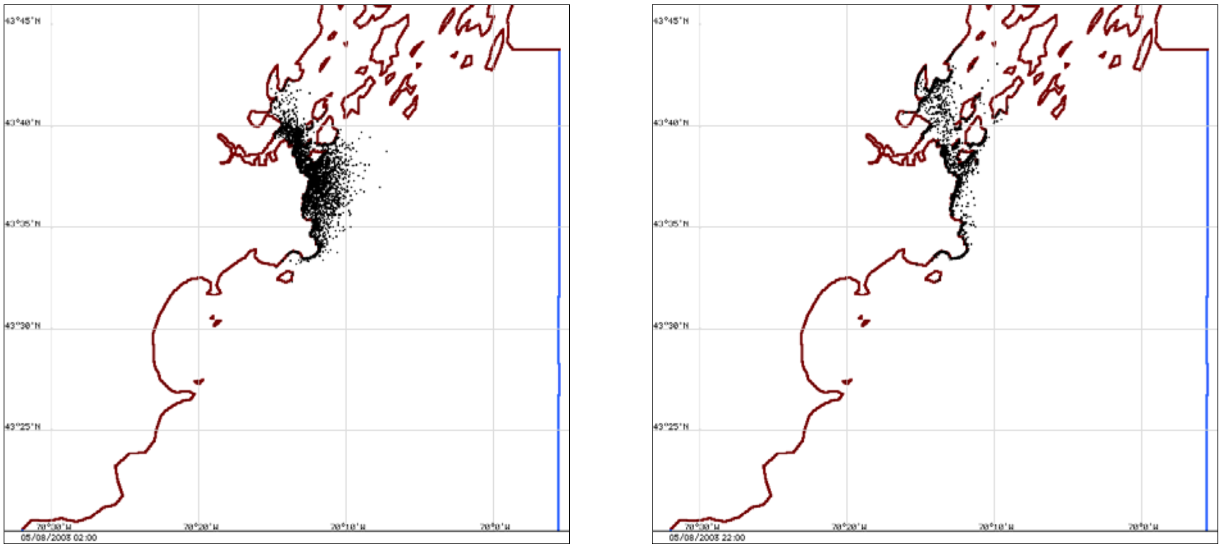
In order to put these exposures into perspective, Figures 3.5 through 3.8 were prepared to compare average and extreme conditions to toxicity thresholds for crustaceans and sensitive life history stages. These thresholds are presented in Table 4.1. The average concentration never exceeded any of the thresholds.

Maximum concentrations based on the model results would represent a risk, but these results are somewhat misleading since the maximum concentrations were present in only very small areas of the plume and then for only very limited times at widely separated locations. In fact, based on a review of the spill trajectory results, they may be an artifact of the model parameters, since they occur only sporadically in cells immediately adjacent to the shoreline, where the model algorithms underestimate dilution. A more accurate reflection is the highest value in the main area of the plume, which never exceeds 1 to 5 ppm, and then rapidly drops to 1 ppm or less (see Figure 3.3). This exposure profile would be close to the levels which could be a concern for sensitive life history stages, but would not represent a threat to crustaceans.



A: 1 Hour

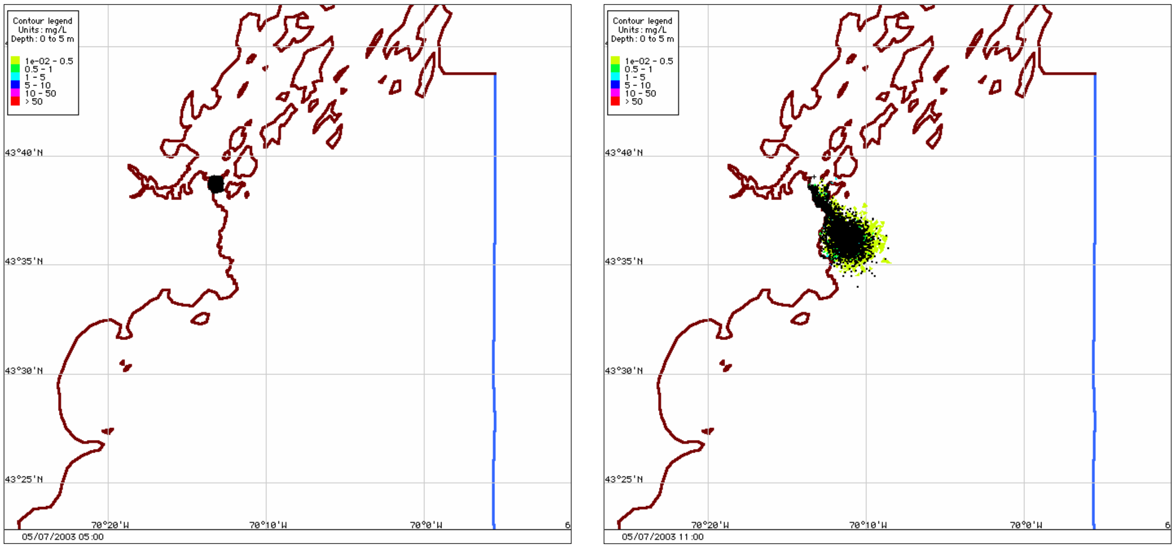
B: 7 Hours



C: 19 Hours

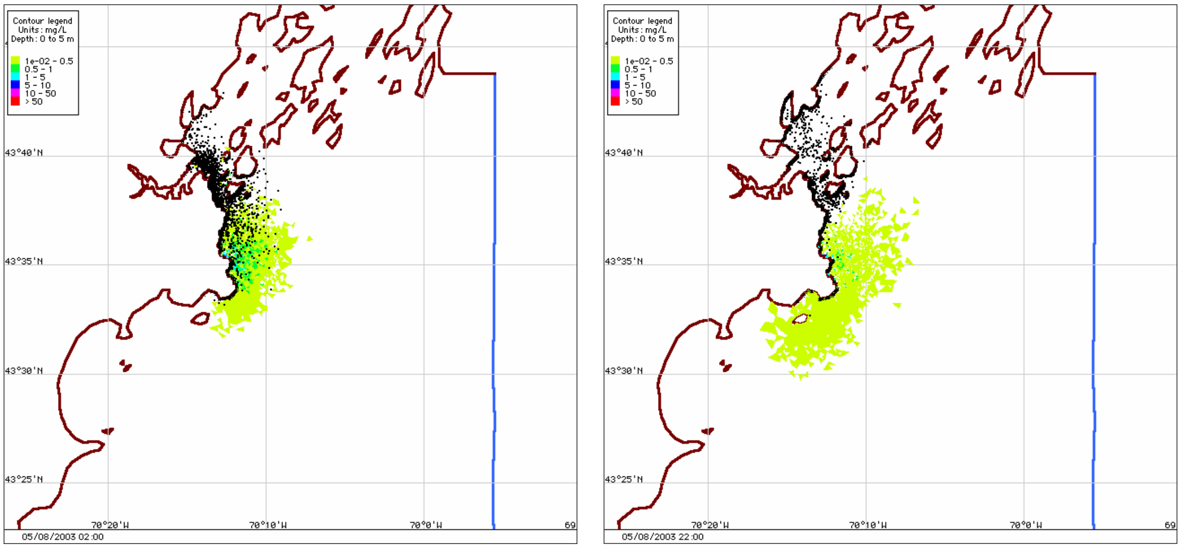
D: 43 Hours

Figure 3.1 *Results from the NOAA scenario modeling for the Casco Bay surface oil slick trajectory*



A: 1 Hour

B: 7 Hours (Initial Dispersion)



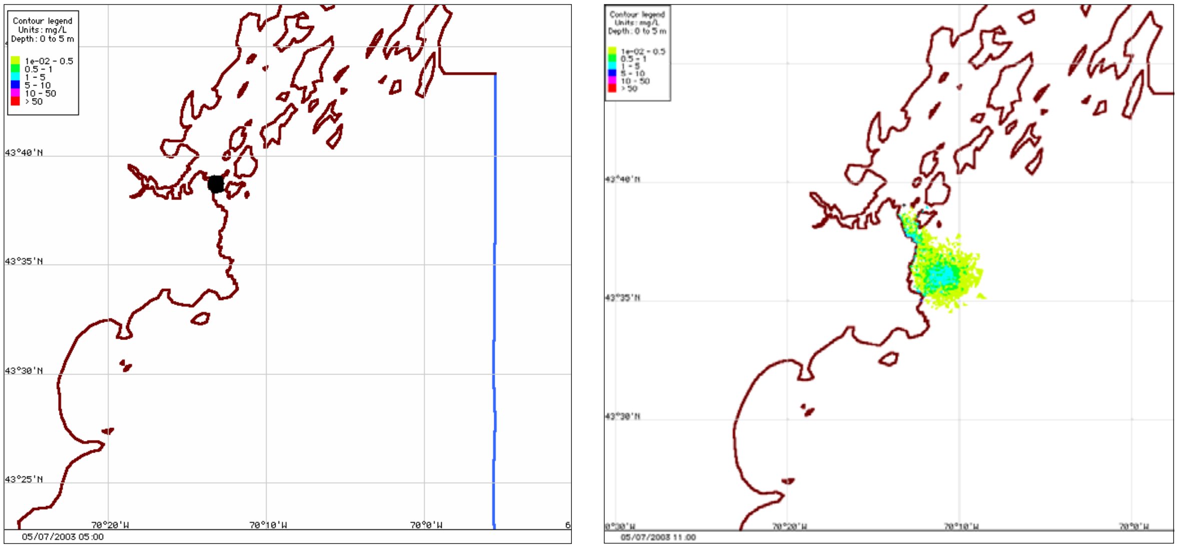
C: 19 Hours (D + 12 hours)

D: 43 Hours (D + 36 hours)

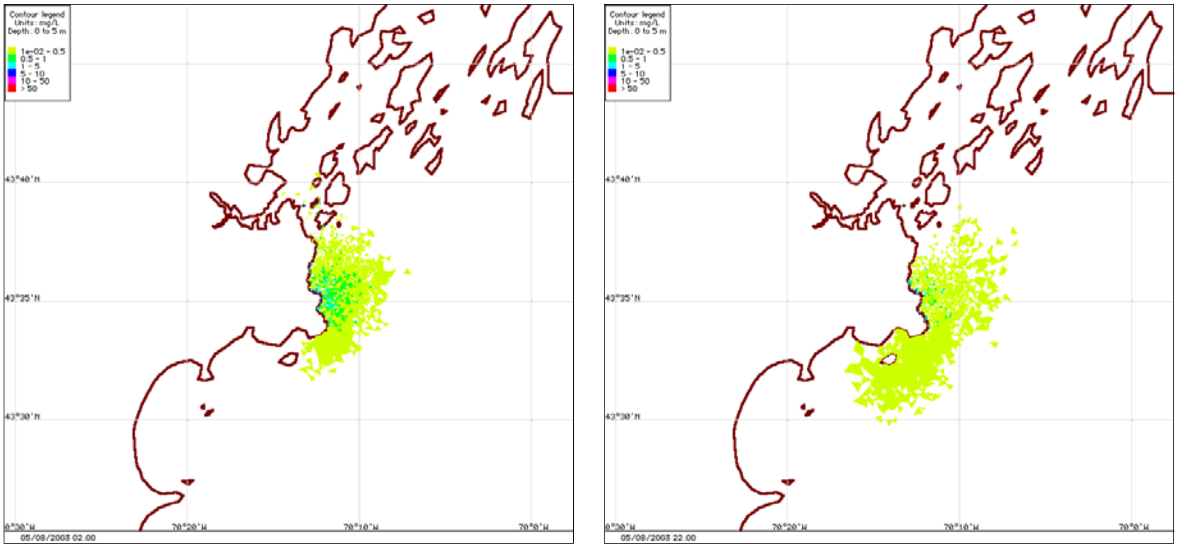
Key:

Light green	<0.5 ppm
Medium green	0.5 - 1 ppm
Light blue	1 - 5 ppm
Dark blue	5 - 10 ppm
Pink	10 - 50 ppm
Red	>50 ppm

Figure 3.2 *Results from the NOAA modeling for the Casco Bay scenario for dispersant use at 80% efficiency showing average dispersed oil concentrations (in ppm) from 0 to 5 meters and surface oil remaining after application*



A: 1 Hour **B: 7 Hours (Initial Dispersion)**



C: 19 Hours **D: 43 Hours**

Key:

Light green	<0.5 ppm
Medium green	0.5 - 1 ppm
Light blue	1 - 5 ppm
Dark blue	5 - 10 ppm
Pink	10 - 50 ppm
Red	>50 ppm

Figure 3.3 *Results from the NOAA modeling for the Casco Bay scenario for dispersant use at 80% efficiency showing average dispersed oil concentrations (in ppm) from 0 to 5 meters without the surface oil slick*

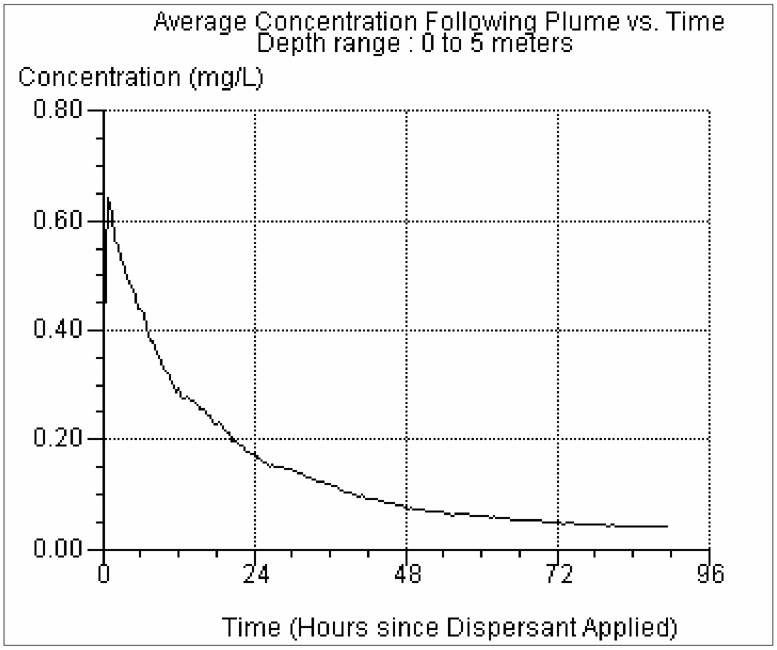


Figure 3.4 *Overall average dispersed oil concentration in the plume versus time*

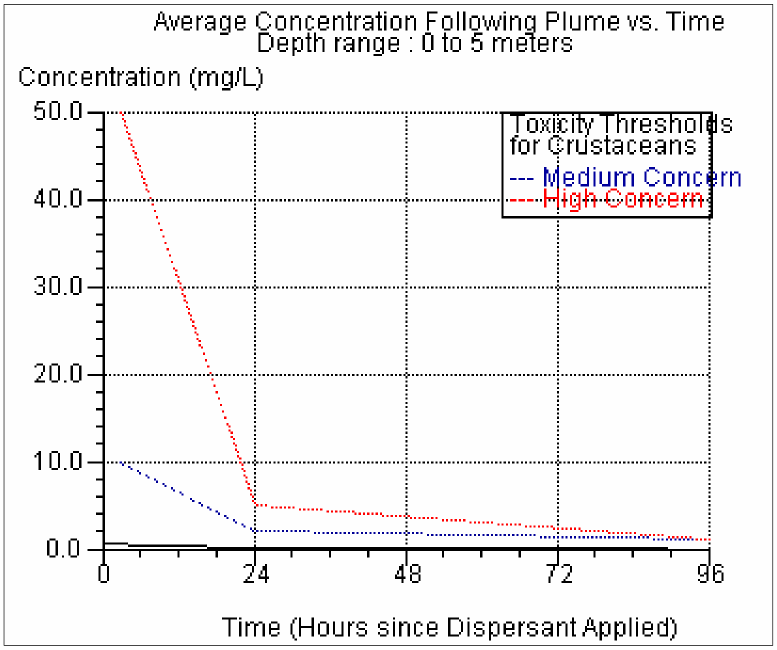


Figure 3.5 *Toxicity thresholds for dispersed oil for crustaceans at average concentrations*

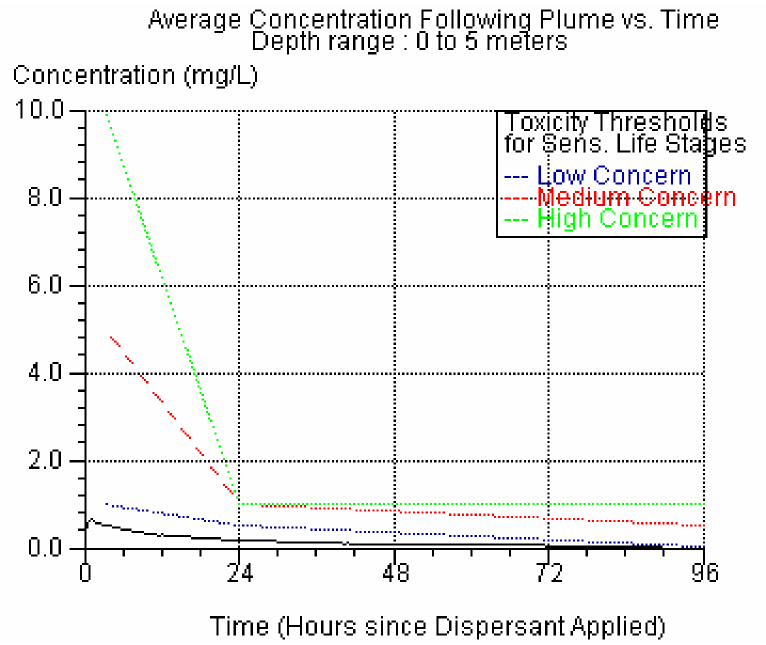


Figure 3.6 *Toxicity thresholds for dispersed oil for sensitive life history stages at average concentrations*

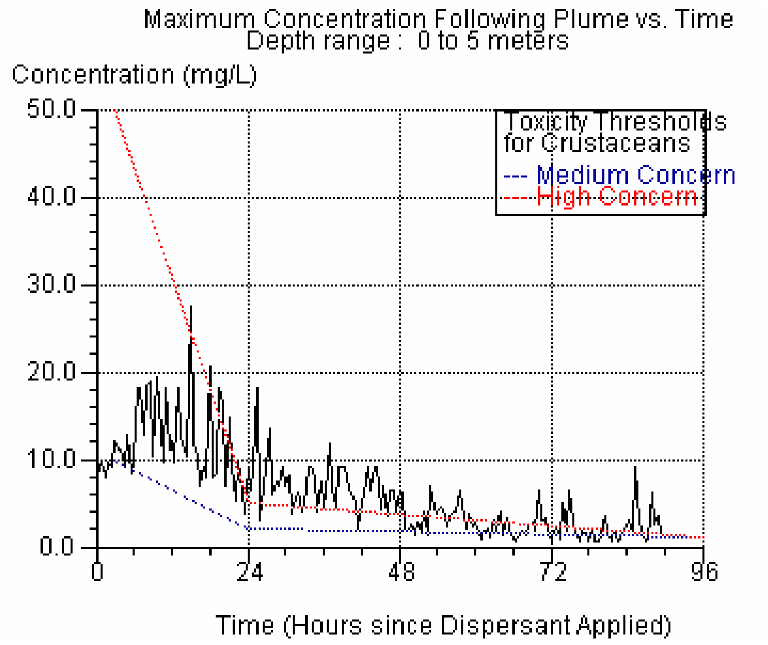


Figure 3.7 *Toxicity thresholds for dispersed oil for crustaceans at maximum concentrations*

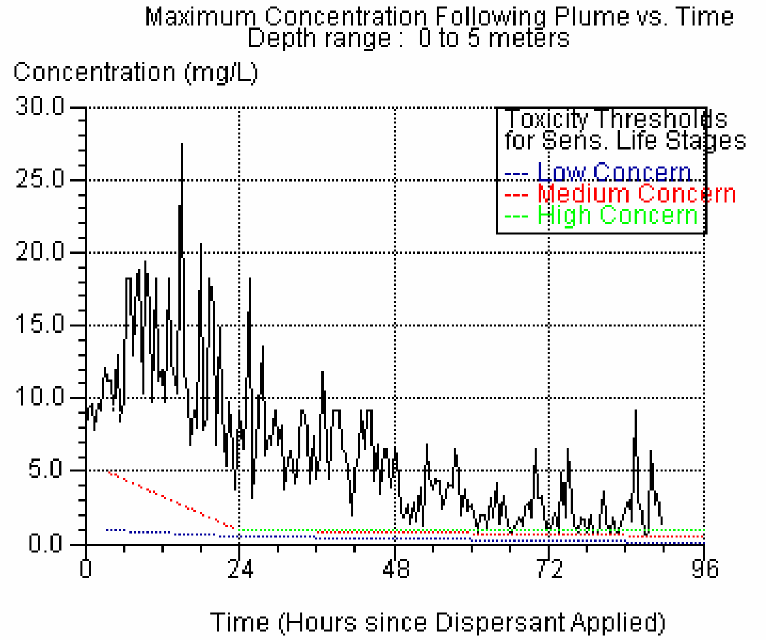
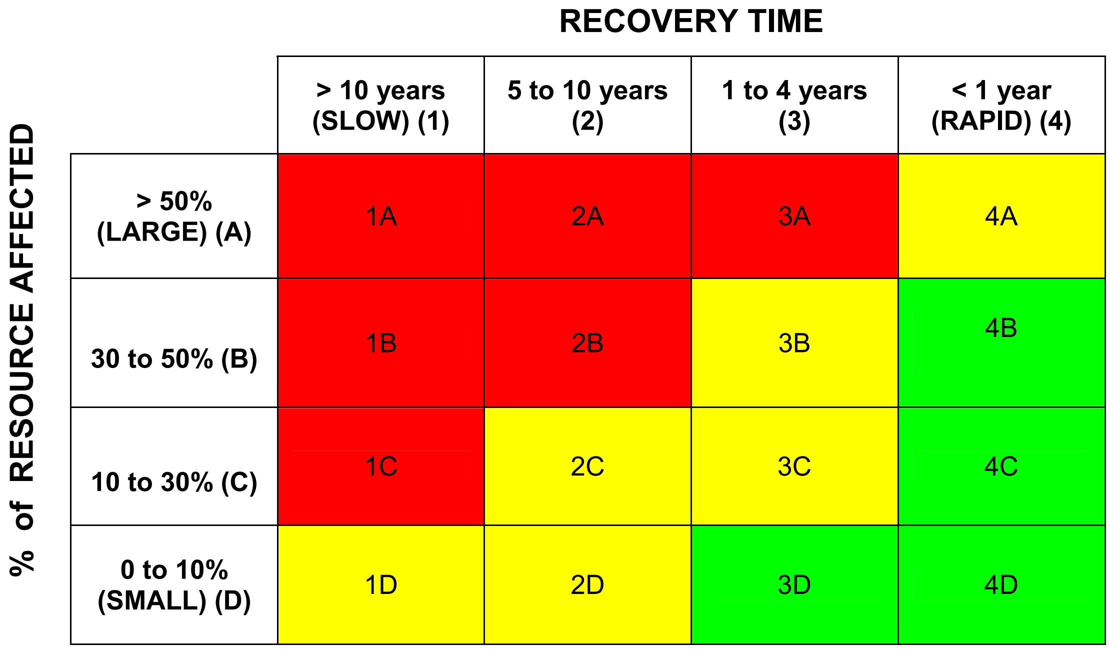


Figure 3.8 *Toxicity thresholds for dispersed oil for sensitive life history stages at maximum concentrations*

4.0 The Results of the Risk Analysis Process

Focus groups used the risk matrix presented in Figure 4.1. Each focus group was tasked with reviewing the scenario, the modeling results, information on exposure and sensitivity to oil and dispersed oil, and basic life histories and distributions in order to develop a group estimate of the percent of each resource affected and the recovery time. In the initial evaluation, the groups used alphanumeric codes to rate the level of concern. At the end of the workshop, color coding was used to develop summary levels of concern.



RECOVERY TIME

% of RESOURCE AFFECTED	> 10 years (SLOW) (1)	5 to 10 years (2)	1 to 4 years (3)	< 1 year (RAPID) (4)
> 50% (LARGE) (A)	1A	2A	3A	4A
30 to 50% (B)	1B	2B	3B	4B
10 to 30% (C)	1C	2C	3C	4C
0 to 10% (SMALL) (D)	1D	2D	3D	4D

Legend: Red cells represent a “high” level of concern, yellow cells represent a “moderate” level of concern, and green cells represent a “limited” level of concern.

Figure 4.1 *Definition of levels of concern for the Casco Bay risk assessment*

Using the ranking matrix requires that the participants develop estimates of the proportion of the resource affected, and how long it will take the resource to recover. A key factor in determining whether or not a resource is affected is to apply thresholds at which impacts, either acute or chronic, would be expected to occur for the various resource groups under consideration. This is perhaps the most difficult part of the consensus process, and has been discussed in detail at all of the workshops. In this case, as in other workshops, very conservative assumptions were presented by the facilitator and accepted by the participants. For shoreline resources and habitats, damage was assumed if oil contacted the habitat. Impacts to birds, mammals and turtles on the water surface were assumed if there was a high probability of any contact with the surface oil slick. The nature of these impacts was developed during the focus group discussions. The only thresholds which can be generally quantified are those related to aquatic toxicity. Table 5.1, reproduced from the Guidebook, presents a series of concentration thresholds which were made available to the participants.

These values are based on a summary of published toxicity information initially developed during the early workshops.

It is important to keep in mind that the participants used the information available to them to develop <u>levels of concern</u> about the risk, and the risk scores do not represent a prediction of actual impacts. Instead they represent a consensus on the part of the participants that such consequences were likely to occur under the scenario under consideration.

Table 4.1 Consensus Exposure Thresholds of Concern (in ppm) for Dispersed Oil in the Water Column

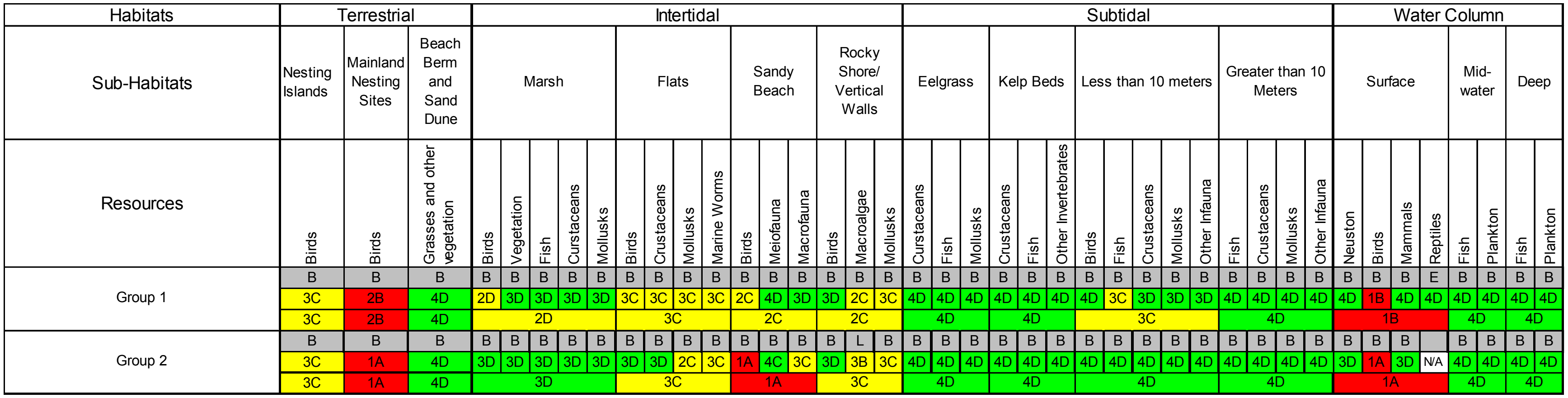
---

Continuous Exposure	Level of Concern	Protective of Sensitive Life Stages	More Protective Criteria	Protective of Adult Fish	More Protective Criteria	Adult Crustacea/ Invertebrates	More Protective Criteria
3 hours	Low	<5	<1-5	<10	<10	<5	<5
	Medium	5-10	5-10	10-100	10-100	5-50	5-50
	High	>10	>10	>100	>100	>50	>50
24 hours	Low	<1	<0.5	<2	<0.5	<2	<0.5
	Medium	1-5	.5-5	2-10	.5-10	2-5	.5-5
	High	>5	>5	>10	>10	>5	>5
96 hours	Low	<1	<0.5	<1	<0.5	<1	<0.5
	Medium			1-5	.0-5	1-5	.5-1
	High	>1	>0.5	>5	>5	>5	>1

The detailed results from the two focus groups for natural recovery are shown in Figure 4.2. Blocks where focus group 2 felt there was no risk are labeled as "N/A". In some cases focus group 1 did not evaluate blocks because they felt it was unnecessary. These are left blank. No attempt was made to reconcile the difference between "not applicable" and "4D" (the lowest level of perceived risk), or the blank scores because of the limited amount of time available.

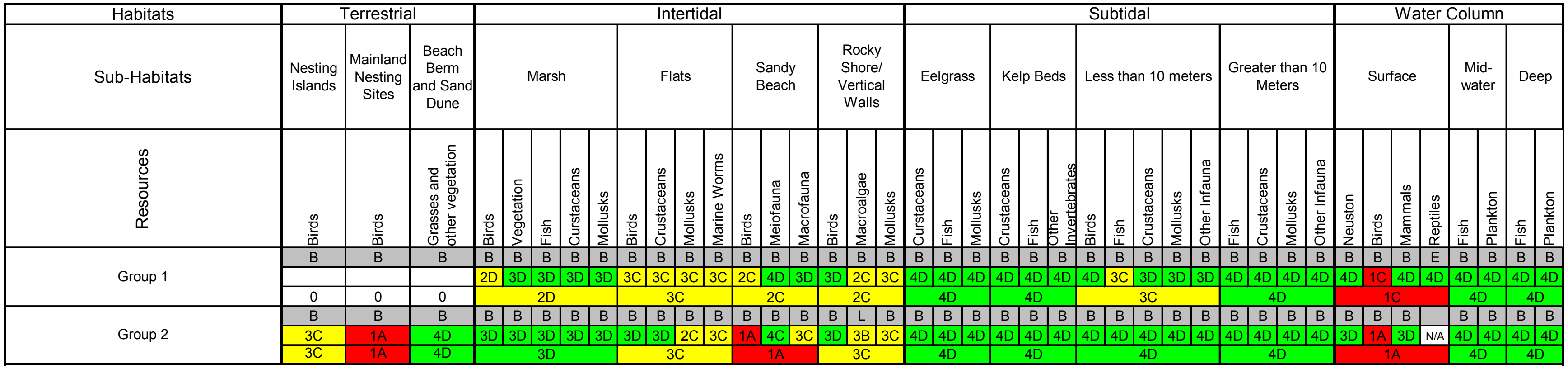
Detailed focus group results for natural recovery are shown in Figure 4.2. Results for the various habitats are relatively consistent, with high levels of concern for birds on mainland nesting sites, sandy beaches, and the water surface. The higher score for sandy beaches by focus group 2 was due to their emphasis on piping plover nesting areas. More moderate concern was expressed for nesting islands, tidal flats and for rocky vertical walls. There was a difference in the perceived risk to marshes, based on perceptions about bird usage.

The risk results for on-water mechanical recovery are shown in Figure 4.3. Both focus groups determined that on-water recovery was unlikely to result in significant benefits to any habitat, given that 18,000 gallons of spilled oil washed ashore before any response option



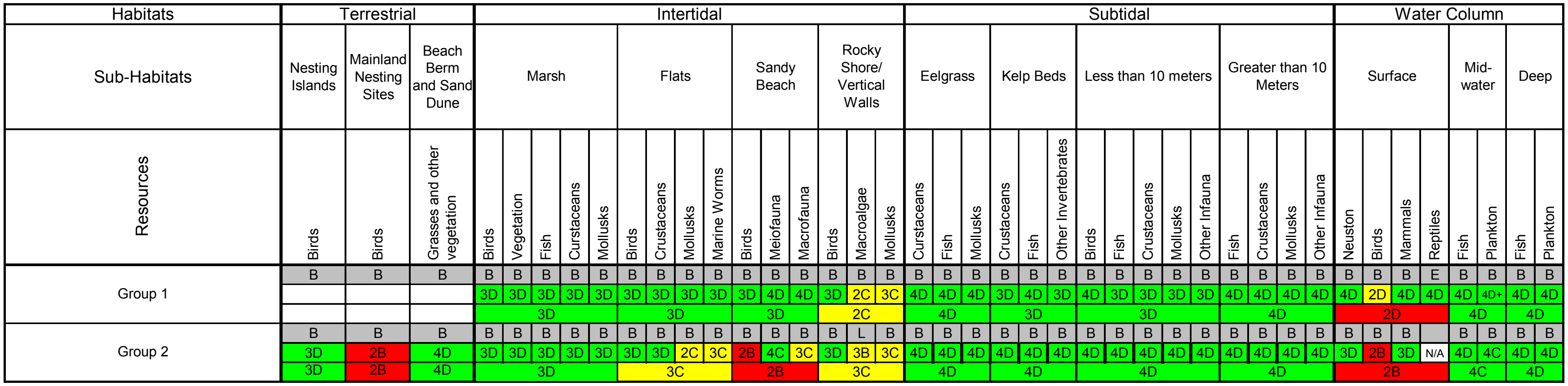
Habitats	Terrestrial			Intertidal															Subtidal															Water Column							
Sub-Habitats	Nesting Islands	Mainland Nesting Sites	Beach Berm and Sand Dune	Marsh					Flats				Sandy Beach			Rocky Shore/ Vertical Walls			Eelgrass			Kelp Beds			Less than 10 meters					Greater than 10 Meters				Surface				Mid-water		Deep	
Resources	Birds	Birds	Grasses and other vegetation	Birds	Vegetation	Fish	Curstaceans	Mollusks	Birds	Crustaceans	Mollusks	Marine Worms	Birds	Meiofauna	Macrofauna	Birds	Macroalgae	Mollusks	Curstaceans	Fish	Mollusks	Crustaceans	Fish	Other Invertebrates	Birds	Fish	Crustaceans	Mollusks	Other Infauna	Fish	Crustaceans	Mollusks	Other Infauna	Neuston	Birds	Mammals	Reptiles	Fish	Plankton	Fish	Plankton
Group 1	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	E	B	B	B	B
	3C	2B	4D	2D	3D	3D	3D	3D	3C	3C	3C	3C	2C	4D	3D	3D	2C	3C	4D	4D	4D	4D	4D	4D	4D	3C	3D	3D	3D	4D	4D	4D	4D	4D	1B	4D	4D	4D	4D	4D	4D
	3C	2B	4D	2D					3C				2C			2C			4D			4D			3C					4D				1B				4D		4D	
Group 2	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	L	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B		B	B	B	B
	3C	1A	4D	3D	3D	3D	3D	3D	3D	3D	2C	3C	1A	4C	3C	3D	3B	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3D	1A	3D	N/A	4D	4D	4D	4D
	3C	1A	4D	3D					3C				1A			3C			4D			4D			4D					4D				1A				4D		4D	

Figure 4.2. *Detailed focus group risk analysis results for natural recovery*



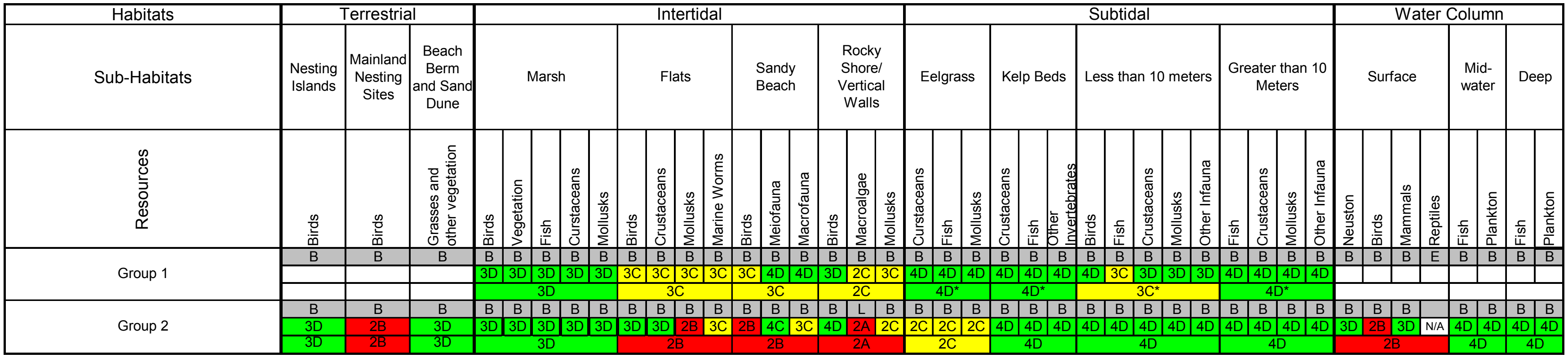
Habitats	Terrestrial			Intertidal															Subtidal															Water Column							
Sub-Habitats	Nesting Islands	Mainland Nesting Sites	Beach Berm and Sand Dune	Marsh					Flats				Sandy Beach			Rocky Shore/ Vertical Walls			Eelgrass			Kelp Beds			Less than 10 meters					Greater than 10 Meters				Surface				Mid-water		Deep	
Resources	Birds	Birds	Grasses and other vegetation	Birds	Vegetation	Fish	Curstaceans	Mollusks	Birds	Crustaceans	Mollusks	Marine Worms	Birds	Meiofauna	Macrofauna	Birds	Macroalgae	Mollusks	Curstaceans	Fish	Mollusks	Crustaceans	Fish	Other Invertebrates	Birds	Fish	Crustaceans	Mollusks	Other Infauna	Fish	Crustaceans	Mollusks	Other Infauna	Neuston	Birds	Mammals	Reptiles	Fish	Plankton	Fish	Plankton
Group 1	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	E	B	B	B	B
				2D	3D	3D	3D	3D	3C	3C	3C	3C	2C	4D	3D	3D	2C	3C	4D	4D	4D	4D	4D	4D	4D	3C	3D	3D	3D	4D	4D	4D	4D	4D	1C	4D	4D	4D	4D	4D	4D
	0	0	0	2D					3C				2C			2C			4D			4D			3C					4D				1C				4D		4D	
Group 2	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	L	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B		B	B	B	B
	3C	1A	4D	3D	3D	3D	3D	3D	3D	3D	2C	3C	1A	4C	3C	3D	3B	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3D	1A	3D	N/A	4D	4D	4D	4D
	3C	1A	4D	3D					3C				1A			3C			4D			4D			4D					4D				1A				4D		4D	

Figure 4.3 *Detailed focus group risk analysis results for on-water mechanical recovery*



Habitats	Terrestrial			Intertidal															Subtidal															Water Column							
Sub-Habitats	Nesting Islands	Mainland Nesting Sites	Beach Berm and Sand Dune	Marsh					Flats				Sandy Beach			Rocky Shore/ Vertical Walls			Eelgrass			Kelp Beds			Less than 10 meters					Greater than 10 Meters				Surface				Mid-water		Deep	
Resources	Birds	Birds	Grasses and other vegetation	Birds	Vegetation	Fish	Curstaceans	Mollusks	Birds	Crustaceans	Mollusks	Marine Worms	Birds	Meiofauna	Macrofauna	Birds	Macroalgae	Mollusks	Curstaceans	Fish	Mollusks	Crustaceans	Fish	Other Invertebrates	Birds	Fish	Crustaceans	Mollusks	Other Infauna	Fish	Crustaceans	Mollusks	Other Infauna	Neuston	Birds	Mammals	Reptiles	Fish	Plankton	Fish	Plankton
Group 1	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	E	B	B	B	B
				3D	3D	3D	3D	3D	3D	3D	3D	3D	3D	4D	4D	3D	2C	3C	4D	4D	4D	3D	4D	3D	4D	3D	3D	3D	3D	4D	4D	4D	4D	4D	2D	4D	4D	4D	4D+	4D	4D
				3D					3D				3D			2C			4D			3D			3D					4D				2D				4D		4D	
Group 2	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	L	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B		B	B	B	B
	3D	2B	4D	3D	3D	3D	3D	3D	3D	3D	2C	3C	2B	4C	3C	3D	3B	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3D	2B	3D	N/A	4D	4C	4D	4D
	3D	2B	4D	3D					3C				2B			3C			4D			4D			4D					4D				2B				4C		4D	

Figure 4.4 *Detailed focus group risk analysis results for dispersant application at 80% effectiveness*



Habitats	Terrestrial			Intertidal															Subtidal															Water Column							
Sub-Habitats	Nesting Islands	Mainland Nesting Sites	Beach Berm and Sand Dune	Marsh					Flats				Sandy Beach			Rocky Shore/ Vertical Walls			Eelgrass			Kelp Beds			Less than 10 meters					Greater than 10 Meters				Surface				Mid-water		Deep	
Resources	Birds	Birds	Grasses and other vegetation	Birds	Vegetation	Fish	Curstaceans	Mollusks	Birds	Crustaceans	Mollusks	Marine Worms	Birds	Meiofauna	Macrofauna	Birds	Macroalgae	Mollusks	Curstaceans	Fish	Mollusks	Crustaceans	Fish	Other Invertebrates	Birds	Fish	Crustaceans	Mollusks	Other Infauna	Fish	Crustaceans	Mollusks	Other Infauna	Neuston	Birds	Mammals	Reptiles	Fish	Plankton	Fish	Plankton
Group 1	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	E	B	B	B	B
				3D	3D	3D	3D	3D	3C	3C	3C	3C	3C	4D	4D	3D	2C	3C	4D	4D	4D	4D	4D	4D	4D	3C	3D	3D	3D	4D	4D	4D	4D								
				3D					3C				3C			2C			4D*			4D*			3C*					4D*											
Group 2	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	L	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B		B	B	B	B
	3D	2B	3D	3D	3D	3D	3D	3D	3D	3D	2B	3C	2B	4C	3C	4D	2A	2C	2C	2C	2C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3D	2B	3D	N/A	4D	4D	4D	4D
	3D	2B	3D	3D					2B				2B			2A			2C			4D			4D					4D				2B				4D		4D	

Figure 4.5 *Detailed focus group risk analysis results for on-shore mechanical recovery*

could be implemented. One group voiced concerns that although sufficient equipment is present in the Casco Bay area, there may not always be enough experienced personnel on-hand to initiate a timely response of all response options. Both groups felt that any recovered oil would ultimately benefit the environment. There was a consensus that many potential scenarios in the area could lead to very rapid shoreline contamination.

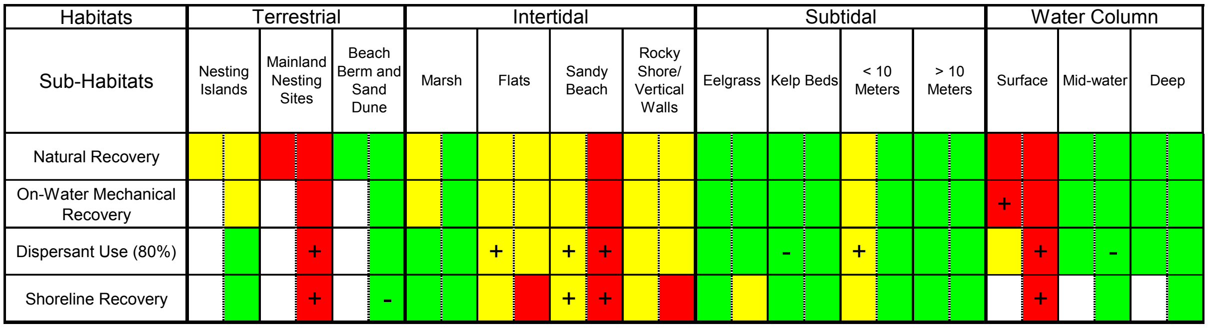
Risk results for dispersant use at an overall effectiveness of 80% are presented in Figure 4.4. Focus group 1 felt that dispersant use was potentially more beneficial than did focus group 2. Group 2 was concerned that only minimal improvements were likely due to the inability to respond with dispersants before initial impacts occurred to the shoreline. Both groups felt that some benefit to birds was very likely. Both groups were very concerned about potential water column impacts to larval and juvenile stages of lobsters, but did not significantly increase their scores, since larval lobsters are not present at this time of the year. Risks to other planktonic or water column organisms were not a serious concern, given the predicted rapid dilution.

Risk results for shoreline removal are presented in Figure 4.5. Neither group expected shoreline removal to prevent major impacts. Some scores for shallow subtidal areas increased as a result of collateral damage from removal operations. Both groups felt that many of the local habitats would recover naturally just as quickly, but supported clean-up operations on shorelines where it was appropriate.

The general consensus of both groups was that in a scenario like this, the most immediate response requirement is shoreline protection. If the shoreline could be protected within the first six hours of the spill, then serious impacts to those resources could be mitigated.

5.0 Summary Risk Analysis Results and Lessons Learned

Table 5.1 presents the summary results for this workshop. Three response options were analyzed along with natural recovery: on-water mechanical recovery, dispersant application at 80% effectiveness, and shoreline removal. In summary, participants felt that the critical issues in this scenario were potential impacts to birds and bird nesting areas and potential impacts to planktonic lobster larvae if dispersants were used. The speed with which the oil stranded on the shoreline significantly limited the effectiveness of all of the response options, but this situation is potentially very realistic, depending on the circumstances.



Habitats	Terrestrial			Intertidal				Subtidal				Water Column		
Sub-Habitats	Nesting Islands	Mainland Nesting Sites	Beach Berm and Sand Dune	Marsh	Flats	Sandy Beach	Rocky Shore/ Vertical Walls	Eelgrass	Kelp Beds	< 10 Meters	> 10 Meters	Surface	Mid-water	Deep
Natural Recovery	🟨 🟨	🟥 🟥	🟩 🟩	🟨 🟩	🟨 🟨	🟨 🟥	🟨 🟨	🟩 🟩	🟩 🟩	🟨 🟩	🟩 🟩	🟥 🟥	🟩 🟩	🟩 🟩
On-Water Mechanical Recovery	🟨	🟥	🟩	🟨 🟩	🟨 🟨	🟨 🟥	🟨 🟨	🟩 🟩	🟩 🟩	🟨 🟩	🟩 🟩	🟥+ 🟥	🟩 🟩	🟩 🟩
Dispersant Use (80%)	🟩	🟥+	🟩	🟩 🟩	🟨+ 🟨	🟨+ 🟥+	🟨 🟨	🟩 🟩	🟩- 🟩	🟨+ 🟩	🟩 🟩	🟨 🟥+	🟩 🟩-	🟩 🟩
Shoreline Recovery	🟩	🟥+	🟩-	🟩 🟩	🟨 🟥	🟨+ 🟥+	🟨 🟥	🟩 🟨	🟩 🟩	🟨 🟩	🟩 🟩	🟥+	🟩	🟩

Legend: Red cells represent a "high" level of concern, yellow cells represent a "moderate" level of concern, and green cells represent a "limited" level of concern. There are two group scores per sub-habitat type (columns). A + indicates reduced concern within the broad risk category, while a – indicates an increased concern within the category.

Figure 5.1 *Final relative risk matrix for the Casco Bay risk assessment*

At the conclusion of the workshop, the participants developed the following list of consensus comments for consideration in future oil spill response planning efforts. They suggested these be presented to the Maine/New Hampshire Area Committee for consideration.

5.1 General Comments on the Workshop Process

1) Recognize that the matrix results from this workshop apply only to the scenario herein, and that the accuracy of the trajectory model was questioned.

2) Recommend that the Area Committee revisit additional scenarios to include looking at multiple seasons, tide stages, locations, oil types, etc., in order to generate well-rounded recommendations.

3) Review results with key participants who were unable to attend.

4) The matrix would be more useful if "short term" was defined as 0-2 years or less than/equal to one year.

5) Sound hydrographic modeling is necessary IF the matrix results from this workshop will "live on" and be used to make recommendations for spill response operations. NOAA and the Area Committee need to work together to obtain/use the most accurate hydrographic modeling data.

6) GOMOOS (Gulf of Maine Ocean Observing System) is a possible source of data for future modeling.

7) The purpose of the trajectory model was to examine impacts of oil entering specific environments. Perhaps the accuracy of trajectory modeling data is not essential BUT the participation and knowledge of experts (responders, trustees, etc.) IS essential.

8) Participation in this workshop does not constitute full consensus on any particular recommendations from this workshop.

9) Education of local groups/agencies/private citizens may be necessary and useful to inform the local community about a) constraints faced during oil spill responses, b) response options, c) the process (planning and response). Address misconceptions via community involvement/information exchange.

10) The scenario reflects a realistic event, i.e., is not unreasonable for Casco Bay.

11) Participants recommend working vertically through the risk matrix (response options) as opposed to horizontally through habitats. The exception is natural recovery; participants still agree that this response needs to be completed prior to assessing others.

12) It would be beneficial to have risk matrices available in large form (wall hanging/screen) to complete.

13) It would be beneficial to have large-scale snapshots of the scenario to review during the assessment process.

5.2 On-Water Mechanical Recovery

1) Response capabilities are scenario-driven. While the area has enough equipment on-hand to respond promptly, there may not be enough experienced personnel to deploy the equipment while undertaking all other response activities.

2) In this scenario, benefits were real but limited for certain habitats. Given the scenario, these results were expected.

5.3 Dispersant Use

1) In this scenario, concerns about dispersed oil concentrations were lower than expected and dispersed oil dissipated more rapidly than expected.

2) In this scenario, most participants expected more toxic effects from dispersed oil prior to workshop discussions and are interested in examining further the trade-offs between protecting shoreline resources vs. water column resources.

3) Dispersant use concerns regarding water column effects were driven by key species (larval and juvenile lobsters, adult mollusks) with local significance and seasonal distributions.

4) Prior to recommending changes to dispersant capabilities, participants would like to see more research and/or data regarding the impacts of dispersed oil on lobster sensitive life stages and mollusks.

6) In this scenario, participants evaluated dispersant use shoreward of 0.5 nautical miles, but it is understood that such used is not pre-approved.

7) In this scenario, participants believed that dispersant use shoreward of 0.5 nautical miles could result in net benefits; however, in this context, the Area Committee needs to consider further impacts/effects (i.e., toxicity to sensitive life stages, bird populations) prior to generating specific recommendations for the RRT.

8) Improve dispersant sections of the Area Plan (i.e., data on the specifics of oil and dispersants).

9) In this scenario, participants found benefits to birds and mammals (assuming 80% dispersant effectiveness).

5.4 Shoreline Oil Removal

1) If methods are too aggressive, this response method could do more harm than good; however, some of the motivation for this method is pressed by non-environmental considerations (e.g., social/political issues).

2) In this scenario, regardless of other implemented options, shoreline oil removal was necessary.

3) In this scenario, this response method was not as successful as participants anticipated (depending on the methods employed).

4) Participants realized that dominant habitats in this region do not lend themselves to successful oil removal.

5) Group 1 discussed potential alternative uses of dispersants (not shoreline cleaners) for cleaning high energy rocky shoreline areas.

- Shoreline cleaners defined as treatments designed to lift and float oil (recoverable).
- Dispersants defined as treatments that will break up and re-enter the water column (non-recoverable).

This alternative is unlikely to be used within Casco Bay, but could be applied in other areas along the Maine coastline following further discussion and considerations. However, little dispersant may be necessary in high energy areas due to natural dispersion, and may be more beneficial than steam cleaning.

6.0 References

Aurand, D., L. Walko and R. Pond. 2000. Developing Consensus Ecological Risk Assessments: Environmental Protection in Oil Spill Response Planning. A Guidebook. United States Coast Guard, Washington, DC. 148 pages. (Also Ecosystem Management & Associates, Inc. Technical Report 00-01)

Pond, RG., D.V. Aurand, and J.A. Kraly (compilers). 2000. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the San Francisco Bay Area. California Office of Spill Prevention and Response. California Department of Fish and Game, Sacramento, CA.

U.S. Environmental Protection Agency. 1998. Guidelines for Ecological Risk Assessment. Federal Register 63 (93) of Thursday, May 14, 1998. pp. 26846-26924.

Appendix A

Participants

GROUP 1

Name	Affiliation	Phone	Email
Barker, Seth	ME DMR	207.633.9579	Seth.Barker@state.me.us
Berry, Rick	NH DES	603.271.0653	rberry@des.state.nh.us
Brown, Carroll	NH DES	603.271.3000	CBrown@des.state.nh.us
Emmons, MST2 K.	USCG MSO Portland	207.780.3773	kemmons@msoportme.uscg.mil
Evans, Bill	NH DES	603.271.2873	wevans@des.state.nh.us
Hansen, Kurt	USCG R&D Center	860.441.2865	khansen@rdc.uscg.mil
Kenney, John	ME Dept. of Inland F&W	207.941.4448	John.kenney@state.me.us
Lundgren, Scott	USCG District 1	617.223.8434	slundgren@d1.uscg.mil
Mearns, Alan	NOAA OR&R	206.526.6336	Alan.Mearns@noaa.gov
Parker, Barbara	ME DEP	207.287.7752	Barbara.t.parker@state.me.us
Stahlnecker, James	ME DEP	207.287.7745	James.stalhnecker@maine.gov

GROUP 2 (* Day 1 only)

Name	Affiliation	Phone	Email
Dlhopolsky, Lucas	USCG Civil Engineering Unit, Providence	401.736.1743	LDlhopolsky@ceuprovidence.uscg.mil
Drew, LT Rebecca*	USCG D1	617.223.8125	rdrew@d1.uscg.mil
Leathers, David	NH DES	603.271.3000	dleathers@des.state.nh.us
McCann, LT Matt	USCG MSO Portland	207.780.3567	mmccann@msoportme.uscg.mil
McLeod, Gretchen*	MSRC, Portland	207.780.8801	macleod@msrc.org
Ott, Gary	USCGRTC Yorktown	757.856.2755	Gary.Ott@noaa.gov
Pietrak, Mike	Maine Aquaculture Association	207.622.0136	mpietrak@worldnet.att.net
Payne, Joe	Friends of Casco Bay	207.799.8574	jpayne@cascobay.org
Raddant, Andrew	US DOI	617.223.8565	Andrew_raddant@ios.doi.gov
Sait, David	ME DEP	207.287.7190	David.C.Sait@state.me.us
Tant, MST2 Christina	USCG MSO Portland	207.780.3773	ctant@msoportme.uscg.mil
Woodard, Lynn*	NH DES	603.271.3000	lwoodard@des.state.nh.us

Appendix B

Resource Table and Data Sources

Broad Habitat	Sub-habitat	Resource Category	Example Organisms (key species)
Terrestrial	Nesting Islands	Birds	Bald eagle, osprey, common eider, double-crested cormorant, roseate tern, arctic tern, common tern, herring gull, great black-backed gull, great blue heron, snowy egret, glossy ibis, black-crowned night-heron
	Mainland Nesting Sites (Maine Dept of Inland Fisheries and Wildlife, 2003)	Birds	Bald eagle, peregrine falcon, least tern, and piping plover plover
	Beach Berm and Sand Dunes (Dickson 2001; SPO, 1983; Timson, 1976; Godfrey et al., 1982; Nelson and Fink, 1980)	Grasses and other vegetation (*American beach grass considered and deleted*)	Beach pea, dusty miller, sea rocket, saltwort, sea blite, beach heather, etc.
	Other, Beach and Sand Dune (Maine Dept of Inland Fisheries and Wildlife, 2003; Maine Natural Areas Program, 2003)	Endangered and threatened plants and animals	Least tern, piping plover; Sand dune and beach strand communities, pitch pine dune semi-forest
Inter-tidal	Marsh (SPO, 1983; Timson, 1976)	Birds	Glossy ibis, snowy egret, great blue heron, black duck, saltmarsh sparrow, shorebirds, gulls
		Vegetation	*Spartina* spp, *Juncus* spp, *Ascophyllum nodosum* form *sorpiodes*, *Ruppia*
		Fish	*Fundulus*, sticklebacks
		Crustaceans	Green crab, *Crangon*, *Palaemonetes*
		Mollusks	Ribbed mussel, gastropods
	Flats (SPO, 1983; Timson, 1976)	Birds	Black duck, mallard, Canada goose, great blue heron, snowy egret, shorebirds, gulls
		Crustaceans	Green crab
		Mollusks	*Mya*, blue mussels, *Macoma*
		Marine Worms	Annelids, nemerteans
		Other infauna	
	Sand Beach (Dickson, 2001; SPO, 1983; Timson, 1976; Maine Dept of Inland Fisheries and Wildlife, 2003; Jaramillo et al., 1987; Larsen and Doggett, 1990)	Birds	Piping plover, least tern, shorebirds, gulls
		Macrofauna	Worms (nemerteans, polychaetes, oligochaetes, nematodes) bryozoans, gastropods, bivalves, crustaceans, arthopods, isopods, amphipods, decapods, insects
		Meiofauna (*considered and deleted*)	
	Rocky Shore/Vertical Walls (Doggett et al., 1978; SPO, 1983; Timson, 1976)	Birds	Gulls, shorebirds
		Macroalgae	Rockweed (*Ascophyllum*, *Fucus*), *Chondrus*
		Mollusks	Blue mussels, gastropods

Broad Habitat	Sub-habitat	Resource Category	Example Organisms (key species)
Sub-tidal	Eelgrass (Wippelhauser, 1996; SPO, 1983)	Crustaceans	Lobster, cancer crabs, isopods
		Fish	Striped bass, winter flounder, juveniles
		Mollusks	Juvenile mussels, gastropods
		Birds	Brant
	Kelp Beds (Wippelhauser, 1996)	Crustaceans	Lobsters, crabs
		Fish	Pollock
		Other Invertebrates	Sea urchins
	Less Than 10 meters (Barnhardt et al., 1996, 1998; Kelley et al., 1998, 2003; SPO, 1983)	Birds	Common eider, double-crested cormorant, merganser, scoter, bufflehead, black duck, brant, Canada goose, goldeneye, common loon, gulls
		Fish	Winter flounder
		Mollusks *(considered and deleted)*	
		Crustaceans	Lobsters, crabs
	Greater Than 10 meters (Barnhardt et al., 1996, 1998; Kelley et al., 1998, 2003; Dickson, 1999)	Fish	Groundfish
		Crustaceans	Lobsters, crabs
		Mollusks	Baltic macoma, common sand dollar, common northern moon snail
		Other Infauna	Worms
Water Column	Surface	Neuston *(considered and deleted)*	
		Reptiles *(considered and deleted)*	
		Mammals *(considered and deleted)*	
		Pelagic seabirds	Storm petrels, shearwaters, seaducks, waterbirds,loons, grebes
	Mid-Water	Pelagics	Herring
	Deep	Groundfish *(considered and deleted)*	

Data Sources for Resource Table

Barnhardt, W. A., J. T. Kelley, S. M. Dickson, and D. F. Belknap, 1998, Mapping the Gulf of Maine with Side-Scan Sonar: A New Bottom-Type Classification for Complex Seafloors, *Jour. Coastal Research*, v. 14, p. 646-659.

Dickson, S. M., 1999, The Role of Storm-Generated Combined Flows in Shoreface and Inner Continental Shelf Sediment Erosion, Transport, and Deposition, Ph.D. Thesis, School of Marine Sciences, University of Maine, Orono, 321 p.

Dickson, S. M., 2001, Beach and Dune Geology Aerial Photos, 80 Open-File maps on a photo base with interpreted geology and legend, Maine Geological Survey, Augusta, Maine, 1:4,800 scale.

Doggett, L. F., P. F. Larsen, and S. C. Sykes, 1978, Intertidal Bedrock Areas of High Species Diversity in Maine, and their Relevance to the Critical Areas Program, Maine Critical Areas Program, Planning Report No. 55 and Bigelow Laboratory Technical Report No. 1-78, 107 p.

Godfrey, P. J., M. M. Godfrey and D. Disraeli, 1982, North America, Coastal Ecology, in: M. L. Schwartz, *The Encyclopedia of Beaches and Coastal Environments, Encyclopedia of Earth Sciences*, v. XV, Stroudsburg, PA, Hutchinson Ross Publishing Co., p. 580-593.

Jaramillo, E., R. A. Croker, and E. B. Hatfield, 1987, Long-term structure, disturbance, and recolonization of macroinfauna in a New Hampshire sand beach, *Can. Jour. Zool*., v. 65, p. 3024-3031.

Barnhardt, W. A., D. F. Belknap, A. R. Kelley, J. T. Kelley, and S. M. Dickson, 1996, Surficial Geology of the Maine Inner Continental Shelf, Maine Geological Survey Geologic Map Nos. 96-7 through 96-13, Augusta, Maine, 1:100,000 scale.

Kelley, J. T., W. A. Barnhardt, D. F. Belknap, S. M. Dickson, and A. R. Kelley, 1998, *The Seafloor Revealed: The Geology of the Northwestern Gulf of Maine Inner Continental Shelf*, Maine Geological Survey, Open-File Report 96-6, 55 p.

Kelley, J. T., S. M. Dickson, D. F. Belknap, W. A. Barnhardt, and D. C. Barber, 2003, Sand volume on the paraglacial inner continental shelf of the northwestern Gulf of Maine, *Jour. Coastal Research.*, v. 19, p. 41-56.

Larsen, P. F. and L. F. Doggett, 1990, Sand beach macrofauna of the Gulf of Maine with inference on the role of oceanic fronts in determining community composition, *Jour. Coastal Research*, v. 6, n. 4, p. 913-926.

Maine Dept. of Inland Fisheries and Wildlife, 2003, Maine Endangered Speicies Program, Essential Habitat listed at: http://www.state.me.us/ifw/wildlife/etweb/habitat/ehintro.htm

Maine Natural Areas Program, 2003, Natural Community Types (Sand Dune, Pitch Pine Dune Semi-Forest, Beach Strand Community, among others) listed at: http://www.state.me.us/doc/nrimc/mnap/factsheets/natcomindex.html

Nelson, B. W. and L. K. Fink, 1980, *Geological and Botanical Features of Sand Beach Systems in Maine*, Maine Sea Grant Publication, University of Maine, Orono, MSG-B-14-80, 163 p.

State Planning Office, 1983, The Geology of Maine’s Coastline, A Handbook for Resource Planners, Developers, and Managers, Augusta, 79 p.

State Planning Office, 1985, Maine’s Intertidal Habitats, A Planner’s Handbook, Augusta, 43 p.

Timson, B. S., 1976, Coastal Marine Geologic Environments Maps, 110 Open-File maps on a 7.5’ USGS topographic map base with interpreted geology and legend, Maine Geological Survey, Augusta, Maine, 1:24,000 scale.

Wippelhauser, Gail S., 1996. Ecology and Management of Maine's Eelgrass, Rockweeds, and Kelps, 73 pp.)