Coastal Vulnerability for Ship-Source Oil Spill Preparedness and Response Planning in Halifax Harbour, Nova Scotia

by

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Submitted in partial fulfillment of the requirements for the degree of
Master of Marine Management

at

Dalhousie University
Halifax, Nova Scotia
November 2015

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LIST OF ABBREVIATIONS USED

AANDC	Aboriginal Affairs and Northern Development Canada
ALERT	Atlantic Emergency Response Team
ARP	Area Response Planning
BN	Bayesian Network
CCG	Canadian Coast Guard
CPm	Causal Probabilistic Model
DFO	Department of Fisheries and Oceans
DND	Department of National Defence
DNV	Det Norske Veritas
EC	Environment Canada
ECRC	Eastern Canada Response Corporation
ECSC	Environment Canada Shoreline Classification dataset
ENA	Exploratory Network Analysis
ESI	Environmental Sensitivity Index
ESPON	European Observation Network, Territorial Development and Cohesion
GDP	Gross Domestic Product
GIS	Geographic Information System
HH	Halifax Harbour
HRM	Halifax Regional Municipality
HRMCD	Halifax Regional Municipality Corporate Database
HS	Halifax Seaport
IPIECA	Global Oil and Gas Industry Association for Environmental and Social Issues
ITOPF	International Tanker Owners Pollution Federation Limited
MARIN	Maritime Activity and Risk Investigation Network
MSP	Marine Spatial Planning
NOAA	National Oceanic and Atmospheric Administration (US)
NRC	National Research Council (US)
NRD	Natural Resource Damage
OECD	Organization for Economic Co-operation and Development (EU)
OHF	Oil Handling Facility
OSCAR	Oil Spill Contingency and Response
OSm	Oil Spill Numerical Model
OSM	Oil Spill Management
OSR	Oil Spill Response
OSRA	Oil Spill Risk Analysis
PGv	Partial Global Vulnerability Index
PTMS	Point Tupper Marine Services Limited
PSEPC	Public Safety and Emergency Preparedness Canada
PWGSC	Minister of Public Works and Government Services Canada
RLUL	Nova Scotia Department of Natural Resources Restricted and Limited Use Land Database
RO	Response Organization

SIMAP	Spill Impact Model Application Package
SpillMod	Russian Hydrodynamic model of Oil Spills
TC	Transport Canada
WCMRC	Western Canada Marine Response Corporation

Chadid, A. 2015. Coastal Vulnerability for Ship-Source Oil Spill Preparedness and Response Planning in Halifax Harbour, Nova Scotia [graduate project]. Halifax, NS: Dalhousie University.

ABSTRACT

Ship-source oil spills are amongst the major sources of oil affecting coastal areas. An end-to-end marine oil spill analysis may provide a model to better allocate response resources or prepare contingency plans for highly vulnerable zones. A consequence assessment, a key aspect of this type of analysis which considers economic, social and environmental aspects of a geographic area, is presented in this study as a GIS index tool, which can be applied in the context of Atlantic Canada. A theoretical framework and conceptual model is developed based on a literature review of oil spill state-of-the-art analysis using Exploratory Network Analysis; and tested on a realistic case study (Halifax Harbour, NS). The novel approach for reviewing the literature provided sound criteria for the conceptual model, which fits the end-to-end marine oil spill analysis, segregating elements regarding exposure and oil behaviour. Furthermore, oil spill management indicators were tailored using expertise from Atlantic Canada's oil spill responders, and many gaps were identified to potentially refine the model later. Finally, this model considers the range of aspects that influence the consequences of a ship-based oil spill, using readily available information and considering relevant stakeholder's interests.

Keywords: Oil Spill Risk Analysis, Vulnerability, Index, Hazard, GIS, Halifax Harbour

AKNOWLEDGEMENTS

First, I would like to thank Dr. Ronald Pelot, my academic supervisor. His guidance, patience, support, and dedication made this project possible. I would like to thank him as well, for giving me the opportunity to be an intern with the Maritime Activity and Risk Investigation Network (MARIN), which has been by far, an important professional and academic experience during my studies in this country. Also, I have not enough words to express my gratefulness to Dr. Hilario Calderon, member of MARIN, a mentor full of patience, who largely helped to create the methodology, analyze the data, and to develop my technical skills. I will never forget his efforts to make me a better researcher.

I would like to thank COLFUTURO who gave me the financial support to pursue my studies, and the Colombian Navy who supported me completely during the entire process, particularly Captain Rafael Torres, Captain Javier Gomez and Dr. Jorge Pierini.

I would like to thank my MMM classmates, my husband, and family back home, that supported me throughout my time in the Marine Affairs Program.

Finally, I must gratefully acknowledge the data and advice provided by EC, ECRC and Mr. Robert Starkes; some data were also acquired from the RLUL DNR and HRM databases. This research is part of the project “Spatial Risk Analysis of Ship-based Spills to Assess Shoreline Vulnerability” supported by the MEOPAR-NCE.

CHAPTER 1 INTRODUCTION

Petroleum and its many derivatives are vital for the maintenance of an industrialized modern society. However, oil spills are a serious threat, including to coastal environments, which may cause irrecoverable environmental effects as well cascading effects to the society and economy in general (Vafai, V. Hadipour, & A. Hadipour, 2013; Olita et al., 2012).

According to Fattal et al., (2010), “Over the last 30 years oil spills have contributed significantly to coastal and marine pollution” (p. 879). Spills can be caused by several risk factors, often associated with maritime transport and port activities (Oliviera, Silveira, & Alves, 2014). As noted by Romero, Abessa, Fontes, & Silva (2013), with the growth of these shipping activities and oil exploitation as well, the risk of oil spills, which is not always preventable, may increase. Therefore, management and prevention tools are essential for producing effective responses and minimize spill effects (Frazao Santos, Carvalho, & Andrade, 2013; Oliviera et al., 2014).

Currently, prevention plans and integrated coastal zone management are widely used to address the hazard of an oil spill; including a large number of studies analyzing vulnerable areas and the associated impacts of oil pollution using diverse data, assessment methods and operational tools, such as hazard potential, vulnerability, sensitivity and risk maps (Frazao Santos et al., 2013; Singkran, 2013).

1.1 MARINE SHIP-SOURCE OIL SPILLS

According to the Minister of Public Works and Government Services Canada [PWGSC], (2010), "marine ship-source oil spills can occur as a result of accidents and operations, or from intentional discharges of oily water; ranging from large quantities of oil from oil tankers to smaller accidental discharges of oil and fuel from smaller craft in marinas" (p. 5).

However, oil tankers often have been involved in some of the most severe oil spills, as can be seen from the International Tanker Owners Pollution Federation Limited [ITOPF] (2015) statistics, which include the Atlantic Empress (287,000 tonnes; off Tobago, West Indies, 1979), the ABT Summer (260,000 tonnes; off Angola, 1991), the Castillo de Bellver (252,000 tonnes, off Saldanha Bay, South Africa, 1983), the Amoco Cadiz (223,000 tonnes; off Brittany, France, 1978), the Prestige (63,000 tonnes; off Galicia, Spain, 2002), and the Exxon Valdez (37,000 tonnes; Prince William Sound, Alaska, USA, 1989).

ITOPF (2015) found that the size of the majority of ship-source oil spills worldwide is less than 7 tonnes, and identifies catastrophic incidents, such as groundings and collisions as the major causes of spills over 700 tonnes, which are considered large spills. A relatively low incidence of large spills, and a decline in the incidence in other spill sizes was also noted. However, O'Brien, (2002) found the following:

> World-wide statistics on oil spills show that the incidence of major oil spills has significantly fallen over the last three decades. However, environmental awareness and sensitivity to the impact of oil spills have grown at an even quicker pace over

> the same period. There is no doubt, therefore, that continued investment in preventive measures and emergency response capabilities is justified (p.1).

PWGSC (2010) suggests that marine ship-source oils spill immediate and long-term impacts on the environment and local coastal communities include disturbance of "marine life and habitats; recreational activities such as swimming and boating; economic activities such as tourism, fishing and aquaculture; and human welfare, caused by public anxiety over lost livelihoods and decay of the living environment" (p. 5).

1.1.1 Marine Ship-Source Oil Spills in Canada

PWGSC (2010) point out that oil spill occurrences in Canada are of small magnitude compared with worldwide statistics. However, Canada has experienced several large ship-source oil spills in the past: the Arrow (10,000 tons; Nova Scotia, 1970), the Golden Robin (400 tonnes; Baie-des-Chaleurs, Quebec, 1974), and the Kurdistan (8,000 tonnes; Cabot Strait between Cape Breton Island and Newfoundland, 1979) (ITOPF, 2015). However, a major oil spill, ranked six worldwide in terms of spilled oil by ITOFP, occurred outside Canada's waters, but considerably close to the East Coast, 700 nautical miles off Nova Scotia in 1988, when 132,000 tons of North Sea Brent crude oil were spilled by the tanker Odyssey (Centre of Documentation, Research and Experimentation on Accidental Water Pollution [CEDRE], 2012; ITOFP, 2015).

Between 2007 and 2009 a total of about 1,580 oil spills from ships were reported in the country (PWSGC, 2010). Transport Canada (2015) observes that Canada's East Coast is accountable for 16 times more tanker trips than the West Coast, with over 82 million tonnes of petroleum and fuel products being moved in and out of 23 Atlantic ports.

However, the latest spill is associated with the West Coast this past April (2015), when the bulk carrier Marathassa spilled an unknown quantity of intermediate fuel oil (estimated as 2.37 Tons for response operations) into English Bay in the Port of Vancouver which, according to Butler's independent review (2015), engendered strong media scrutiny and public attention. He suggests that this incident caused a considerable increase of the general public's awareness of oil transportation and marine safety in Canada, particularly given emerging oil-related projects.

1.1.1.1 Marine Pollution Preparedness and Response System for Ships

Canada has a marine pollution preparedness and response system for ships constituted by two equally important components: the Marine Oil Spill Preparedness and Response Regime and the Government operational response capacity, both complemented by a support system of federal, provincial, territorial and municipal departments and agencies (PWSGC, 2010) (Figure 1-1).

The regime is a partnership between the government and the private sector, in which the industry operates and funds the operational elements of the preparedness regime, while the government has responsibility for the legislative and regulatory framework, including standards, overseeing and monitoring response activities, and enforcement (Transport Canada, 2010). The regime requires that certain ships have arrangements with a Transport Canada certified Response Organization (RO) to ensure a 10,000 tonne response capability at locations below 60º North Latitude (Canada Shipping Act, 2001). Currently, four ROs have been established in Canada: Western Canada Marine Response Corporation (WCMRC), Eastern Canada Response Corporation (ECRC),

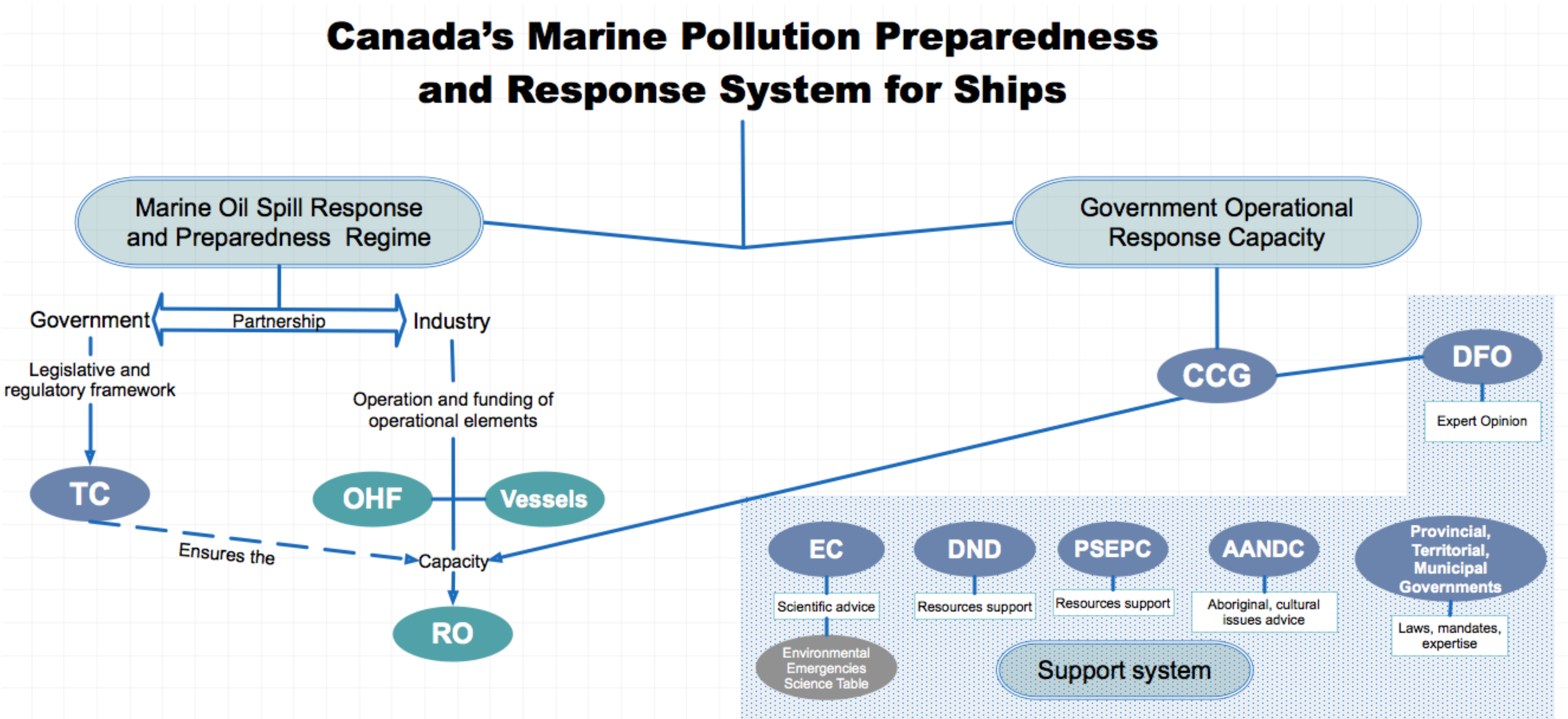

Figure 1-1 Depiction of main components and responsible institutions of Canada's Marine Pollution Preparedness and Response System for Ships: the Marine Oil Spill Response and Preparedness Regime, the Government Operational Response Capacity and their Support System.

Atlantic Emergency Response Team (ALERT) and Point Tupper Marine Services Limited (PTMS). They are independent agencies linked through various support and mutual aid agreements (Eastern Canada Response Corporation Ltd. & Western Canada Marine Response Corporation [ECRC & WCMRC], 2012). Meanwhile, the system's operational capacity is shared between the ROs and the Canadian Coast Guard (CCG). CCG is the responsible agency for ensuring an appropriate response, fulfilling monitoring and/or on-scene command roles for the Government, acting as response agency for spills outside ROs' geographic areas of response, mystery spills and spills, from ships not subject to Part 8 of the Canada Shipping Act (such as DND vessels) (Transport Canada, 2010, 2014).

1.1.1.2 Current Situation

The year 2013 was significant for Canada's marine pollution preparedness and response system for ships. The firm WSP, widely known previously as GENIVAR, commissioned by Transport Canada, conducted a countrywide risk assessment for ship-source spills, which was used to inform a review of the regime occurring at that time.

The regime's review, conducted by the Tanker Safety Panel Secretariat was the first since the regime creation in mid 1920's (Tanker Safety Panel Secretariat, 2013). Main conclusions pointed to the need to tailor preparedness and response arrangements to suit each region due to the varied levels of risk across Canada. Based on these recommendations the Area Response Planning (ARP) pilot project was created. In this project four areas were chosen as pilot projects (southern portion of British Columbia, St. Lawrence River, Port Hawkesbury and the Strait of Canso, Saint John and the Bay of Fundy), with the intention to refine Canada's response planning models and be used in the near future to implement the approach in other locations across Canada (Transport Canada, 2015; WSP Canada Inc. & SL Ross, 2014).

There is no publicly available information about the ARP project, which is in its early stages. According to R. Starkes, ECRC's Atlantic Region Manager, ARP's coordination has been assigned to ROs, and only two projects are currently ongoing, with expected outcomes in about two years. ECRC's ARP (Atlantic Canada) has not started, being delayed due to legal constraints (personal communication, August 27, 2015).

1.2 A Thorough Approach to Ship-based Oil Spills

A recent study by Calderon and Pelot (2015) argues the following:

> "Key aspects for the analysis of ship-source oil spills are contained within the question of 'where': where are the oil spills likely to occur?; where is the oil likely to go?; and where are the areas that might be impacted most? While many research papers and software packages incorporate these elements, especially the last two items, few studies combine them in such a way as to characterize shoreline areas, which are most susceptible to spills" (p. 1).

Following the preceding premise, the Maritime Activity and Risk investigation Network (MARIN) Research group is advocating for an end-to-end marine oil spill analysis for strategic planning: a model that can serve to better allocate response resources or prepare contingency plans for highly vulnerable zones, in which the previous "where" questions provide a framework for its analysis (Pelot, Calderon, Niu, Chadid, & Li, 2015). In this framework each block is a sequential component (Figure 1-2), contributing to reach the final stage: the consequences or impacts caused by an oil spill.

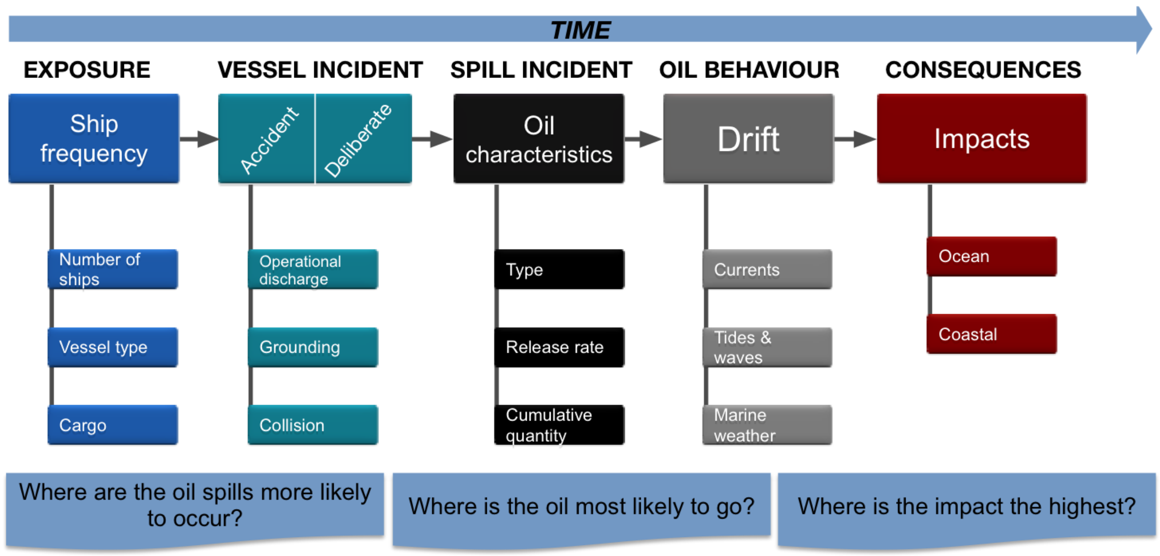

Figure 1-2 End-to-end Marine ship based oil spill analysis Framework. This model describes a ship-based oil spill timeline, linking three questions (bottom) to the different stages of development of a marine oil spill. This model was presented by Professor R. Pelot as an overview of a MARIN project, of which this study is part. The figure is adapted from that presentation (Pelot et al., 2015).

1.2.1 Assessing the Consequences of an Oil Spill

Sensitivity and vulnerability are two common concepts used for assessing the consequences of an oil spill, materialized as vulnerability and sensitivity indexes and maps. These once paper maps, born in late 1970's, have been transformed into electronic ones, recognizing the dynamic aspect of the environment, such as seasonality and temporary activities (Castanedo et al., 2009; Vafai et al., 2013).

Determining which of these two indexes is more advantageous is a difficult task. Moreover, it is unclear where one ends and the other begins, as noted by Romero et al. (2013), "the terms sensitivity and vulnerability have been used interchangeably in many studies, although they may have different meanings" (p. 157). On the one hand, there is agreement about what sensitivity generally means, and standards have been produced for sensitivity mapping, known as the Environmental Sensitivity Index (ESI) approach (i.e.

International Maritime Organization [IMO], The Global and Gas Industry Association for Environmental and Social Issues [IPIECA], & International Association of Oil and Gas Producers [OGP], 2012; Petersen et al., 2002), generally defined as the degree to which a system is affected. On the other hand, there is little agreement on vulnerability, which comprises both hazard exposure and social response.

A sensitivity approach is the choice of recent country-level risk assessments, such as Australia and Denmark in 2011 (i.e. Det Norske Veritas [DNV], 2011; Stejernholm, Boertmann, Mosbech, & Nymand, 2011), and Canada in 2014 (i.e. WSP Canada Inc. & SL Ross, 2014). Meanwhile, vulnerability is common in peer-reviewed papers. Recent vulnerability studies attempt a holistic approach recognizing social and environmental vulnerability as well, combining two or three different authors' methodologies for their calculations, often including the ESI approach. However, the number and type of variables included in these publications varies notably.

1.2.1.1 Sensitivity

Sensitivity can be defined as the degree to which a system is affected or how negatively it responds to an impact (Catto, 2011; Romero et al., 2013), or more specifically from an oil spill perspective, "the likelihood of a resource to be affected by an oil event even without direct contact" (Oliveira, et al., 2014, p. 113).

For the determination of shoreline sensitivity to oil spills, NOAA's ESI, which is the USA standard, remains one of the most broadly used approaches and an integral part of oil spill contingency plans, emergency responses, as well as coastal resources management worldwide (Ng, Vijayan, Chow, & Sulaiman, 2008; Oliveira et al., 2014;

Vafai et al., 2013). ESI maps compile features such as a shoreline geomorphology sensitivity rank to oiling, biological and socio-economic resources at risk, and complementary guidelines for decision-making support systems in oil spill contingency plans (Oliveira et al., 2014).

1.2.1.2 Vulnerability

According to Roberts, Nadim, & Kalsnes, (2009) two fundamentally different perspectives for assessing vulnerability exist: those that have their roots in natural sciences and those that are based on the social science concepts. The former considers the human system as passive, so vulnerability only considers the physical vulnerability of the elements at risk. Meanwhile, there is no unique definition of vulnerability in social sciences, but emphasis is made on underlying structural factors that may reduce the capacity of the human system to cope with a range of hazards, rather than the negative impacts following one specific hazard.

Traditional studies of oil spill coastal vulnerability are examples of the former perspective; most of them focus on the collection of baseline data for biological impact and physical characteristics of the shorelines. However, a recent trend indicates that these indexes must consider a “broad range of factors, biophysical as well as social, and their interactions, which influence the consequences of an oil spill” (Chang, Stone, Demes, & Piscitelli, 2014, p.1). Likewise, several authors made the integration of these factors the focus of their study (i.e. Castanedo et al., 2009; De Andrade, Szlafstein, Souza-Filho, Dos Reis, & Tavares, 2010; Fattal et al., 2010; Frazao et al., 2013; Ng et al., 2008).

1.3 Purpose and Research Questions

This project aims to find an approach to assess the consequences of a ship-based oil spill within an end-to-end marine oil spill analysis, which can be applied in the context of Atlantic Canada. The goal is to develop an index methodology that: 1) considers the range of aspects that influence the consequences of a ship-based oil spill using the best information available, 2) is spatially-centred in Atlantic Canada, 3) represents the interests of relevant stakeholders.

The main research question to be answered is: How could a ship-source oil spill's consequences be best assessed using an index methodology in Atlantic Canada?

To answer the preceding research question, the following sub-questions will be sequentially addressed:

1. Which publications contain the most valuable information to develop an index method to assess the consequences of an oil spill?
2. What are the best methods contained within those relevant publications?
3. How can these methods be applied in Atlantic Canada?

1.4 Research Approach

The research for this project was completed in three parts, presented in separate chapters. The first chapter presents a Literature Review on the subject of oil spill state-of-the-art assessment. In order to answer this project's Nº 1 sub-question, these publications were prioritized for usefulness based on how relevant they are within their network using Exploratory Network Analysis. The software Gephi 0.8.2-beta was used for this purpose.

Sub-question Nº 2 is answered in the second chapter, where a comparison of the methodologies used by relevant sources is presented. Trends and best practices are identified and expressed in a theoretical framework and conceptual model.

In the last chapter, sub-question Nº 3 is answered through a hazard and spatially centred-approach, using Halifax Harbour as a case study to determine the applicability of the conceptual model previously produced. Area particularities, as well as relevant stakeholders in the case of a ship-based oil spill, are considered. ArcGIS 10.2 was the software used for spatial data analysis, and visualization of results.

CHAPTER 2 LITERATURE REVIEW: A NETWORK APPROACH

A literature review may be pivotal to recognize objective and scientifically sound criteria to develop a theoretical framework, which must be the foundation of a methodology to measure the consequences of a ship-based oil spill. However, a traditional literature review in this particular case (for an end-to-end oil spill analysis) appears not to be the most efficient option by virtue of the many approaches to Oil Spill Risk Analysis (OSRA) in the publications, and the time constraints of this study. In other words, the vast information is distributed partially in many publications, each with a different focus on this issue.

A Network Analysis approach is a recent technique for analyzing complex networks, which identifies trends and patterns more quickly (Heymann & Le Grand, 2014). Hence, this study uses this innovative approach to reduce the number of publications retained while diminishing the risk of overlooking some important ones, by considering the reviewed literature as a network, which can be considered as "complex" due to the aforementioned issues.

2.1 EXPLORATORY NETWORK ANALYSIS

As stated in Heymann and Le Grand (2014), "a network is made of a set of entities, called nodes, and a set of relationships between entities, called links or edges" (p. 1). These nodes and edges have several attributes associated with them, which can be potentially unlimited and diverse, constituting a complex network. Therefore, analysts usually prefer first an exploratory network analysis approach (ENA) to inspect data and outline interesting perspectives before further exploring specific issues.

According to the U.S. National Research Council [NRC] (2005), Network Analysis is part of a new and emerging scientific discipline known as Network Science, which is defined as " the organized knowledge of networks based on their study using the scientific method" (p. 26). Basically, ENA consists of the understanding of the network statistical properties, identification of significant entities, and the detection of anomalies (Heymann & Le Grand, 2014). It is an intuitive process based on visualization and manipulation of data, which reveals data properties hard to reveal otherwise. Its many advantages include a reduction of time spent searching information, better recognition of patterns and communication of meaningful findings (Few, 2006).

2.1.1 Gephi

The key importance that relationships have in complex network data led to the development of multiple methods and techniques for their representation, including ENA which aims to provide visualization and interaction techniques in conjunction with storage and data mining solutions (Heymann & Le Grand, 2014). One of these tools is the open source software Gephi©, created in 2008, which is suitable for the analysis of all kind of complex networks, although it is mostly used for social network analysis (Kong & Philip, 2014).

Gephi is coded in Java and can be extended by plugins (Bastian, Heymann, & Jacomy, 2009), which are frequently being updated by collaborators based on scientifically sound publications (peer-reviewed paper or PhD thesis). According to

Kong and Phillip (2014), it was designed to facilitate the non-linear process of information discovery, focusing on the visualization of the network using node-link diagrams, real-time interaction, and the use of a visual language. Its users can compute classic metrics of social network analysis and study the correlation of node attributes within a network, interacting with the visualization in real-time to position the nodes in a two or three-dimensional space using layout algorithms or by manually moving nodes.

2.2 MATERIALS

Publications were searched within the last 10 years, yielding 29 publications including reports and peer-reviewed papers (Table 2-1). A list of reviewed publications and references is presented in Appendix A. The inclusion criterion was if they were related to any of the stages of the aforementioned end-to-end marine ship based oil spill analysis framework (Figure 1-2). The reports in Table 2-1 (i.e. Catto,2011; DNV,2011; Sterjernholm,2011; WSP,2014) were excluded from the ENA. Although reports may contain relevant information, they require a more careful treatment, and mixing them with scientifically rigorous information contained in peer-reviewed papers could result in misleading results. Therefore, 25 sources (peer-reviewed papers) were used for the following analysis.

There are two distinctive categories among the publications: a “methods” category, which compiles publications that include a methodology for analysis of any of the oil spill stages; and a “theory” category, which compiles only articles addressing guidelines, frameworks or literature reviews. Most of the documents correspond to the methods category. They were distributed along the oil spill stages aforementioned questions (Figure 1-2) as follows: approximately 30% of them covered all questions, and more than

Table 2-1 List of publications included in the Literature Review, showing: a visualization ID (short identifier including the principal corresponding author and the year of the publication); country of affiliation of the principal corresponding author; a brief description of how the paper is described by its authors; and a categorization of the scope.

Nº	Visualisation ID	Principal author's Affiliation Country	Brief description	METHODS – Stages: Where are the oil spills more likely to occur?	METHODS – Stages: Where is the oil more likely to go?	METHODS – Stages: Where is the impact the highest?	THEORY
1	Adler,2007	Kenya	A semi-quantitative sensitivity index to determine shoreline sensitivity			X	
2	Alves,2014	UK	A three step method for assessment of susceptibility to oil spills	X	X		
3	Azevedo,2014	Portugal	Oil spill model		X		
4	Castanedo,2009	Spain	Oil spill vulnerability index integrating physical, biological and socio-economical characteristics			X	
5	Catto,2011	Canada	A Petroleum Vulnerability Index, considering sensitivity and exposure			X	
6	Chang,2014	Canada	A summary literature review and overview framework of factors and linkages that would influence consequences of a potential oil spill				X
7	De Andrade,2010	Brazil	A vulnerability index based on environment and socioeconomic profile			X	
8	DNV,2011	Australia	An estimate of risk pollution from marine oil spills, limiting the level of detail of oil spill modeling for a large-scale national study	X	X	X	
9	Fattal,2010	France	A vulnerability index based on multicriteria analysis including environmental and socioeconomic parameters			X	
10	Frazao Santos,2013a	Portugal	A Hazard-spatially centred quantitative vulnerability assessment and mapping methodology			X	
11	Frazao Santos,2013b	Portugal	Analysis of Marine Spatial Planning (MSP) and Oil Spill Risk Assessment (OSRA)'s frameworks and proposal of an operational model to implement their link				X
12	Ihaksi,2011	Finland	An index-based method that can be used to make decisions concerning which populations of natural organisms should primarily be safeguarded from a floating oil slick with oil booms.			X	
13	Lamine,2013	China	A numerical modeling application to evaluate the potential oil spill risks assessment	X	X		
14	Li,2014	Canada	A model to classify a given site into distinguished zones representing different levels of offshore Oil Spill Vulnerability Index (OSVI). (Monte Carlo simulation based two-stage adaptive resonance theory mapping (MC-TSAM))	X	X	X	
15	Ng,2008	Malaysia	An oil spill vulnerability index following the Environmental Sensitivity Index approach			X	
16	Olita,2012	Italy	A model based method for evaluating hazard of oil slicks contact with shorelines, that can be combined with vulnerability data	X	X	X	
17	Oliveira,2014	Portugal	Several alternative methodologies to support the optimization of civil protection assets in the occurrence of oil spill events			X	
18	Perhar,2014	Canada	Review of the role of crude oil toxicity on aquatic organisms from a food web point of view, followed by an overview of the modelling literature and a modelling plan to o fill the biological/ecological gap in contemporary oil spill models.				X
19	Pincinato,2009	Brazil	A decision tree coupled with a knowledge-based approach using GIS to assign oil sensitivity indices			X	
20	Romero,2013	Brazil	An index of environmental vulnerability to oil (IEVO), by combining information about environmental sensibility to oil and results of numerical modeling of spilled oil	X	X	X	
21	Frazao Santos,2009	Portugal	A comparison of two oil spill sensitivity assessment approaches			X	
22	Singkran,2013	Thailand	A classification of oil spill risk zones based on the average percentage risk of critical variables (including incidents frequency and important resources)	X	X	X	
23	Stejernholm,2011	Denmark	An oil spill sensitivity Atlas			X	
24	Tansel,2014	US	A quantitative impact assessment methodology to categorically assess the propagation of potential impacts after oil spills			X	
25	Vafai,2013	Iran	A fuzzy method to evaluate shoreline sensitivity area to oil spills (fuzzy multi-criteria decision making model (MCDM))			X	
26	Wiezorek,2007	Brazil	An environmental sensitivity map			X	
27	Wirtz,2006	Germany	A Decision Support System (DSS) consisting of a combination of modelling and evaluation methods which in particular assesses various impacts on habitats and local economies	X	X	X	
28	WSP,2014	Canada	An overall risk pollution estimate from marine oil spills, using a country-scale formal process that could be applied and further refined in future assessments	X	X	X	
29	Jolma,2014	Finland	A software system for assessing the spatially distributed ecological risk posed by oil shipping, based on existing oil spill simulation model, an observation database of threatened species, and a valuation method	X	X	X	

50% covered only the question “Where is the impact the highest?” (i.e. consequence stage).

The theory category includes recent studies which have focused on economic and biophysical impacts of oil spills, such as the summary literature review of factors and linkages that influence oil spill consequences presented by Chang et al., (2014), which also contains a framework that identifies transferable lessons from several oil spill disasters; and the review of the state of knowledge on the subject of modelling oil spills from a food web point of view, presented by Perhar and Arhonditsis (2014), which provides a modelling plan to fill the gaps in contemporary oil spills models. Also, a discussion of approaches to measure the consequences of an oil spill is presented in Frazao Santos et al., (2013), including a comprehensive review on vulnerability assessment approaches and the linkages between marine Spatial Planning (MSP) and OSRA.

2.3 METHODS

2.3.1 Keywords’ Network

A network based on the Keywords used in the reviewed literature was created in Gephi, with nodes representing the papers and their keywords, and edges representing their linkages. The resulting graph is directed (which means that it is a one-way relationship). In order to simplify the graphic output, only the principal author and date were used as identifiers for the graphs (i.e. visualization ID, Table 2-1). Also, the identifiers were “normalized”, in the sense that only one identifier corresponds to a given author, although several authors may refer to him/her differently (e.g. NOAA, 2002 or Petersen 2002; FRAZAO, 2009 or FRAZAO SANTOS, 2009 or SANTOS, 2009).

The network was broken down into subunits (or communities), which are sets of highly connected nodes, using the Modularity Class Algorithm, a heuristic method based on modularity optimization contained in a Gephi Plugin (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008). Force Atlas 3D, a force-directed algorithm based on Noack (2007) and developed by Levallois (2014), was used for the network layout. A force-directed algorithm is a layout that relies on a physical metaphor to position the nodes according to the position of others (i.e. connected nodes tend to be closer, while disconnected nodes tend to be further apart) (Kong & Philip, 2014).

2.3.2 Publications' Network

A directed graph was created in Gephi for the literature review network. The network contains nodes representing the publications (i.e. all the cited literature in the 25 papers), and edges representing their linkages. The network was broken down into communities and presented using the same layout as the aforementioned Keywords' Network Analysis. The metrics used for analysis of this graphic were Local Connectivity, Transit Centrality and Authority. These were defined by Levallois (2014), and can be interpreted as:

- Local Connectivity (also called Degree Centrality): Measures how well-connected is a source with the other sources. Nodes with lots of neighbours are central.
- Transit Centrality (also called Betweenness Centrality): Measures how well situated the source in the network is, where a lot of transit can happen. A node has strong Transit Centrality if is situated on many shortest paths (a shortest path is

the shortest way to go from one node to another). This notion of traffic is defined by Easly and Kleinberg (2010), as follows:

> For each pair of nodes A and B in the graph that are connected by a path, we imagine having one unit of fluid "flow" along the edges from A to B. (If A and B belong to different connected components, then no fluid flows between them). The flow between A and B divides itself evenly along all the possible shortest paths from A to B: so if there are k shortest paths from A and B, then 1/k units of flow pass along each one (p. 74).

- Authority (also called Eigenvector centrality): Measures how valuable the information stored in that source is. A node is central to the extent that the node is connected to others who are central.

2.4 RESULTS

2.4.1 Keywords' Network

The results are presented in Figure 2-1. 173 connections (edges) among the sources and their keywords were found. The network was divided by its modularity into five (5) groups of nodes (with dense connections within groups and sparser connections between groups). Table 2-2 presents the communities with the authors connected by the most relevant keywords in each group. Local Connectivity and Authority rank the keywords' relevance. The former is the mean number of connections per node on the graph, which is confirmed by the latter, a measure of node importance in the network based on the node's connections. The keywords with higher Authority scores in respective order are: oil spill, vulnerability, risk, sensitivity, and GIS (Figure 2-1). The publications with higher Local

Connectivity scores, which can be interpreted as strongly connected with others in reason of their keywords are: Wirtz,2006; Frazao,2013a; Vafai,2013; Li, 2014; Alves,2014; Castañedo,2009; Tansel,2014; Frazao,2013b and Ihaksi,2011. Weakly connected publications are: Chang,2014; Wieczoreck,2007; Pincinato,2009; and Oliviera,2014.

Table 2-2 Modularity classes of the Keywords' ENA, with corresponding publications and relevant keywords

Communities	1	2	3	4	5
Relevant Keywords	*Oil Spill, Index & Hazard*	*Vulnerability, Risk, Sensitivity & GIS*	*Pollution & ESI*	*Analysis & Uncertainty*	*Assessment*
Publications	Li,2014 Olita,2012 De Andrade,2010 Chang,2014	Alves,2014 Oliviera,2014 Castanedo,2009 Adler,2007 Pincinato,2009 Frazao,2009 Fattal,2010 Frazao,2013a Fattal,2010 Frazao,2013a Frazao,2013b Ihaksi,2011 Vafai,2013 Wieczorek,2007	Azevedo,2014 Romero,2013 Perhar,2014 Ng,2008	Wirtz,2006 Tansel,2014	Singkran,2013 Jolma,2014 Lamine,2013

2.4.2 Publications' Network

This analysis contains 1111 papers (from 25 primary sources). The network, with 1241 linkages, was divided using modularity into six communities of nodes (Figures 2-2, 2-3). Table 2-3 presents these communities with several secondary relevant sources (with high Local Connectivity scores). Communities 1 and 3 contain the great majority of the primary sources, which are strongly connected. Interestingly, several papers were excluded from these communities and appear to be only connected to another author, such as 2, 4 and 5. The size of communities 4 and 5 is easily explained, as they are Literature Review documents, obviously with an elevated number of publications.

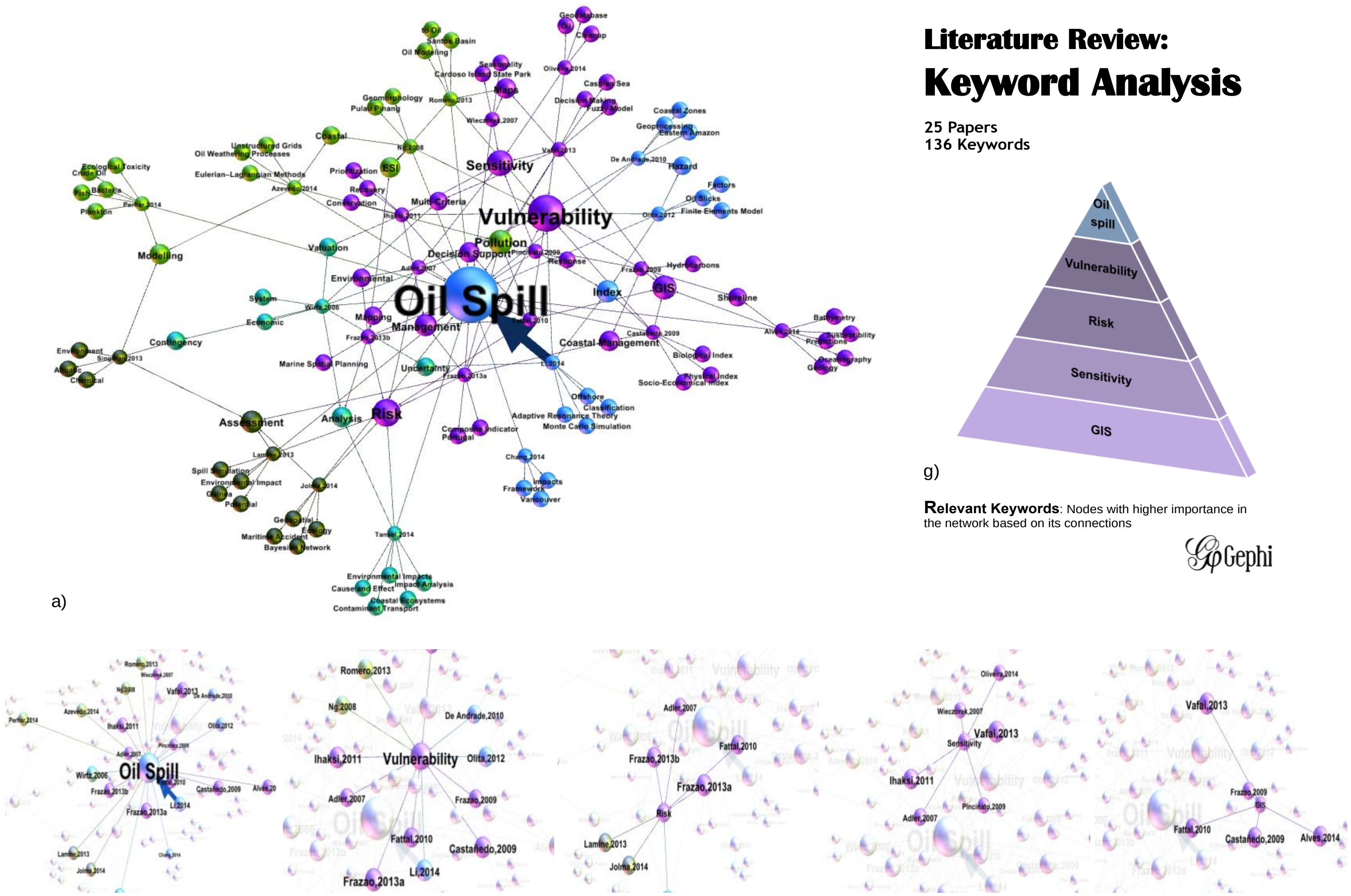

Figure 2-1 Keywords' Exploratory Network Analysis using Gephi, including: a) Keyword graphic layout (the color of the nodes represent different modularity classes, class 1=blue, class 2 =purple, class 3 =green, class 4 = cyan, class 5 =brown). b) Zoom depicting connections of the keyword "oil spill". c) Zoom depicting connections of the keyword "vulnerability. d) Zoom depicting connections of the keyword "risk". e) Zoom depicting connections of the keyword "sensitivity". f) Zoom depicting connections of the keyword "GIS". g) Graphic depicting the most relevant keywords within the network.

However, despite their size, they were poorly connected to other publications. It was found that Alves,2014 is a weakly connected publication, as it appears alone in community 0. The results of the metrics are presented in Figure 2-4, and summarized as follows:

- 14 of 25 publications presented Authority scores above negligible. Higher scores were exhibited by Adler,2007; Wieckzoreck,2007;Wirtz,2006, Ihaksi,2011 and Castañedo,2009.
- 13 of 24 publications presented Transit Centrality scores above negligible. Higher scores were associated with Castanedo,2009; Wirtz,2006; Romero,2013; Ihaksi,2011; Wieckzorek,2007; Adler,2007; and Fattal,2010.
- Local Connectivity is less representative of a relevant role of a publication in the network (because it depends highly on the number of connections, but not on their quality). As expected, papers in the "theory category" received higher scores.
- Publications with higher Authority scores are, at the same time, the ones with higher Transit Centrality scores (with the exception of Jolma,2014, which obtained a slightly low Transit Centrality score). These publications are well situated in the network, and thus it can be assumed that they enjoy recognition by their peers, and are hubs of valuable information. Their country affiliations are scattered among the globe, with a small cluster in Brazil (3 of 14) and Finland (2 of 14).
- Secondary papers were determined to be relevant when they presented high scores of Authority, such as Gundlach,1978; NOAA,2002; Jensen,1990; and IMO/IPIECA,1996 (Table 2-3). These can be considered to be the "text books" for the network.

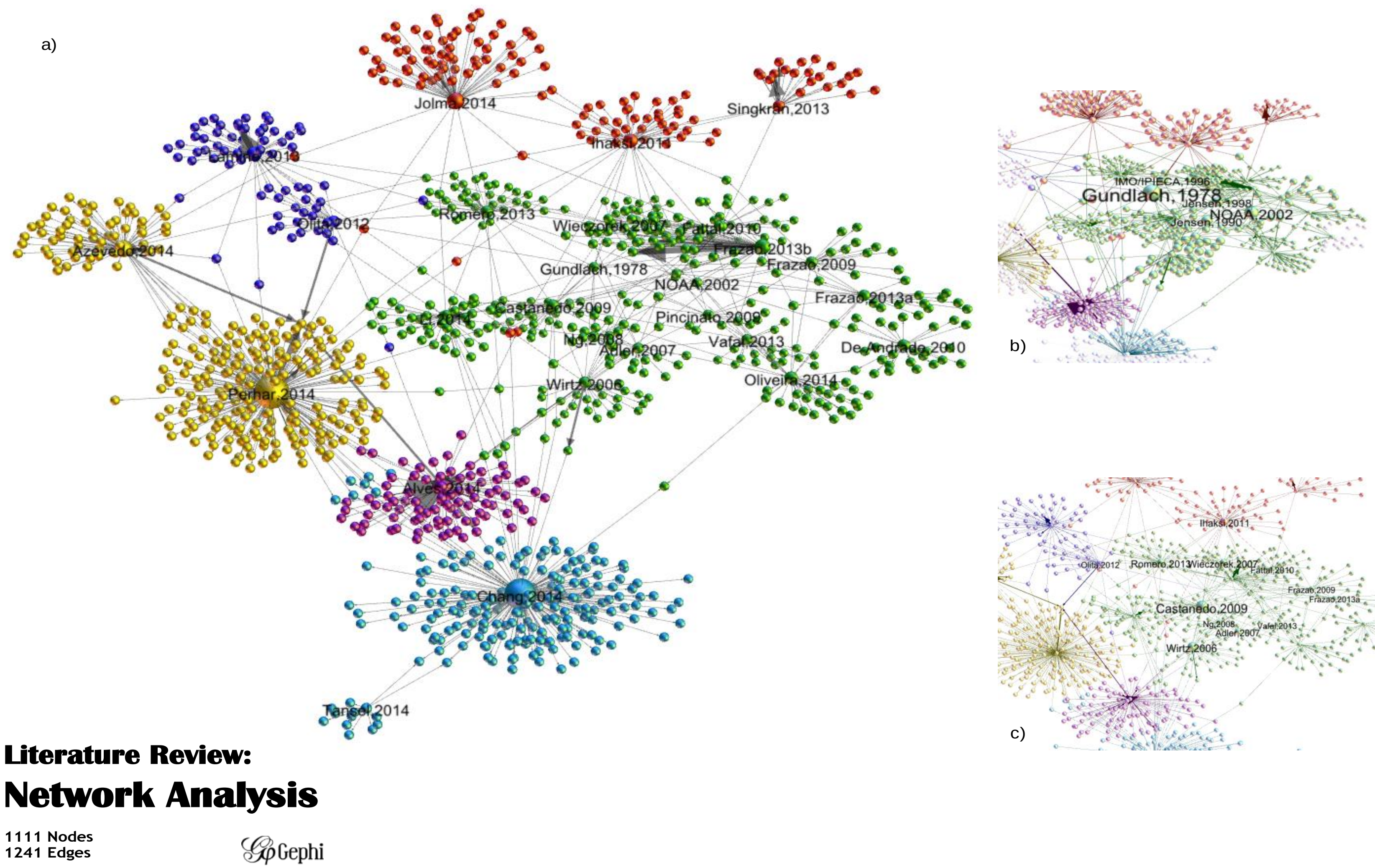

Figure 2-2 Publications' Network Exploratory Network Analysis using Gephi, including: a) graphic layout (modularity classes are shown with different colors, the size of the node and its label is related to its local connectivity; class 0= magenta, class 1=green, class 2= blue, class 3= red, class 4= yellow, class 5= cyan). b) Authority scores. c) Transit centrality scores.

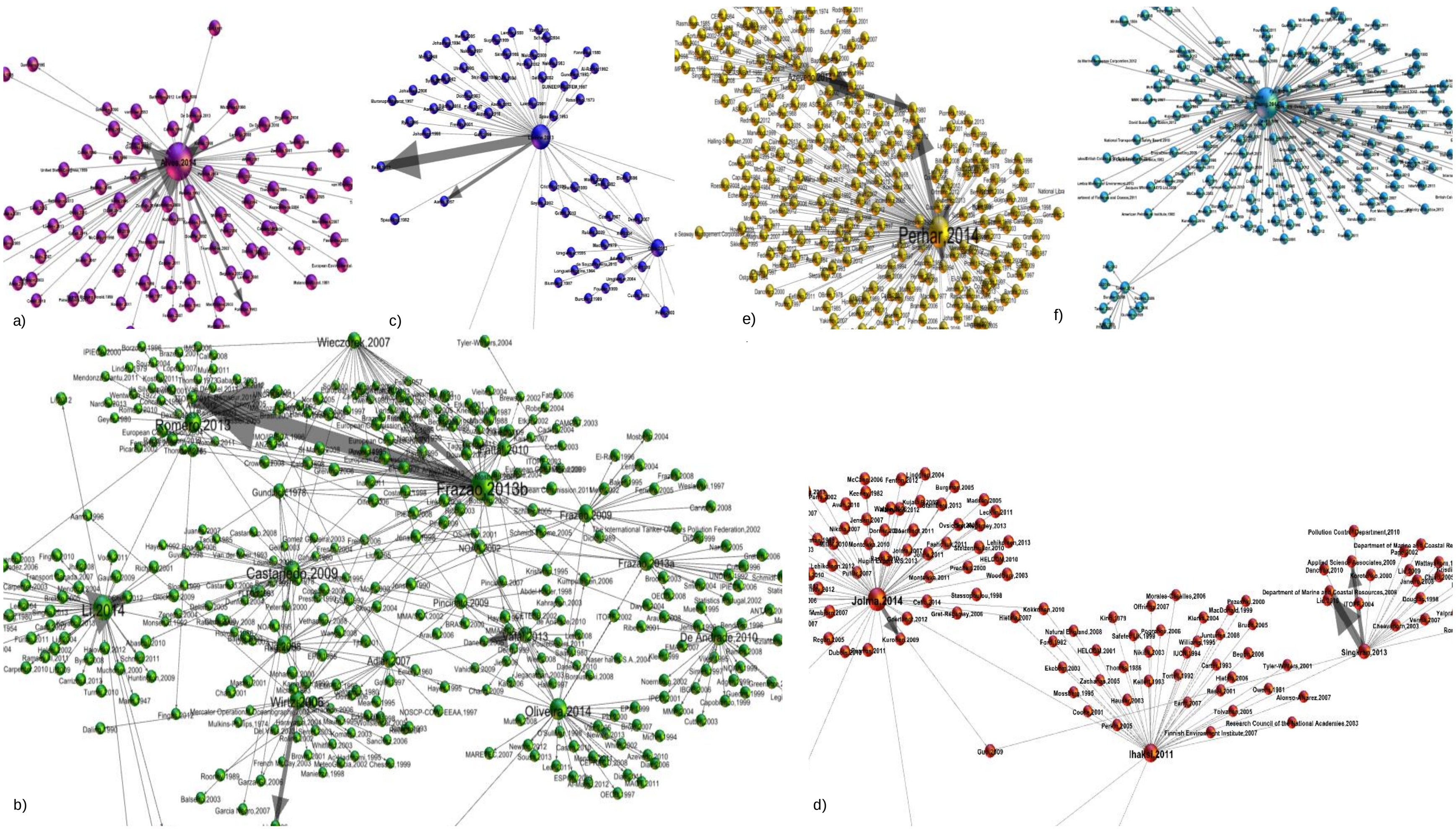

Figure 2-3 Modularity classes of the Publications' Network. a) class 0. b) class 1. c) class 2. d) class 3. e) class 4. f) class 5

Table 2-3 Modularity classes of the Publications' Network, depicting: primary sources (literature review sources) and relevant secondary sources (primary sources connections).

Communities	0	1	2	3	4	5
Primary sources	Alves,2014	Frazao,2013b Li,2014 Romero,2013 Castanedo,2009 Wirtz,2006 Oliviera,2014 Wieczorek,2007 De Andrade,2010 Vafai,2013 Frazao,2009 Ng,2008 Pincinato,2009 Adler,2007	Lamine,2013 Olita,2012	Jolma,2014 Ihaksi,2011 Singkran,2013 Wirtz,2006 Fattal,2010	Perhar,2014 Azevedo,2014	Chang,2014 Tansel,2014
Relevant Connections		NOAA,2002 Jensen,1990		Gundlach,1978 IMO/IPIECA,1996		

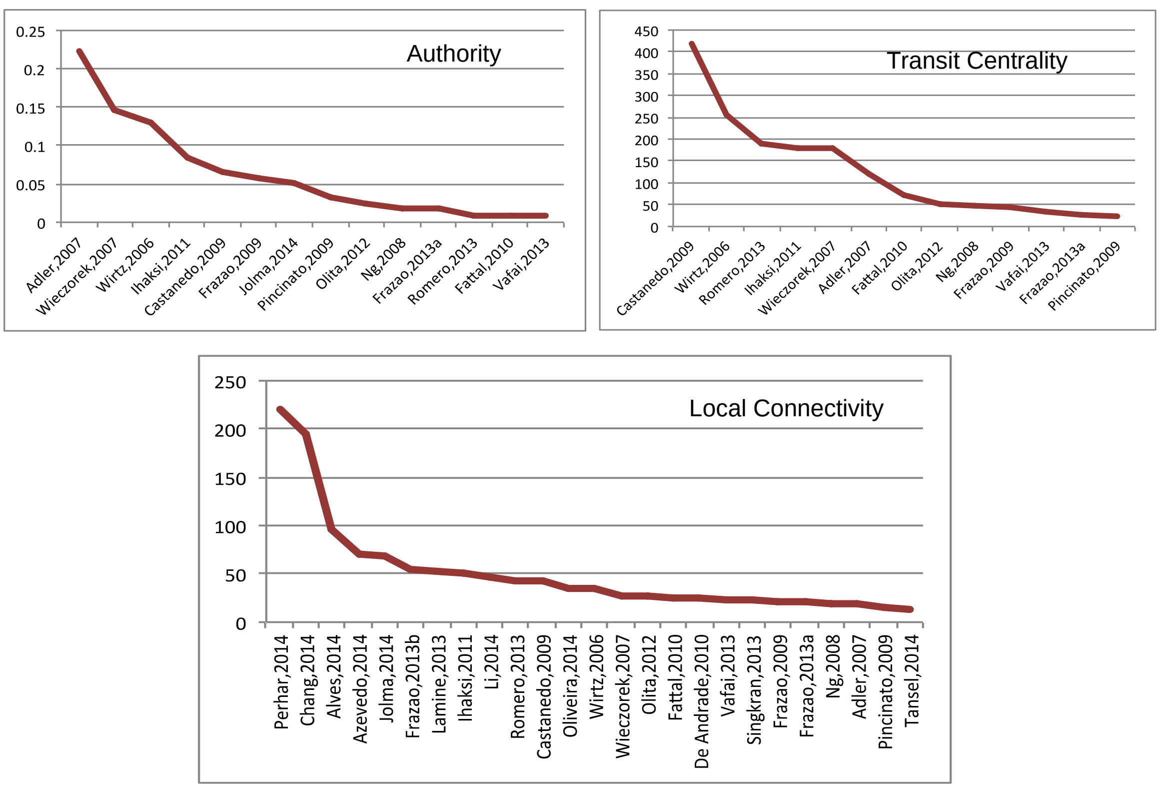

Figure 2-4 Metrics of the Publications' Network, depicting: Authority, Transit Centrality and Local Connectivity. Although the numbers are not really useful for interpretation outside the Gephi graph, they indicate visually indicate variation of scores (red line).

CHAPTER 3 THEORETICAL FRAMEWORK

According to the Organization for Economic Co-operation and Development [OECD], (2008), composite indicators in new emerging areas tend to be very subjective and usually do not have solid theoretical and empirical foundations, which is problematic in the way that “what is badly defined is likely to be badly measured” (p. 22). Therefore, a sound theoretical framework is suggested as the starting point for a composite index construction. The aim is to provide a clear understanding and definition of the phenomenon to be measured, allowing the determination of subgroups of a multi-dimensional concept, creating a nested structure that makes the understanding of its driving forces easier, and determination of relative weights across different factors (OECD, 2008).

In this chapter, a theoretical framework is developed following the guidelines for the construction of composite indicators, published by OECD (2008), an approach undertaken by Frazao et al., (2013) as well. First, several considerations for the construction of the theoretical framework are made, and then the framework is presented.

3.1 CONSIDERATIONS

3.1.1 Considerations of the Network Analysis

The network analysis provided hints for paring down the literature review: publications with high scores of Authority and Transit Centrality were identified as relevant as part of the OSRA state-of-the-art. The first seven publications with high scores were chosen from both lists, and their union resulted in a total of nine publications.

The assumption is that the most valuable information is contained within these, thus allowing the prioritization of sources to aid in the development of the theoretical framework.

The country of affiliation of the sources varies, but more than half derive from European countries. Also, small clusters were found in Brazil and Finland. Finland's publications are part of the same research team. Interestingly, the sources that are stated as the network "text books" are United States affiliated, with exception of the global initiative IMO/IPIECA/OGP, which in recent years has produced a new version of their 1996's publication (i.e. IMO et al., 2012).

3.1.2 Considerations for Integration

Because the focus of this study is not the matter of spill simulation or causality, only the consequences will be discussed. However, a possible methodology for integration should still be considered, because this will shape how the data should be collected, stored and presented. Three of the nine literature sources cover all the oil spill stages within the Pelot et al., (2015) end-to-end Marine ship based oil spill analysis Framework (Figure 1-2), while the rest focus only on the consequences stage. These three sources are briefly summarized below.

- Wirtz and Liu (2006): The approach undertaken by this Germany affiliated publication is called a "Decision Support System (DSS)", and consists of a combination of modelling and evaluation methods to assess short- to mid-term impacts on habitats and local economies, tested with the Prestige oil spill (2002) off the coast of Spain. A multi-criteria and linear additive model was used to analyze ecological and economic outcomes. The ecological outcomes that were considered include semi-quantitative indicators for the sensitivity and importance of local habitats (i.e. reproductive capacity, vulnerability, and protection level) and the vulnerability index described by Gundlach and Hayes (1978). The economic impact was assessed on the basis of income losses.

- Romero et al., (2013): The approach undertaken by this Brazil affiliated publication is called "Integrated Assessment of Environmental Vulnerability to Oil (IEVO)", and consists of a combination of modelling and evaluation methods to develop an IEVO index, tested with a hypothetical spill off the coast of Santos Basin (Brazil). NOAA's ESI Maps guidelines (i.e. Petersen et al., 2002) (including physical, biological and socio-economic aspects) were used for the consequence assessment. This paper criticizes the sole use of sensitivity (without including susceptibility) to measure vulnerability to oil.
- Jolma, Lehikoinen, Helle, & Venesjarvi, (2014): The approach undertaken by this Finland affiliated publication is called a "Software System For Assessing The Spatially Distributed Ecological Risk Posed By Oil Shipping", and consists of a combination of modelling and evaluation methods using two computational methodologies (i.e. Bayesian Network [BN], and GIS), tested with a hypothetical spill resulting from a Bayesian probabilistic model on the northern coast of Finland. A database of ecological data was used for the consequences, which includes the Ihaksi et al., (2011) ecological criteria.

A comparison was made among these preceding sources within the end-to-end Marine ship based oil spill analysis Framework (Figure 3-1). It was found that they use a combination of modelling and evaluation methods, acknowledging the need for integration among several tools or systems, most of them already in existence, such as dispersion models, probabilistic models and environmental indices, based on the hypothesis that the lack of integration may lead to a failure in establishing priority areas for contingency or emergency planning.

Source	TIME		
	EXPOSURE VESSEL INCIDENT	SPILL INCIDENT OIL BEHAVIOUR	CONSEQUENCES
	Spill simulation	**Numerical model**	**Sensitivity + Adaptability**
Wirtz & Liu, 2006	Probabilistic model for 1 fixed incident	OSCAR (Oil Spill Contingency and Response)	Ecological Socio-economic
Romero et al., 2013	Fixed point	SIMAP (Spill Impact Model Application Package)	Ecological Socio-economic
Jolma et al., 2014	Causal probabilistic model of oil tanker accidents	SpillMod (Russian developed model)	Ecological

Figure 3-1 Comparison of selected sources within the end-to-end ship-based oil spill framework, positioned according the stages they cover. It can be observed that Romero et al., (2013) only considers sensitivity for the consequences, while the other two sources combine sensitivity and adaptability factors.

Regarding the integration methodology, Jolma et al., (2014) provides a software system solution, which consists of two computational methodologies: BNs and GISs. It integrates all the different pieces (i.e. spill simulation, numerical model, sensitivity and adaptability). This comprehensive integration is missing from the two other sources, in which the spill simulation was fixed (i.e. not a model).

Regarding the consequences assessment, for Wirtz and Liu (2006) and Jolma et al., (2014), it is a combination of sensitivity and adaptability of the system, while for Romero et al., (2013) only sensitivity was considered. Furthermore, all sources considered different dimensions (of vulnerability), such as ecological, or socio-economic and used different criteria for assessing. For example, the ecological dimension only considered biological resources for Jolma et al., (2014), while Romero et al., (2013) included shoreline character (ESI type).

The findings may have several implications for the present study summarized as follows:

- Three components could be sufficient to analyze the ship-based oil spill framework: a causal probabilistic model, an oil spill numerical model, and a consequence assessment. Therefore, the latter should include factors carefully in order to avoid redundancy with the other two components.
- Including susceptibility factors into the overall concept of vulnerability is deemed to be critical, and three dimensions of vulnerability should be recognized as well: social and economic (or socio-economic), and ecological. Also, each dimension may be represented ideally by both Sensitivity and Adaptability factors.
- GIS techniques should be used for data collection, analysis and presentation, considering their proven flexibility for integration.

3.1.3 Considerations for the Consequences Assessment

The elements included for assessment of consequences are not consistent among the publications. Therefore, a matrix of elements used for the creation of indicators was constructed in order to detect patterns or trends (Table 3-1). A glossary describes the meaning of the different elements in the matrix, reducing the variety through standardization of terms (Appendix B).

To draw conclusions, priority was given to the information contained within the publications determined as relevant by the Network Analysis. However, the matrix included all reviewed publications, assuming that patterns may be easier to detect. 21 of 29 publications were included (the excluded ones were limited to theory, not covering the

Table 3-1 Matrix of elements used for the creation of indicators within the reviewed literature, classified in two dimensions (ecological and socio-economic), and subdivided into categories and sub-categories when applicable. Empty spaces denote that the source did not explicitly mention the element as part of its methods.

Dimension		Ecological																												Socio-economic																						
Category		Exposure				Oil Bv		Physical									Biological													Human activities												Population				Cultural			Oil Spill Management			
								Coastal Morphology									Resources							Areas			Management																								
Publication ID	Element	Vessel exposure	Spill location	Vessel characteristics	Spill frequency	Climatic and Oceanographic conditions	Oil characteristics	Relative exposure to wave & tidal energy	Shoreline slope	Substrate type	Biological productivity & sensitivity	Landform	Hydrodynamic	Marine weather	Exposure	Wave exposure	Marine mammals	Meroplankton	Plants	Birds	Reptiles and amphibians	Fish	Invertebrates	Habitats and plants	Wetlands	Coastal environments	Management areas	Special management areas	Species at risk	Aquaculture	Aboriginal commercial fishing	Commercial fishing	Mining	Agriculture	Military	Industry	Tourism	Subsistence	Port	Fresh water	Coastal infrastructure	Population	Education	Income	Relationship with natural resources	Recreation	Heritage	Archaeological sites	Oil booms efficiency	Accessibility	Operability	Crisis management
1	Adler,2007							X	X	X	X										X			X				X	X						X	X										X		X				
2	Castanedo,2009								X							X											X	X	X		X		X					X		X							X						
3	Catto,2011							X		X					X																																					
4	De Andrade,2010											X																															X	X	X							
5	DNV,2011	X		X	X	X	X	X	X	X	X						X			X				X	X		X	X		X		X					X									X					
6	Fattal,2010							X	X	X	X			X	X	X								X								X					X									X					X
7	Frazao Santos,2013a							X	X	X	X																X	X				X					X					X										
8	Ihaksi,2011																X		X	X		X	X						X																				X			
9	Li,2014	X	X		X	X							X	X								X		X																												
10	Ng,2008							X	X	X	X																X		X	X					X				X	X					X		X				
11	Olita,2012									X		X															X																									
12	Oliveira,2014							X	X	X	X				X	X										X				X				X							X					X				X	X	
13	Pincinato,2009							X	X	X																																									
14	Romero,2013		X			X	X	X	X	X																			X		X		X												X		X				
15	Singkran,2013	X			X	X	X										X			X	X	X		X	X		X										X													
16	Stejernholm,2011									X					X		X			X		X						X				X						X				X						X				
17	Vafai,2013									X		X	X				X			X				X			X					X	X			X	X		X			X						X				
18	Wiezorek,2007							X	X	X							X			X	X	X	X									X			X	X			X		X							X				
19	Wirtz,2006		X	X		X	X											X				X	X							X		X					X		X													
20	WSP,2014	X		X	X	X	X	X	X	X	X						X	X		X	X	X	X				X		X	X	X	X					X		X	X												
21	Jolma,2014	X	X	X	X	X	X												X	X			X						X																				X			

consequences stage, or how they involve it was not practical for this exercise). The information compiled in the matrix depends on the information provided explicitly in the publication. The elements were positioned considering two vulnerability dimensions, which were recurrent among the reviewed literature: 1) ecological, and 2) socio-economic. The findings are summarized below.

- **Ecological dimension:** ESI is the most used approach describing coastal morphology, comprising a set of items that may include: substrate type, shoreline slope, relative exposure to wave and tidal energy, and biological productivity and sensitivity. Many publications acknowledge NOAA/Petersen et al., (2002), Jensen et al., (1990) and IMO/IPIECA/OGP (1996) ESI standards, whereas others apply a similar approach without an established standard classification. A sensitivity mapping methodology is also the most common approach for biological resources, in which fish, marine mammals and birds are the most often included species. The use of established ecological important areas, such as management areas for assessing biological resources, is also a widely used approach.

Ihaksi et al, (2011) criticized the latter approach because charismatic or economically valuable species overshadow other taxa such as invertebrates or macrophytes. They presented an index tailored to prioritize natural organisms for protection from a floating oil slick, taking in account parameters such as oil booms effectiveness and relative exposure of the populations. It can be said that this is a best practice for analyzing the consequences on biological resources, but entails a high level of complexity and expertise. This approach was incorporated by Jolma et al., (2014).

- **Socio-economic dimension:** The social and economic dimensions are considered as a combined dimension, in which the most used socio-economic elements in respective order are 1) commercial fishing, 2) aquaculture, tourism and port activities, and archaeological sites (Figure 3-2). More emphasis is generally given to economic activities, whereas the social dimension is often neglected.

Different approaches have been undertaken to assess consequences for economic activities, with different degrees of complexity. The most common approach relies on sensitivity. It uses the number of economic activities happening inside a coastal segment for assessing its vulnerability, with the assumption that a potential income loss may result from interrupting those activities, regardless of the productivity or adaptability factors of each economic activity. Wirtz and Liu (2006) and Castanedo et al., (2009) presented an innovative but perhaps complex combination of indicators estimating the economic damage in terms of the interruption of activities related to coastal uses. Their approaches differ widely, but are similar in one respect because of the use of coefficients representing the adaptability and sensitivity of each economic activity, which requires stakeholder consultation.

Few oil spill management elements are considered in the reviewed literature. Only four publications have specific oil spill management indicators: Ihaksi et al., (2011) and Jolma et al., (2014) indicators uniquely consider biological resources. Fattal et al., (2010) analyze local oil spill management plans (crisis management) according to many variables, such as staff training and the plan creation date. Oliveira et al., (2014) uses an indicator for assessing the degree of access to the study area (accessibility), and an indicator for assessing the availability for deployment of contingency means (operability).

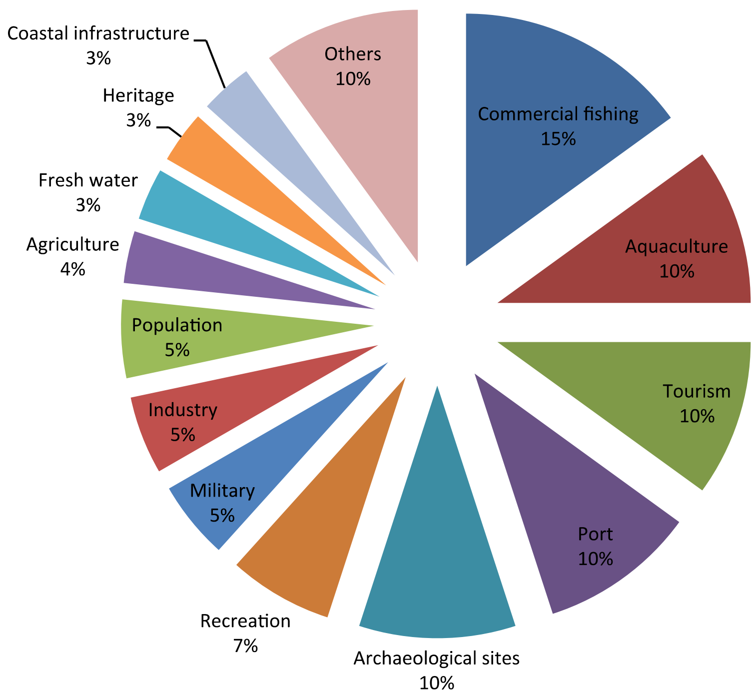

Figure 3-2 The most used socio-economic elements within the reviewed literature.

3.2 Theoretical framework

3.2.1 Concepts

In agreement with the recommendations made by the European Observation Network, Territorial Development and Cohesion [ESPON] Project (Schmidt-Thomé, 2006) about future research needs on vulnerability (which is result of extensive research on natural and technological hazards and risk of European regions, applied by Frazao et al, (2013), and evident among many papers determined as relevant publications through the network analysis) this study acknowledges vulnerability as “vulnerability of places” (Kumpulainen, 2006), in which vulnerability is place-specific and takes in account damage potential and coping capacity factors, which are often associated with the words sensitivity and adaptability as well. Also, this study acknowledges three dimensions of vulnerability, as follows:

- **Ecological:** Acknowledges a hazard-centred and spatially centred ecosystem or environmental vulnerability, defined by Silva, Ferreira, and Araujo (2012) as “the environment’s capacity to suffer an impact on the basis of its susceptibility and sensitivity to an oil spill” (p. 3), which according to Romero et al., (2013) can be determined by “the environmental susceptibility to a certain impact, considering the structural weakness, sensitivity and maturity of the involved ecosystems… where sensitivity is related to how the environment responds negatively to the impact of an oil spill and susceptibility is the probability of a specific area of being reached and affected by oil, depending on climatic and oceanographic conditions, spill location, type and amount of spilled oil” (p. 157).

- **Economic:** According to Kumpulainen (2006), this dimension represents “the risk to production, distribution and consumption” and acknowledges economic damage potential, understood as “anything concrete that affects the economy of a region and can be damaged by a hazard” (p. 66).

- **Social:** According to Kumpulainen (2006), this dimension acknowledges the "vulnerability of people, and the emphasis is on coping capacity" (p. 66). In agreement with the Fattal et al., (2010) study, this project emphasises Oil Spill Management as part of the elements that should be included, which may serve the needs of decision makers and responders in the case of a ship-based oil spill.

3.2.2 Conceptual Model

Frequently used elements within the literature review were used for the construction of a conceptual model for measuring vulnerability within an end-to-end marine oil spill analysis (Figure 3-3). Its basic structure is based on the Fattal et al., (2010) conceptual framework, with modifications based on findings of the OSRA literature review using Network Analysis.

In the model, Global Vulnerability (Gv) is determined initially as the sum of the three following vulnerability dimensions:

- Ecological vulnerability (EGv) with 4 components: Oil Behaviour (Ob), Exposure (Ex), Physical (Py), and Biological (Bi).
- Social vulnerability (SOv) with 3 components: Oil Spill Management (Ma), Cultural (Cu), and Population (Po). Ma acknowledges factors of coping capacity, Cu the value of recreation and significant places for human wellbeing and preservation of cultural heritage, and Po considers different features of the population that can make specific population groups more vulnerable.

- Economic vulnerability (ECv) with 1 component: Human activities (Ha), composed of commercial fishing, aquaculture, and tourism and port activities.

Exposure (Ex) and Oil Behaviour (Ob) factors are outside the scope of this study. It was found that these elements could be integrated later within the end-to-end marine oil

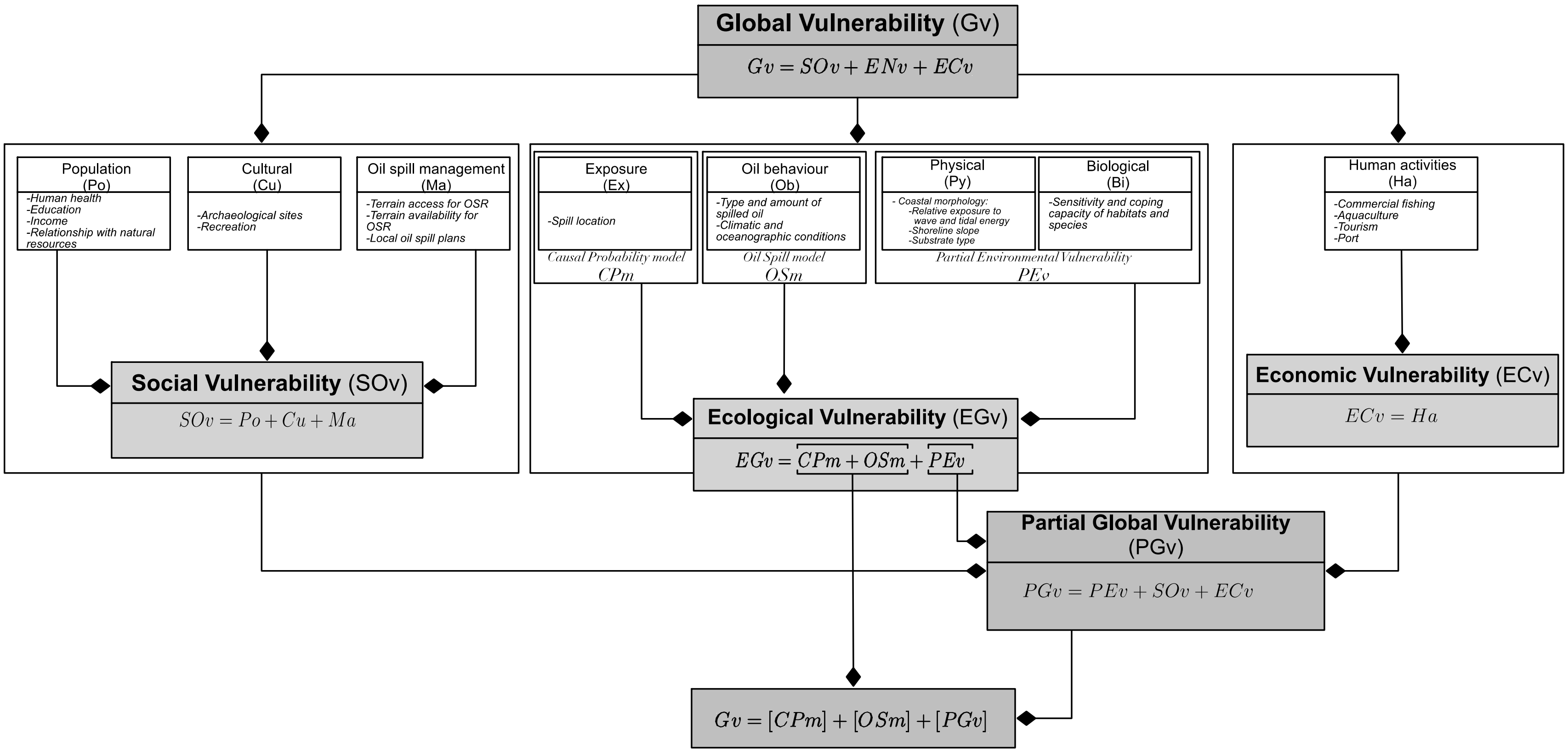

Figure 3-3 Conceptual Model for a vulnerability assessment within an end-to-end ship-based oil spill analysis. Its basic structure is based on Fattal et al., (2010) with many modifications based on findings of the OSRA state-of-the-art scope literature review. An overall vulnerability, called Global vulnerability here, is the sum of three dimensions of vulnerability: Social, Ecological and Economic. Each dimension is composed of categories comprising related elements. Using these categories and extracting the ones that are outside the scope of the present study, a Partial Global Vulnerability (PGv) Index is defined as the parameter to be measured in this research.

spill analysis framework, as presented in the Jolma et al, (2014), Romero et al., (2013) and Wirtz and Liu (2006) studies, in the form of a Causal Probabilistic Model (CPm) and Oil Spill Numerical Model (OSm). Therefore, Global Vulnerability can also be expressed as an aggregation of CPm, OSm, and a Partial Global vulnerability (PGv) index, which considers social and economic vulnerability dimensions and a partial ecological vulnerability dimension, called Partial Environmental Vulnerability (PEv), which contains physical and biological components. This study will develop a methodology for determining the latter, which can also be referred to as "the consequences" in the Ship-based Oil Spill Framework.

CHAPTER 4 CASE STUDY: HALIFAX HARBOUR

In this chapter, an assessment of the consequences of an oil spill, using the proposed Partial Global Vulnerability (PGv) Index, is tested in a case study in Atlantic Canada. Due to this study's timeframe, it does not intend to be a comprehensive analysis, but a first step to identify advantages, limitations, and areas for further development of this approach.

4.1 STUDY AREA

4.1.1 Halifax Harbour

Halifax Harbour (HH) is located at coordinates Latitude 44º 37' 32' N and Longitude 63º 34' 25' W in the Province of Nova Scotia, Atlantic Canada. It is a long, irregular and narrow bay, which extends inland for over 28 km to the northwest in a complex geography (Figure 4-1), composed of: outer and inner divisions, shallow (20 m) in the Inner Harbour and The Narrows, and deeper at the bowl-shaped Bedford basin (70 m); two projecting arms (i.e. Northwest Arm and Eastern Passage); three distinctive islands in the Middle and Inner Harbour (i.e. McNabs, Lawlor and Georges); and a main shipping channel, deeper than most Harbour areas, which represents the original bed of the Sackville River (Conover, Griffiths, Parker, & Thirumurthi, 1993; Fader & Miller, 2008).

The harbour is "actually the remnant of an old valley formed by an early Sackville River that eventually drowned by rising sea level" (Fournier et al., 1990, p. 24). It generally behaves as an estuary and as such, is characterized by a two-layered flow with saltier incoming waters in the bottom while outgoing flow is near the surface. Freshwater is coming from the Sackville River and other sources distributed around its periphery. The strongest currents are found in The Narrows and the weakest in Bedford Basin (Conover et al., 1993; Fournier et al., 1990).

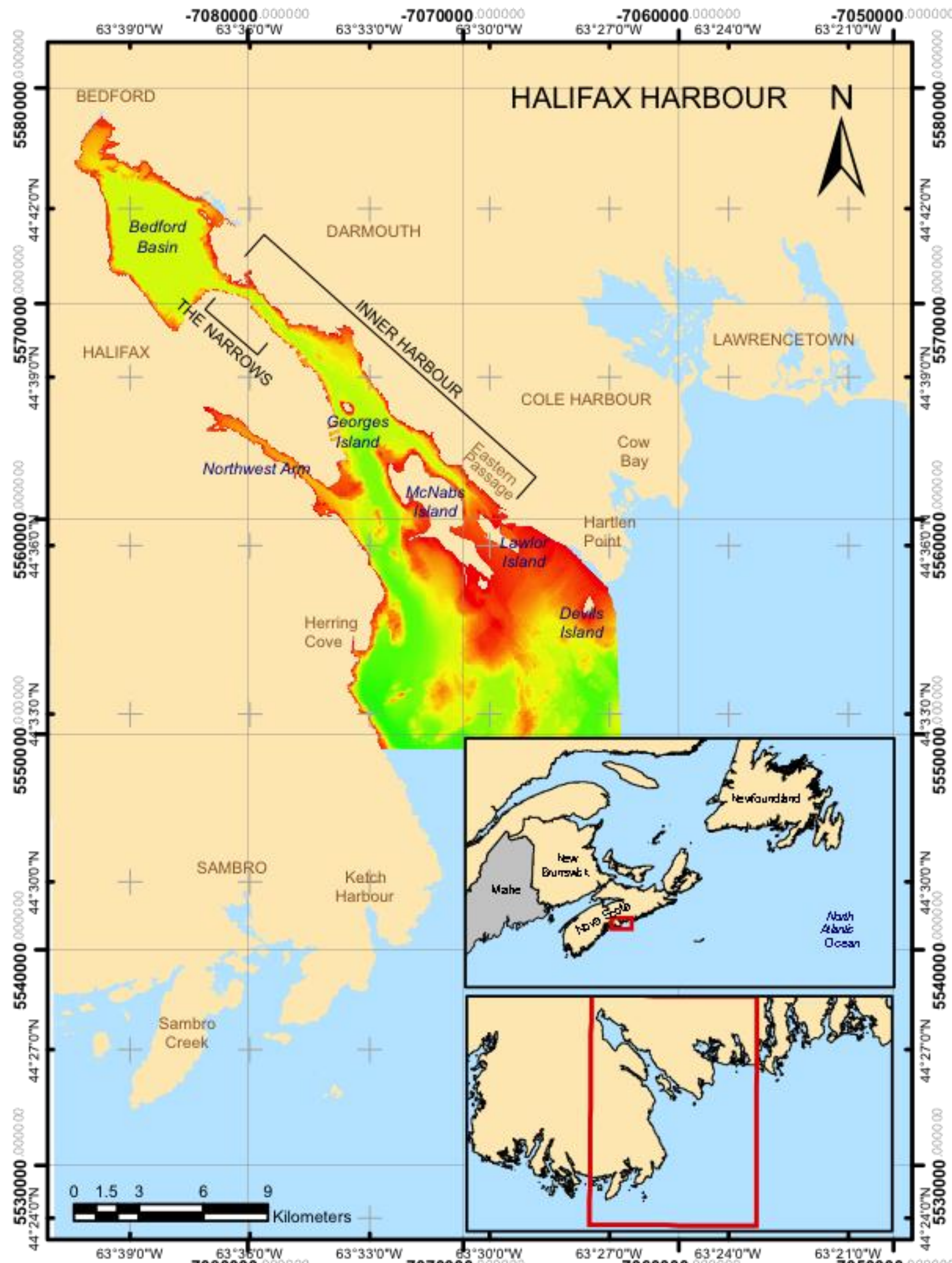

Figure 4-1 Geographic divisions of Halifax Harbour. Map depicts HRM major communities and inner harbour bathymetry.

It is the major Eastern seaport of Atlantic Canada, surrounded by the major communities of Halifax and Dartmouth and smaller centres of Herring Cove, Bedford, and Eastern Passage, collectedly referred as the Halifax Regional Municipality [HRM] (Fader & Miller, 2008). In Fournier et al., (1990) the harbour is described as a “busy multi-use waterway” (p. 36), where many activities converge, such as extensive use by research institutions (e.g. Bedford Institute of Oceanography), cooling purposes from industrial facilities (e.g. Tufts Cove generating station), public transportation (e.g. Darmouth ferries), recreation, tourism, fisheries (e.g. herring, mackerel, cod and an intense lobster fishery happening mostly in the vicinity of McNabs island) and military and shipping uses. It is also DND’s major naval facility in Canada’s East Coast, and a major shipping port.

The harbour is also highlighted as “a life support system for an extensive marine food web, which includes plankton, molluscs, birds, and seals, porpoises and whales” (Fournier et al., 1990, p. 38). Mussels and clams are abundant, many species of marine mammals frequent the harbour periodically, and diverse resident and migratory birds are supported as well as several seasonal commercial fisheries.

4.1.2 Halifax Port

The HH is recognized for its geographical and natural characteristics that favour port activities. It provides excellent shelter, an ice-free environment throughout the winter season, depths affording easy access for large vessels, good holding ground for anchoring, and is strategically located near major shipping lanes (Calderon, Griffin, Pelot, & Chadid, 2015; Fader & Miller, 2008; Halifax Port Authority, 2015).

The port, ranked as Canada's fourth largest port as measured by container volume, after Vancouver, Montreal and Prince Rupert, is a major terminal for trade throughout North America, with container and other loading and offloading facilities (e.g. gypsum, bulk grain, automobiles) and its primary markets are South Asia and Europe. It is served by the largest Canadian Class I railway in terms of revenue and physical size of its rail network. It also has a showcase community project managed by the Halifax Port Authority, known as the Halifax Seaport (HS). The Seaport is an art and cultural district encompassing waterfront lands with historic buildings, artisans, retailers, event facilities, a museum, a university, and a cruise terminal among others, which annually attracts over a million visitors. The Port and HS are a regional economic engine, estimated to worth over $1.6 billion to the economy of Atlantic Canada (Halifax Port Authority, 2015).

The range and type of facilities around the Port of Halifax changed substantially after the closure and conversion into a marine terminal in 2013 of the Dartmouth Refinery, which was no longer competitive (Halifax Port Authority, 2015). Despite this fact, this port, which can operate vessels over 500 ft., has witnessed a significant increase in general cargo maritime traffic, including oil transportation in recent years. While several measures have been taken to improve the safety of sea traffic in the area, the risk of a major accident that could lead to an oil spill incident exists, considering the restrictions of the under keel clearance imposed by fairly narrow and shallow areas with rocky seabed, which surround the recommended navigation track for accessing the port (Calderon et al., 2015).

4.2 DATA

Data access was obtained through the MARIN research group. Two geodatabases and one dataset were used:

- The Nova Scotia Department of Natural Resources (DNR) Restricted and Limited Use Land Database [RLUL], (2014), which contains spatial boundaries for protected or limited land in use for conservation, ecological, resource management or heritage purposes. Data ownership belongs to the Department of Natural Resources [DNR].
- Halifax Regional Municipality Corporate Database [HRMCD], (2012), which contains many features and activities occurring in the HRM area. Data ownership belongs to HRM, and its use is limited to educational purposes.
- Environment Canada Shoreline Classification dataset [ECSC], (2013), which is part of EC's Atlantic Shoreline Classification and Pre-Spill database. It contains shorelines classified according the character of the upper intertidal (foreshore) or upper swash zone. Data ownership belongs to EC.

4.3 SELECTION OF INDICATORS

The basic criterion for choosing vulnerability indicators follows that proposed by ESPON (Schmidt-Thomé, 2006), and applied by Frazao et al., (2013), which is that they should cover both damage potential and coping capacity. Damage potential indicators "measure anything concrete that can be damaged by a hazard and measure the scale of possible damage in a particular region. Coping capacity indicators measure the ability of a community or a region to prepare or respond to a hazard…[They] point out social and place inequalities" (Kumpulainen, 2006, p. 68).

The second criterion is the scale and particular conditions of the study area, which are deemed as crucial for establishing meaningful indicators. The last criterion is practicality with respect its data availability and the expertise required to assess aspects of the area. Figure 4-2 presents the selected indicators, which are explained below. The resultant qualitative scale for each indicator is presented in Table 4-1. A complete list of the indicators' metadata is presented in Appendix C.

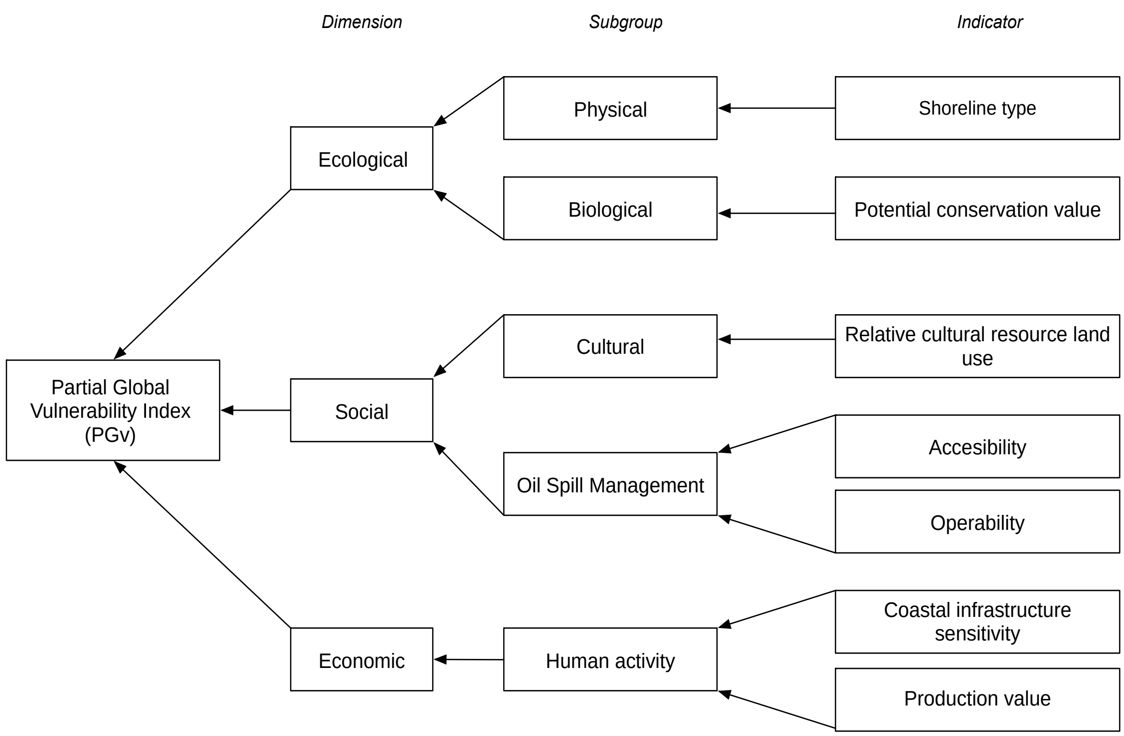

Figure 4-2 Halifax Harbour factors for PGv Index

Shoreline type	Potential conservation value	Relative cultural resource land use	Operability	Accessibility	Coastal infrastructure Sensitivity	Production value
1 10A Salt- and brackish-water marshes	*1 National parks, Reserves of biosphere* Indian Reserve Lands, Ramsar Wetland Sites, National migratory bird sanctuary, National park and adjuncts, HRM Significant Habitats Species at Risk	1 Bathing beaches	*Danger risk* 1 ESI: 1C - 2B - 3C 2 ESI: 7 3 ESI: 2A - 6B - 6C 4 ESI: 3B - 8A - 8C -8D - 9A -10C 5 ESI: 1A - 1B - 3A - 4 -5 - 6A - 8B - 8E - 9B -9C - 10A -10B - 10D -10E	*Remoteness* 1 Remote location 2 Close to population centers	1 Cooling water basins of power stations	1 Fishing industry
2 9A Sheltered tidal flats		2 Leisure and sports marinas			2 Defence and military infrastructure, mainly Navy bases	2 National Defence
3 8C Sheltered riprap 8B Sheltered, solid man-made structures/Sheltered rocky shores 8A Sheltered scarps in bedrock, mud, or clay/ Sheltered rocky shores (impermeable)*		3 Coastal and marine archaeological sites		*Restrictive social accessibility* 1 Aboriginal settlements 2 Homeland security (DND-Navy) 3 No value	3 Commercial ports	3 Fisheries and Oceans
4 7 Exposed tidal flats	*2 Marine reserves, natural parks* Natural watershed Municipal Surface Water Supply Areas, Designated Provincial Parks and Park Reserves, Protected beaches under the Beaches Protection Act	4 Urban beaches and shoreline leisure facilities (such as cornices, playing grounds)	*Damage risk* 1 ESI: 10A - 10B 2 ESI: 10E 3 ESI: 10C - 9C -8E 4 ESI: 10D 5 ESI: 1A - 1B - 1C - 2A - 2B - 3A - 3B - 3C - 4 - 5 - 6A - 6B - 6C - 7 - 8A - 8B - 8C - 8D - 9A - 9B	*Land access* 1 Road distance +600 m 2 Road distance 600 m 3 Road distance 450 m 4 Road distance 300 m 5 Road distance 0-150 m	4 Bathing and tourist beaches	4 Port of Halifax
5 6C Riprap 6B Riprap/Gravel Beaches (cobbles and boulders) 6A Gravel beaches (granules and pebbles)		5 No value			5 Marine aquaculture facilities and activities and marine fishing ports and facilities	5 Shipbuilding and boat building, marine construction, marine manufacturing and aquaculture
6 4 Coarse-grained sand beaches	*3 Nature reserves, important bird areas* Operational Non-designated Parks and Reserves, Nature Conservancy of Canada Lands, Provincial Wildlife management areas, HRM Significant Habitats Migratory Bird areas			*Backshore Restriction* 1 Cliff 2 No value	6 No value	6 Ocean tourism
7 3A Fine-to medium-grained sand beaches				*Ocean Access* 1 Restricted depth (between 0-2 meters from 5-10 isobaths) 2 No value		7 No value
8 1C Exposed rocky cliffs with boulder talus base 1A Exposed rocky shores	*4 Protected landscapes, fisheries reserves* Canadian Heritage Rivers, Trail Act Lands, HRM Significant Habitats Ecologic Sites, Sites of ecological significance under moratorium, Areas under the Special Places Act					
	5 No Value					

Table 4-1 Qualitative scales for PGv Index's indicators (Z > A)

4.3.1 Ecological Dimension

Shoreline Type was the indicator selected for the physical category, because it met with all selection criteria. The NOAA ESI standard approach made it extremely practical, because the data necessary for its construction were readily available from the ECSC dataset.

Shoreline Type: Depicts relative shoreline sensitivity to oil spills, using NOAA's ESI approach (Petersen et al., 2002), comprising information regarding oil behavior in different coastal habitats related to its relative degree of exposure to wave and tidal energy, shoreline slope, substrate type and biological productivity/sensitivity. The ECSC dataset information used was: 1) mid-upper intertidal zone shoreline type: a combined morphology and substrate indicator, and major indicator for oil spill retention and response; 2) lower intertidal zone material: provides indication of material in the lower half of the intertidal zone; 3) lower intertidal zone form: provides indication of morphology in the lower half of the intertidal zone.

Practical considerations limited the use of the best practice (i.e. Ihaksi et al. 2011) for the Biological category. Specific species data were not available, but only data on management areas. Therefore, a Potential Conservation Value indicator was deemed to be appropriate.

Potential Conservation Value: considers the value for conservation of the segment according to its legal protection status (geographic spaces that are recognised, dedicated and managed through legal and other effective means to achieve long-term conservation of nature with associated ecosystem services). The scale assigns scores to areas identified in the RLUL and HRMCD databases, based on the "singularity indicator" presented by Castanedo et al., (2009).

4.3.2 Social Dimension

The scale criterion was crucial for disregarding any population indicator. The study area is quite small, so any important information based on population features is unlikely. Indicators of this type are deemed to be meaningful when comparing diverse municipalities or communities. For the Cultural category a "Relative Cultural Resource Land Use" was selected, covering all criteria.

Relative Cultural Resource Land Use: Depicts a ranked value of the area of land attributed to cultural resource uses in relation to the coastal buffer and shoreline length. These resources include archaeological, historic and recreational sites. The scale is adapted from the hierarchical priority of socio-economic resources presented by Adler and Inbar (2007), which presented the resources requiring priority efforts in protection from oil spills and clean-up operations after a spill.

For the Oil Spill Management category, a crisis management indicator (evaluating local oil spill management plans) was discarded because it was not practical for our case study. This is easily explained by the degree of expertise required to do such an assessment. Moreover, these plans are not publicly available, and are the direct responsibility of private corporations. The accessibility and operability indicators seem more plausible but, as presented by Oliveira et al., (2014) they were unclear, because they seem to measure twice the access factor (detailed descriptions follow). Therefore, an expert on the matter of OSR was consulted in this regard.

Accessibility: measures the intervention potential, which depends on the degree of accessibility (if the cleaning methods cannot reach the shoreline, the intervention potential is null); in order to do this, it uses emergency locations (i.e. fire stations and civil protection headquarters) and the respective best available accesses to each shoreline segment. Scores are given based on the degree of access from the emergency locations to each shoreline segment. The degree of access is classified (from high to low) in terms of width and pavement type: 1) paved roads and paved walking/cycling paths; 2) unpaved roads wider than 2.5 m; and 3) unpaved roads and paths narrower than 2.5 m.

Operability: measures operational limitations of the use of response methods. Is an assessment of each shoreline segment considering two factors: access proximity and terrain availability for contingency means deployment. The Operability indicator is the sum of proximity and availability scores. Proximity is in relation to the closest obstacle-free available access and it is scored according to: 1) near to paved roads and paved walking/cycling paths; 2) near to unpaved roads wider than 2.5 m; and 3) near unpaved roads and paths narrower than 2.5 m. 4) no land access. The terrain availability factor is defined in terms of the existence of free adjacent terrain (1: $<800\ m^2$; 0: $>800\ m^2$).

4.3.2.1 Tailoring of OSM Indicators

A series of meetings were held with Mr. Robert Starkes, current ECRC Atlantic Region Manager. The OSR expertise of Mr. Starkes is extensive, being part of an RO for over 20 years, and acting as both responder and advisor. His background education is in geography with interest an interest in coastal geomorphology (Eastern Canada Response

Corporation Ltd. [ECRC], 2013). With his help, operability and accessibility indicators were tailored for the Atlantic Canada context as follows:

Adjusted Accessibility: Unlike the aforementioned indicator presented by Oliveira et al., (2014), the location of emergency stations is irrelevant for oil spill response in Atlantic Canada, whereas the response team and equipment is a mobile caravan with a standardized travel time. In Atlantic Canada, ECRC guarantees moving all the equipment for a response in their area of responsibility in less than six (6) hours. According to Mr. Starkes several considerations should be made, that can be classified as macro or micro considerations. Remoteness is a macro consideration, which should have more weight than micro considerations. Its importance arises from a critical logistic problem for response operations: people management. A remote location often lacks of appropriate infrastructure for providing shelter, food, fuel and others logistic aspects of a response operation.

However, the scale of our study makes the remoteness factor not meaningful, because Halifax Harbour is not a remote location, and the logistics are homogeneous. Therefore, four (4) micro considerations may be used for calculating the accessibility indicator, all with equal value: restrictive social accessibility, backshore restriction, land access, and ocean access. Restrictive social accessibility identifies complications accessing an area that may require special permissions, delaying response operations, ranked in level of difficulty as 1) aboriginal land, and 2) land with homeland security restrictions (e.g. DND). Backshore restriction identifies shoreline areas where backshore geomorphology constrains equipment access, particularly cliffs. Land access identifies the level of difficulty involving the availability and proximity to paved roads, since all the ECRC equipment is transported by road. Ocean access identifies the level of difficulty which may arise from shallow waters close to the response area at the shoreline, which causes danger to vessels and boats, and reduces the available operational time due to tidal restrictions.

Adjusted Operability: Mr. Starkes identified two operational limitations, both with equal value: danger risk and damage risk. The former is the danger that a particular shoreline represents for the response crew, in which aspects such as cliffs and steep slopes play an important role. Damage risk represents the level of damage that response operations may cause to the environment, such as fragile salt marshes which suffer tremendously with such operations. Using NOAA's ESI Shoreline Classification, Mr. Starkes ranked them from low to high, then this information was used for constructing the scoring.

4.3.3 Economic Dimension

The approach that uses the number of economic activities happening inside a coastal segment for assessing its vulnerability covers damage potential, but does not take in account coping capacity. Meanwhile, the approach of estimation of economic damage does not comply with the third selection criteria, because data were not available (e.g. coefficients representing the adaptability of each economic activity should be a product of stakeholder and expert consultation, estimates of degree of damage should be based on economic estimates tailored to a specific type of oil, etc.). Therefore, a way around these issues was to create indicators to reach a middle ground between both approaches. This was done with two indicators using coastal infrastructures as a proxy of economic activities. However, this oversimplified approach still represents damage potential more than coping capacity aspects.

Coastal Infrastructure Sensitivity: Indicator modified from Fattal et al., (2010), which assesses the sensitivity of coastal infrastructures (used for economic activities) in relation to a coastal buffer and shoreline length. The scale is adapted from the hierarchical priority of socio-economic resources made by Adler and Inbar (2007), which presented the resources requiring priority efforts in protection from oil spills and clean-up operations after a spill, recognizing critical infrastructure for an oil spill clean-up, such as naval bases and basins of power stations.

Production Value: An indicator estimating economic damage in terms of potential income losses resulting from interrupting activities, hypothesizing that interrupting an activity that contributes greatly to the local economy affects the economic system at a higher level when compared to interrupting an activity with a low contribution to the local economy. The scale is based on the rankings of economic impact measured in Gross Domestic Product (GDP), given by the "Economic Value of the Nova Scotia Ocean Sector" Report (Gardner, Fraser, Milloy, & Frost, 2005).

4.4 METHODS

The data was manipulated using ArcGis 10.2.2. The area scope is Halifax Harbour's shoreline from 44°43' to 44°28' N latitude and 63°38' to 63°23' W longitude, which represents an area that merges several nautical charts representing the inner and outer harbour.

The basic methodology followed is presented in Figure 4-3, with details provided subsequently. A buffer was created 600 m inland from the EC designated shoreline. In this buffer all characteristics concerning each indicator were identified. Once all data were collected for each dimension, the indicators were created using a merge of a ranking scheme or qualitative scale, which determines the level of vulnerability in descending order (the lower the value the greater the vulnerability) (Table 4-1).

Data normalization was performed inside the GIS workspace using a simple interval scale. This was done by restricting the range of values in the dataset using min-max values of the categories inside the indicators. Two categories were constituted for each indicator with values ranging from low to medium vulnerability and from high to very high vulnerability. The indicators were then aggregated into their corresponding vulnerability dimension. The vulnerability dimensions (i.e. ecological, social, economic) were aggregated with equal weighting into a composite index (i.e. PGv) (this was decided due to considerations presented in the next section). Then, the composite index was re-scaled into four categories ranging from very high to low vulnerability. This was done taking in consideration ECRC's advice: generally, more than 4 levels of vulnerability are confusing and not useful for response operations.

Finally, the area was discretized into 200 m cells, with each cell characterized by a value of the composite index (using the fishnet ArcTool). Then, these values were extrapolated to the shoreline (using overlay ArcTools). The final map depicts 2252 shoreline segments (each with a 200 m length) ranging from very high to low vulnerability.

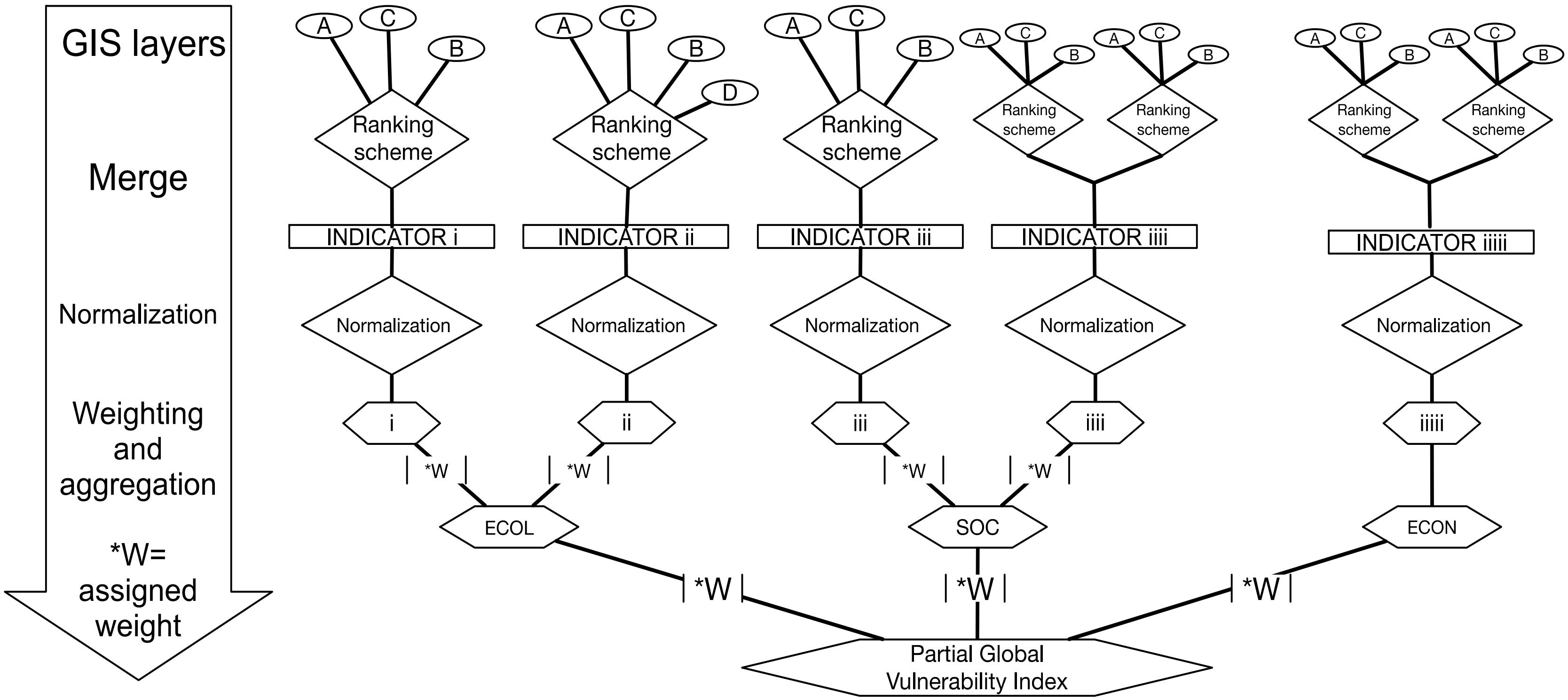

Figure 4-3 Proposed methodology for the PGv index

4.4.1 Weighting

Weights are value judgments that may have a significant effect on the overall composite indicator, because almost all quality dimensions are affected by this choice, such as accuracy, coherence and interpretability. Therefore, the choice of a weighting and aggregation model is crucial in the construction of composite indicators (OECD, 2008). The choice of most composite indicators is to rely on equal weighting, implying that all variables worth the same in the composite. However, the OECD, (2008) found the following:

[Equal weighting] could also disguise the absence of a statistical or an empirical basis, e.g. when there is insufficient knowledge of causal relationships or a lack of consensus on the alternative. In any case, equal weighting does not mean "no weights", but implicitly implies that the weights are equal. Moreover, if variables are grouped into dimensions and those are further aggregated into the composite, then applying equal weighting to the variables may imply an unequal weighting of the dimension (the dimensions grouping the larger number of variables will have higher weight). This could result in an unbalanced structure in the composite index (p. 31).

The literature was reviewed in order to find possible weighting schemes for our study. It was found that the majority of studies used equal weighting in their analysis. Other approaches are: Castanedo et al., (2009) and Wirtz and Liu (2006) both used a participatory-based weighting scheme; and Fattal et al., (2010) used a weighting scheme based on insights from an analysis of cost evaluations from oil slicks, with references to studies ranging from 1999 to 2002, in which socioeconomic and ecological dimension are approximately weighted 3:1. Also, ecological indicators weights are all equal, while for socioeconomic indicators of the human economic activities are approximately two times higher than other indicators, and heritage does not have any value.

A participatory method incorporating various stakeholders such as experts, citizens and politicians for assigning weights was not an option for this study due to time constraints. Therefore, an unequal weighting scheme among dimensions, such as the one presented by Fattal et al. (2010), will be considered. The weights used in that paper are based on quite dated publications and in a quite different geographic area. Therefore, it was necessary to search for more recent and similar geographic area information for comparison.

WSP Canada Inc., (2014) is more recent and particularly suited for Canada. It presented the same weighting scheme previously proposed by a DNV Australian risk assessment (2011). In this approach, socioeconomic and ecological dimensions are weighted 1:4. Also, within socioeconomic indicators, fisheries and tourism activities are weighted 4:1; and for ecological indicators, physical and biological indicators are approximately weighted 1:1.5. These numbers result from an analysis made on cost breakdown (referenced 2001) and were estimated taking into account the clean-up cost, the valuation of natural resource damage (NRD) and commercial losses caused by the spill (DNV, 2011).

In comparison, WSP Canada Inc. & SL Ross, (2014) and Fattal et al., (2010) could not be more different. The former gave more importance to the ecologic dimension and the latter to the socioeconomic dimension. Their average is 2:2.5 for socioeconomic and ecological dimensions respectively, which is practically equal weightings to both dimensions.

4.5 RESULTS

4.5.1 Indexes' Dimensions

4.5.1.1 Ecological

The study area contains twelve (12) ESI shoreline classifications and eight (8) categories of sensitivity, ranging from 1 to 8 (Figure 4-4). The closest to the mean score is gravel beaches, the most sensitive are salt marshes and tidal flats, and the least sensitive are exposed rocky shores. The ecological index's higher values are concentrated around Cole Harbour and Lawrencetown, Southwest of McNabs Island and Northwest of Lawlor Island and Eastern Passage (Figure 4-5). These areas are salt marshes and sandy tidal flats shorelines, with designated provincial parks and reserves.

4.5.1.2 Social

The social dimension depicts similarities to the ecological dimension, with higher values around Cole Harbour, Lawrencetown and McNabs and Lawlor Islands (Figure 4-5). Also, higher values are found in a small area between the South East Passage and Devil's Island. In these areas, important beaches and archaeological sites are found; also they have land and ocean accessibility restrictions, and operational restrictions due to the risk of damage to the fragile environments.

4.5.1.3 Economic

The economic dimension does not show similarities with the other dimensions (Figure 4-5). Higher values are concentrated around the inner bay, where there is a concentration of sensitive infrastructure (such as the TUFTS Cove generating station), as well a highly productive infrastructure, such as those belonging to the Halifax Port Authority. Also, higher values can be found East of Cow Bay, where fishing areas are concentrated.

4.5.2 Composite Index

The PGv index is presented in Figure 4-6, showing that approximately 40% of the shoreline can be considered highly vulnerable to oil spills, concentrated in the outer harbour. The first 20% are the most vulnerable areas, denominated as “very high vulnerability”, concentrated at the Western HH, between the South of McNabs and Lawlor Islands, and from Cole Harbour to Lawrencetown. The next 20%, denominated “high vulnerability”, is dispersed on the map, such as the shorelines located Northwest of McNabs Island, Cole harbour and Lawrencetown, Northwest of Bedford Bay, and Sambro and Ketch Harbours in the Eastern shore.

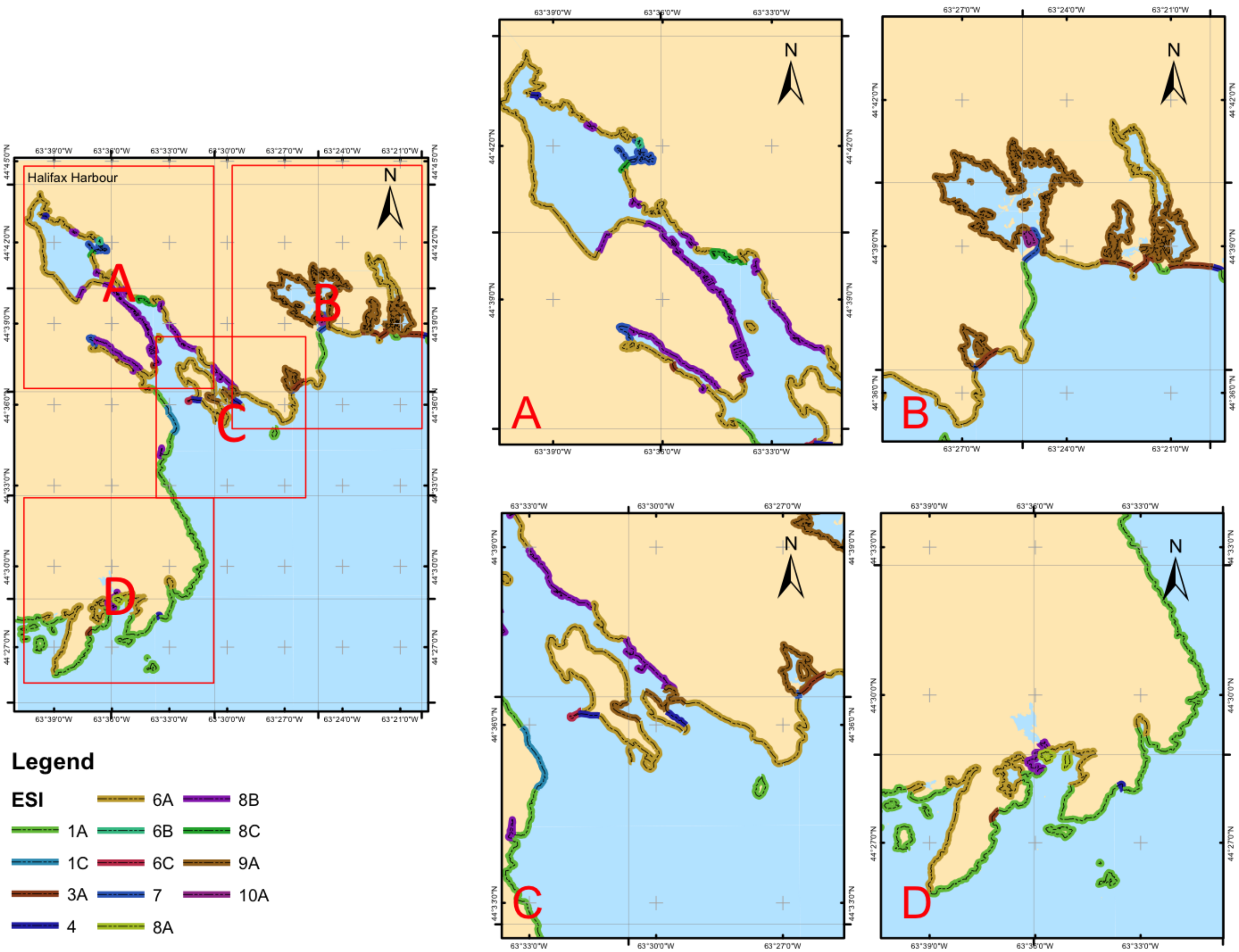

Figure 4-4 Halifax Harbour's shoreline classification using NOAA's ESI approach

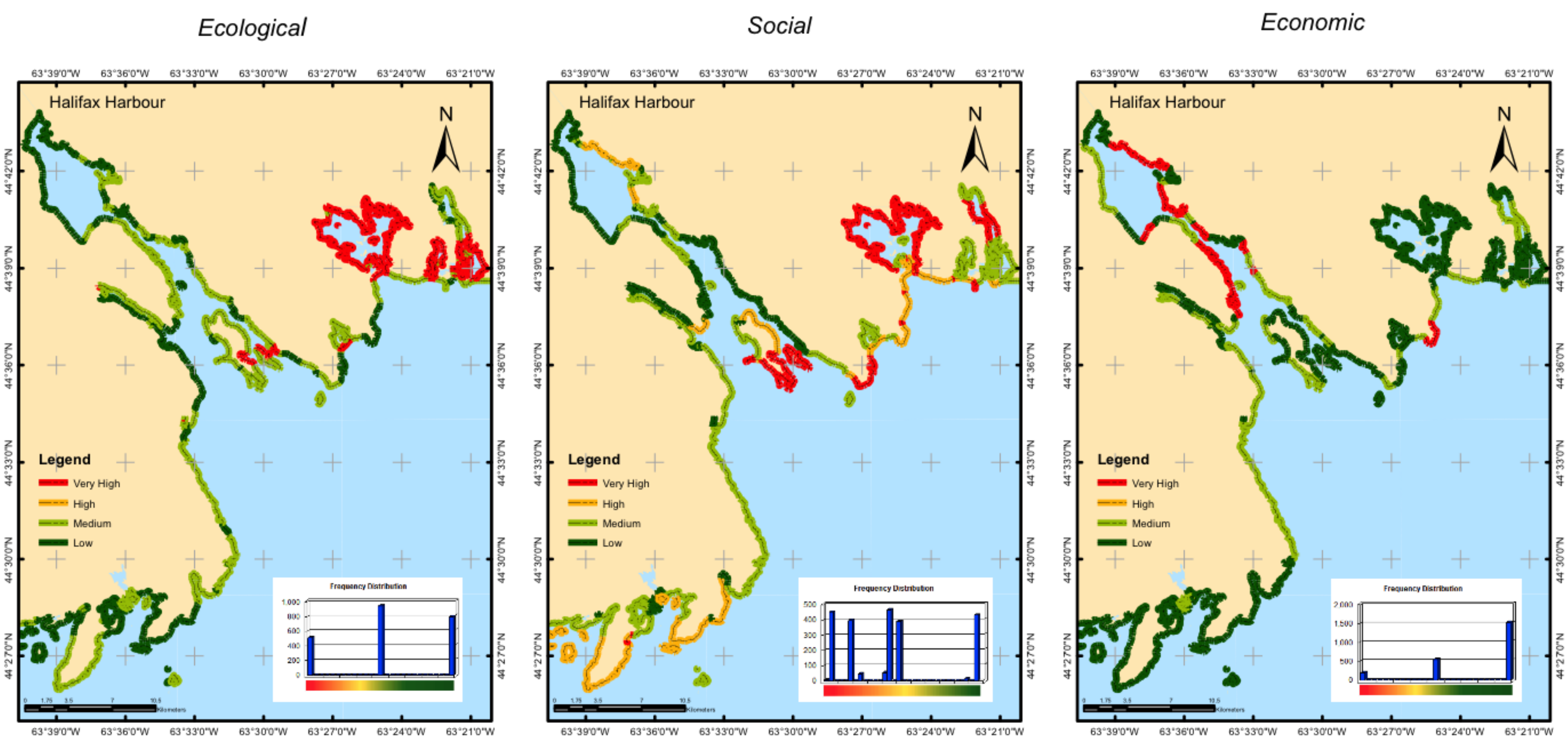

Figure 4-5 Ecologic, social and economic dimensions of the PGv index (Halifax Harbour)

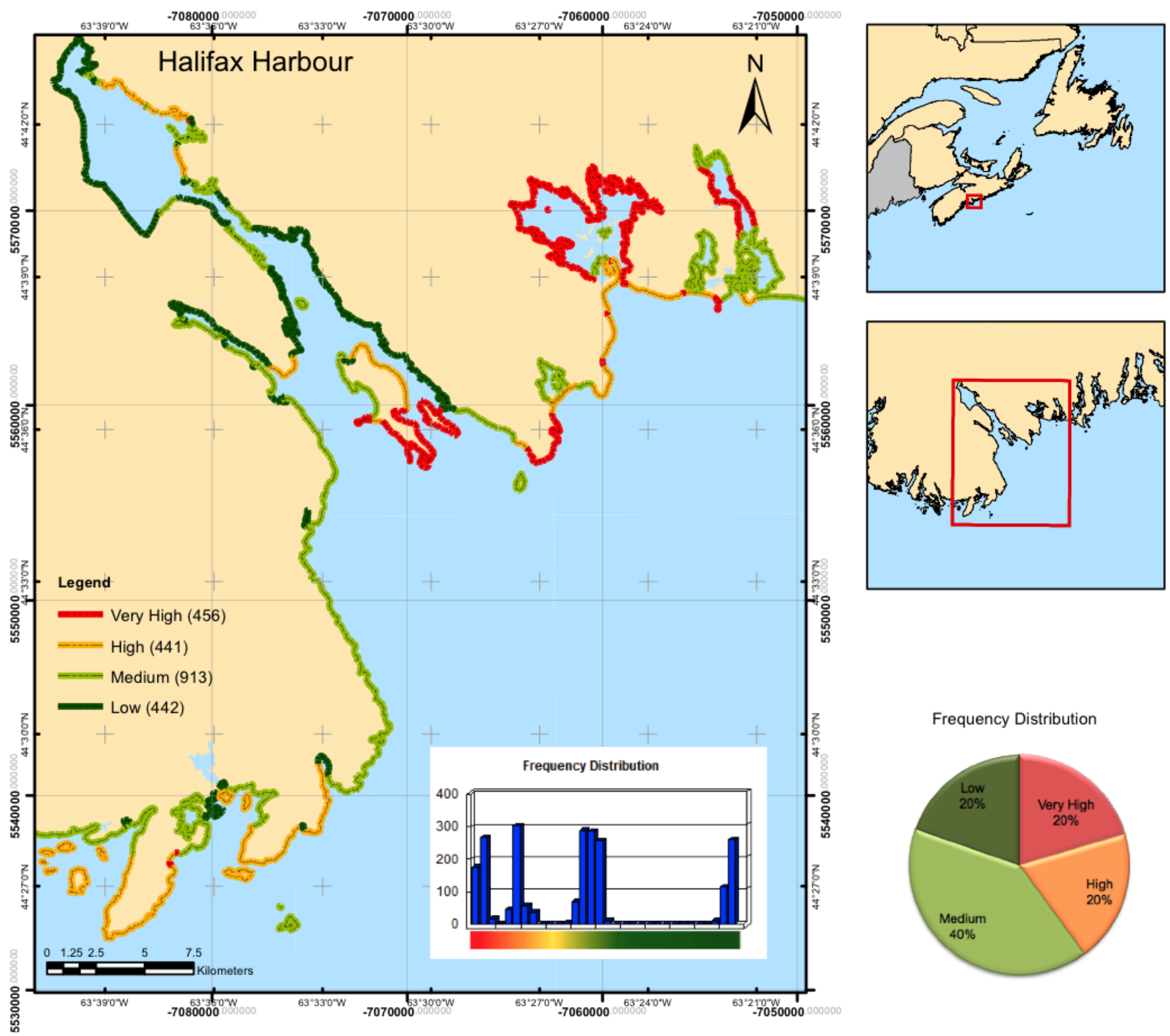

Figure 4-6 Halifax Harbour's PGv index.

CHAPTER 5 DISCUSSION

5.1 LITERATURE REVIEW: A NETWORK ANALYSIS

The semi-quantitative procedures of the Network analysis allowed for an efficient exploration given the short time for project, identifying publications that can be considered more relevant to the time of the present study, according to its value on the network. Also, Keyword analysis provided a guiding route for this project to focus on. Furthermore, several publications that can be considered state-of-the-art were identified, and a clear indication about associations among several authors was produced.

5.1.1 Data Gaps and Limitations

In order to develop a full picture of the development in the OSRA field and associated publications, additional data and attributes must be included, such as more publications and a co-authors attribute. The latter can expand the analysis further, finding deeper connections along the network. For example, if the co-authors are representative of a scientific team or institute, only analysing the first author could overlook this.

Our study however has several limitations. ENA for citation analysis (also called co-citation) is a new and growing trend, used mostly by humanists and social scientists (Weingart, 2011). However, it is unclear if this type of analysis provides a reliable and complete picture of the network. The extraction of valuable knowledge and insights from the network remains challenging, as it requires a deep understanding of the methodology and metrics. This limitations has been published by Weingart (2011) in his online series "Networks Demystified". The author describes the dependence in the user's "good intuition" for the network under analysis, the deceitful character of network structures, which despite having nodes, edges and certain attributes, still lack memory and embed no information on how those networks are generally traversed. Additionally, network's approaches tend to be of a more quantitative rather than a qualitative nature which may ignore crucial contextual aspects.

5.2 THEORETICAL FRAMEWORK

The literature review suggested that Roberts et al., (2008) findings of the disassociation between natural and social sciences about risk concepts are evident. They stated this as follows:

> Risk is recognized in both the social sciences and natural sciences as some combination of hazard and vulnerability, and often includes exposure and coping capacity. How these four components are defined, measured and evaluated differs greatly between the two disciplines, especially in the case of vulnerability and coping capacity: in natural sciences methods are generally quantitative, but consideration of vulnerability is limited and consideration of coping capacity is non-existent; in social sciences vulnerability and coping capacity are considered in broader detail, but because of the resulting complexity qualitative methods are favored (p. 164).

According to Roberts et al., (2008) to overcome this problem "risk analysis in the physical sciences can benefit from introduction of simplified and more quantitative adaptations of approaches in the social sciences. Realization of these benefits, however, requires clear and consistent understanding of vulnerability…" (p.164). While integrating vulnerability components, it was found that major incongruences appear in the ecological dimension, often oversimplified by many studies that concentrate primarily on the social science aspects. Therefore, this study acknowledges as essential to include the considerations made by Romero et al., (2013) and proposed by Silva et al., (2012), which basically acknowledge ecologic damage potential as a combination of susceptibility and sensitivity factors.

The previous consideration made our concept of "vulnerability of places" slightly different from the one used by ESPON, and allowed us to differentiate components by theme of quantification, which could have facilitated a more realistic quantification of components. Most importantly, it allowed us to call what was measured by its real name: the assessment of consequences in this study is a Partial Global Vulnerability Index, since it did not include susceptibility components thus it cannot be considered a complete measurement of vulnerability to oil.

5.2.1 Data Gaps and Limitations

The theoretical framework was produced using information contained within the reviewed literature, and because of space constraints, the theory behind a model presented in a scientific paper is often not detailed, which can induce wrong assumptions. Besides, the modeller's lack of expertise and biases could have affected the framework as well.

5.3 MODEL

5.3.1 Model Development

The conceptual framework provided a guiding route for the model development, and the selection criteria made the procedure more standardized when compared with several observed approaches in many studies, which can be considered more random and subjective in choosing indicators. This model appears to be a good fit in terms of current available data, and requires a minimum of expertise. Therefore, it can be easily replicated in a short time in any other place in Atlantic Canada or with minor changes elsewhere. Additionally, the PGv index was developed with the intention of being later integrated within an end-to-end marine ship-source oil spill analysis. Therefore, the integration may be expected to occur smoothly.

5.3.1.1 Data Gaps and Limitations

The practicality aspect of the model can also be seen as a drawback. There is a risk of oversimplification that should not be avoided. Two best practices were not used (i.e. biological and human use category), mainly because of lack of data as well as expertise. Besides, a note of caution is required since the model is not fully developed due to this study's time constraints: an uncertainty and sensitivity analysis, which is deemed to be extremely important to improve transparency and gauge the robustness of composite indicators (OECD, 2008), was not performed. It is also important to bear in mind that the tailoring of OSM indicators was made solely based on the advice from one OSR organization (i.e. ECRC).

The resultant model confirms the observations made by Frazao et al., (2013) recent study: despite the intention to choose indicators representing sensitivity and adaptability factors, and even when some indicators can be seen as representative of both, the majority of chosen indicators represents solely sensitivity.

5.3.2 Model Testing

As previously stated, the model is not fully developed, so the results of the model tested on the HH case study must be interpreted with caution. These findings will doubtless be well scrutinised, but there are some immediately dependable general conclusions. It was clear that the economic dimension is not in agreement with the other two dimensions. An implication of this is the possibility that the index may be a useful tool in oil spill prevention, bolstering dialogue between conflicting stakeholder interests. Besides, it can serve as an educational tool to better inform conflicting stakeholders about the many considerations that should be taken in oil spill scenario, ranging from the social to the issues affronting the responders in the field, that guide OSR decision making. Moreover, it can serve decision makers who are part of the Marine Pollution Preparedness and Response System for Ships, to identify possible areas of conflict that could lead to public outrage in an oil spill scenario, which increasingly has been affecting their credibility.

5.3.2.1 Data Gaps and Limitations

The intention was to use the most recent data for the model testing in HH. Despite our efforts, the EC dataset that was used in this study is not the most recent or official version of it. EC's database developers have made clear that this information is in a verification process. Also, it has been acknowledged that this updated version of their database is not publicly available, but it is the information that the ARP's pilot projects will be allegedly be using for their development. The EC dataset that was used contains many obvious errors. This issue was highlighted by ECRC, who are using this information as well. The obvious errors were corrected by hand, but to use this data on a larger scale, an automated method and verification protocol should be developed to solve this issue, if better data are not available.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

This study does not aim to debate how vulnerability is measured, but only to understand this issue through common techniques recently used, that in particular may be practical and applicable to the study area. OSRA state-of-the-art suggested that coastal vulnerability to oil spills can be measured by linking exposures, sensitivities and adaptability factors contained within the social, economic and ecological systems, to produce a global vulnerability or composite indicator.

In the context of an end-to-end marine oil spill analysis, the vulnerability contained within the receptors of the system can be assessed using a Partial Global Vulnerability (PGv) index. The synthetic character of this simple approach may be useful in policy, decision-making processes and communication and perception as well. However, there is still a long path to making this index a strong instrument. Based on the findings of this study, the following are recommendations for the next steps in the refinement and further integration of the PGv index model within the end-to-end marine oil spill analysis:

1. Establish a theoretical framework for the MARIN's end-to-end marine oil spill analysis.

This study presented a preliminary discussion about concepts and a possible theoretical framework for the overall MARIN project, which considers vulnerability as the sum of susceptibility, and sensitivity, and adaptive capacity factors. This fits the preliminary name given to MARIN's end-to-end marine oil spill analysis "A Coastal Environmental Vulnerability Index [CEVIOS]"; but further work is required to establish its viability, exploring these concepts in depth and with the expertise required for this matter. What is clear is that the overall end-to-end marine oil spill analysis urgently requires a guiding route that should be embedded in a theoretical framework. Moreover, because researchers of different disciplines are intended to merge their models, and without a clear understanding of established meanings and measurements of risk concepts behind this project, this task may be difficult due to redundancy and lack of standards.

2. Explore the ARP initiative to understand similarities and exploit potentials benefits for the end-to-end marine oil spill analysis.

There is no public access to information regarding the development of the ARP initiative, but almost certainly, data will be produced or updated for it. This data may be highly valuable for the MARIN end-to-end marine oil spill analysis, which doesn't have funding for this massive data acquisition. Besides, it is worth exploring lessons from the ARP pilot projects, which can be highly valuable to be incorporated into this project.

3. Include the identified best practices into the model.

Including indicators representative of coping capacity or adaptability factors can help to overcome the excessive weight of sensitivity indicators. Two options, both of them requiring acquisition of data currently not available and requiring technical expertise, were identified as best practices: Ihaksi et al., (2011) biological index, and Castanedo et al., (2009) socio-economic index. It should be explored if is possible to incorporate these approaches.

4. Perform an uncertainty and sensitivity analysis.

The PGv index needs to be assessed in terms of the selection criteria for indicators, the normalization scheme, and the choice of weights. A sensitivity analysis should identify sources of uncertainty and determine how they influence the scoring. As it is, the index is not robust enough to produce meaningful results. It is necessary to tweak its indicators and assess the overall methodology, exploring in detail methods to overcome the drawbacks of multivariate analysis.

5. Investigate different weighting schemes and aggregation systems.

The model used an equal weighting scheme for the vulnerability dimensions. Different weighting schemes can drastically change the results. Therefore, further research should be undertaken to investigate the intended approach to this issue by the ARP initiative, as well as new trends for weighting and aggregation, and the effect of public perception and stakeholder consultation.

6. Refine the Oil Spill Management indicators.

Further work is required to establish the appropriateness of the proposed OSM indicators. Several measures should be undertaken to refine the concepts and weighting of the considerations made by ECRC. A literature review on this subject should be completed, and an expert consultation among other oil spill responders in Canada also may be helpful for validation or refinement of the proposed indicators.

7. Develop the PGv index as a GIS automated program.

A further study may develop the proposed model as a GIS automated program, that may allow fast processing of large quantities of data, and keep the information updated. This program could run with modifiable factors (such as weighting schemes) that can represent the changes of public perception about environmental, social or economic values.

8. Consult other relevant stakeholders and prospective users.

Appendix D presents a preliminary ranking of prospective stakeholders for this project. This study took the point of view of decision makers and responders in case of an oil spill. But, only one response organization was consulted. There is abundant room for further progress in determining the usefulness of this model, as well of the entire MARIN research project, including the point of view of several prospective users, such as Transport Canada, the Canadian Coast Guard, other Response Organizations, Environment Canada, and Provincial, Territorial, and Municipal Governments.

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Stejernholm, M., Boertmann, D., Mosbech, A., & Nymand, J. (2011). *Environmental Oil spill Sensitivity Atlas for the Northern West Greenland (72º-75º N) Coastal Zone* (No. 828) (p. 210). National environmental Research Institute AARHUS University.

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Appendix A Revised Publications and References

Table A-1 List of reviewed OSRA primary publications with corresponding references, indicating whether the publications were included or not in ENA. A visualization ID is presented if it was included.

Nº	Visualisation ID	Reference
1	Adler,2007	Adler, E., & Inbar, M. (2007). Shoreline sensitivity to oil spills, the Mediterranean coast of Israel: Assessment and analysis. *Ocean & Coastal Management*, *50*(1–2), 24–34. http://doi.org/10.1016/j.ocecoaman.2006.08.016
2	Alves,2014	Alves, T. M., Kokinou, E., & Zodiatis, G. (2014). A three-step model to assess shoreline and offshore susceptibility to oil spills: The South Aegean (Crete) as an analogue for confined marine basins. *Marine Pollution Bulletin*, *86*(1-2), 443–457. http://doi.org/10.1016/j.marpolbul.2014.06.034
3	Azevedo,2014	Azevedo, A., Oliveira, A., Fortunato, A. B., Zhang, J., & Baptista, A. M. (2014). A cross-scale numerical modeling system for management support of oil spill accidents. *Marine Pollution Bulletin*, *80*(1-2), 132–147. http://doi.org/10.1016/j.marpolbul.2014.01.028
4	Castanedo,2009	Castanedo, S., Juanes, J. A., Medina, R., Puente, A., Fernandez, F., Olabarrieta, M., & Pombo, C. (2009). Oil spill vulnerability assessment integrating physical, biological and socio-economical aspects: application to the Cantabrian coast (Bay of Biscay, Spain). *Journal of Environmental Management*, *91*(1), 149–159. http://doi.org/10.1016/j.jenvman.2009.07.013
5	Not included	Catto, N. (2011). *Coastal Erosion in Newfoundland* (Report commissioned by the Atlantic Climate Adaptation Solutions Association (ACASA)) (p. 136). Policy and Planning Division of the Department of Environment and Conservation, Newfoundland and Labrador.
6	Chang,2014	Chang, S. E., Stone, J., Demes, K., & Piscitelli, M. (2014). Consequences of oil spills: a review and framework for informing planning. *Ecology and Society*, *19*(2). http://doi.org/10.5751/ES-06406-190226
7	De Andrade,2010	De Andrade, M. M. N., Szlafsztein, C. F., Souza-Filho, P. W. M., Araújo, A. dos R., & Gomes, M. K. T. (2010). A socioeconomic and natural vulnerability index for oil spills in an Amazonian harbor: A case study using GIS and remote sensing. *Journal of Environmental Management*, *91*(10), 1972–1980. http://doi.org/10.1016/j.jenvman.2010.04.016
8	Not included	DNV. (2011). *Assessment of the Risk of Pollution from Marine Oil Spills in Australian Ports and Waters* (Report for the Australian Maritime Safety Authority No. PP002916) (p. 44). London, UK: Australian Maritime Safety Authority.
9	Fattal,2010	Fattal, P., Maanan, M., Tillier, I., Rollo, N., Robin, M., & Pottier, P. (2010). Coastal Vulnerability to Oil Spill Pollution: the Case of Noirmoutier Island (France). *Journal of Coastal Research*, *265*, 879–887. http://doi.org/10.2112/08-1159.1
10	Frazao Santos,2013a	Frazão Santos a, C., Carvalho, R., & Andrade, F. (2013). Quantitative assessment of the differential coastal vulnerability associated to oil spills. *Journal of Coastal Conservation*, *17*(1), 25–36. http://doi.org/10.1007/s11852-012-0215-2
11	Frazao Santos,2013b	Frazão Santos b, C., Michel, J., Neves, M., Janeiro, J., Andrade, F., & Orbach, M. (2013). Marine spatial planning and oil spill risk analysis: Finding common grounds. *Marine Pollution Bulletin*, *74*(1), 73–81. http://doi.org/10.1016/j.marpolbul.2013.07.029
12	Ihaksi,2011	Ihaksi, T., Kokkonen, T., Helle, I., Jolma, A., Lecklin, T., & Kuikka, S. (2011). Combining Conservation Value, Vulnerability, and Effectiveness of Mitigation Actions in Spatial Conservation Decisions: An Application to Coastal Oil Spill Combating. *Environmental Management*, *47*(5), 802–813. http://doi.org/10.1007/s00267-011-9639-y
13	Lamine,2013	Lamine, S., & Xiong, D. (2013). Guinean environmental impact potential risks assessment of oil spills simulation. *Ocean Engineering*, *66*, 44–57. http://doi.org/10.1016/j.oceaneng.2013.04.003
14	Li,2014	Li, P., Chen, B., Li, Z., Zheng, X., Wu, H., Jing, L., & Lee, K. (2014). A Monte Carlo simulation based two-stage adaptive resonance theory mapping approach for offshore oil spill vulnerability index classification. *Marine Pollution Bulletin*, *86*(1-2), 434–442. http://doi.org/10.1016/j.marpolbul.2014.06.036
15	Ng,2008	Ng, T. F., Vijayan, V. R., Chow, W. S., & Sulaiman, A. (2008). Assessment of oil spill vulnerability of Southwest Pulau Pinang shoreline. *Bulletin of the Geological Society of Malaysia*, (54), 123–131.

Nº	Visualisation ID	Reference
16	Olita,2012	Olita, A., Cucco, A., Simeone, S., Ribotti, A., Fazioli, L., Sorgente, B., & Sorgente, R. (2012). Oil spill hazard and risk assessment for the shorelines of a Mediterranean coastal archipelago. *Ocean & Coastal Management*, *57*, 44–52. http://doi.org/10.1016/j.ocecoaman.2011.11.006
17	Oliveira,2014	Oliveira, E. R., Silveira, B., & Alves, F. L. (2014). Support mechanisms for oil spill accident response in costal lagoon areas (Ria de Aveiro, Portugal). *Journal of Sea Research*, *93*, 112–117. http://doi.org/10.1016/j.seares.2013.11.002
18	Perhar,2014	Perhar, G., & Arhonditsis, G. B. (2014). Aquatic ecosystem dynamics following petroleum hydrocarbon perturbations: A review of the current state of knowledge. *Journal of Great Lakes Research*, *40*, 56–72. http://doi.org/10.1016/j.jglr.2014.05.013
19	Pincinato,2009	Pincinato, F. L., Riedel, P. S., & Milanelli, J. C. C. (2009). Modelling an expert GIS system based on knowledge to evaluate oil spill environmental sensitivity. *Ocean & Coastal Management*, *52*(9), 479–486. http://doi.org/10.1016/j.ocecoaman.2009.08.003
20	Romero,2013	Romero, A. F., Abessa, D. M. S., Fontes, R. F. C., & Silva, G. H. (2013). Integrated assessment for establishing an oil environmental vulnerability map: Case study for the Santos Basin region, Brazil. *Marine Pollution Bulletin*, *74*(1), 156–164. http://doi.org/10.1016/j.marpolbul.2013.07.012
21	Frazao Santos,2009	Santos, C. F., & Andrade, F. (2009). Environmental Sensitivity of the Portuguese Coast in the Scope of Oil Spill Events — Comparing Different Assessment Approaches. *Journal of Coastal Research*, 885–889.
22	Singkran,2013	Singkran, N. (2013). Classifying risk zones by the impacts of oil spills in the coastal waters of Thailand. *Marine Pollution Bulletin*, *70*(1-2), 34–43. http://doi.org/10.1016/j.marpolbul.2013.02.004
23	Not included	Stejernholm, M., Boertmann, D., Mosbech, A., & Nymand, J. (2011). *Environmental Oil spill Sensitivity Atlas for the Northern West Greenland (72º-75º N) Coastal Zone* (No. 828) (p. 210). Denmark: National environmental Research Institute AARHUS University.
24	Tansel,2014	Tansel, B. (2014). Propagation of impacts after oil spills at sea: Categorization and quantification of local vs regional and immediate vs delayed impacts. *International Journal of Disaster Risk Reduction*, *7*, 1–8. http://doi.org/10.1016/j.ijdrr.2013.11.001
25	Vafai,2013	Vafai, F., Hadipour, V., & Hadipour, A. (2013). Determination of shoreline sensitivity to oil spills by use of GIS and fuzzy model. Case study – The coastal areas of Caspian Sea in north of Iran. *Ocean & Coastal Management*, *71*, 123–130. http://doi.org/10.1016/j.ocecoaman.2012.05.033
26	Wiezorek,2007	Wieczorek, A., Dias-Brito, D., & Milanelli, J. C. C. (2007). Mapping oil spill environmental sensitivity in Cardoso Island State Park and surroundings areas, São Paulo, Brazil. *Ocean & Coastal Management*, *50*(11–12), 872–886. http://doi.org/10.1016/j.ocecoaman.2007.04.007
27	Wirtz,2006	Wirtz, K. W., & Liu, X. (2006). Integrating economy, ecology and uncertainty in an oil-spill DSS: The Prestige accident in Spain, 2002. *Estuarine, Coastal and Shelf Science*, *70*(4), 525–532. http://doi.org/10.1016/j.ecss.2006.06.016
28	Not included	WSP Canada Inc. (2014). *Risk Assessment for Marine Spills in Canadian Waters. Phase 1: Oil Spills South of 60th Parallel* (Report prepared for Transport Canada No. 131-17593-00) (p. 256). Transport Canada.
29	Jolma,2014	Jolma, A., Lehikoinen, A., Helle, I., & Venesjärvi, R. (2014). A software system for assessing the spatially distributed ecological risk posed by oil shipping. *Environmental Modelling & Software*, *61*, 1–11.

Table A-2 List with references of secondary publications (referenced by primary sources) with high scores of Authority (ENA).

Nº	Visualisation ID	Reference
1	Gundlach,1978	Gundlach, E.R. and Hayes, M.O., 1978. Vulnerability of coastal environments to oil spill impacts. Marine Technology Society Journal, 12, 18–27.
2	NOAA,2002	Petersen, J., Michel, J., Zengel, S., White, M., Lord, C. Park, C. (2002) Environmental Sensitivity Index Guidelines. Version 3.0. NOAA Technical Memorandum NOS OR & R 11. Seatle: Office of Response and Restoration, National Oceanic and Atmospheric Administration.
3	Jensen,1990	Jensen JR, Ramsey EW, Holmes JM, Michel J, Savitsky B, Davis BA. Environmental sensitivity index (ESI) mapping for oil spills using remote sensing and geographic information system technology. International Journal of Geographical Information Systems 1990;4(2):181–201.
4	IMO/IPIECA,1996	IMO/IPIECA (1996) Sensitivity mapping for oil spill response, IMO/IPIECA Oil Spill Report Series: 1, p. 24

Appendix B Glossary of Elements Contained in the Matrix of the Reviewed Literature

Table B-1 Glossary of elements contained in the matrix of the reviewed literature. The definitions are based on the NOAA Environmental Sensitivity Index Guidelines (Petersen et al., 2002) and information contained within the reviewed literature.

			Category	Description
Ecologic	Exposure		*Vessel exposure*	Shipping traffic density.
			Spill location	Location where oil spill occurs.
			Vessel characteristics	Ship type and size.
	Oil Behaviour		*Spill frequency*	Oil spills rate of occurrence.
			Climatic and Oceanographic conditions	Meteorological and oceanographic conditions such as wind speed, direction and degree, sea surface temperature, pressure, wave height, current speed, direction and degree.
			Oil characteristics	Oil type and volume.
	Physical	Coastal morphology	*Relative exposure to wave and tidal energy*	Physical factors (wave-energy flux and tidal-energy flux) that primarily determine the degree of exposure at the coastline.
			Shoreline slope	A measure of the steepness of the intertidal zone between maximum high and low tides.
			Substrate type	Classification of substrates, such as Bedrock (impermeable or permeable), Sediments divided by grain size (mud fine, coarse, granule, pebble, cobble, boulder) and Man-made material.
			Biological productivity and sensitivity	Biological productivity factors, such as benthic productivity, which reflects the general sensitivity of shoreline habitats.
			Landform	Coastal geomorphology.
			Hydrodynamic	Effects of wind and waves.
			Marine weather	Integration of different sub variables: flow orientation, swell height, and wind direction and speed.
			Exposure	Describes If a coastal unit is sheltered or not.
			Wave exposure	Arithmetic sum of the orientation and the sinuosity of the assessment unit.
	Biological	Resources	*Marine mammals*	Animals such as dolphins, manatees, seals, sea lions, walruses, polar bears, sea otters, whales.
			Meroplankton	Larvae that are temporarily part of the plankton, such as larvae from many benthic invertebrates and larval fish.
			Plants	Vascular plants and lichens
			Birds	Animals such as alcids, diving birds, gulls, terns, landfowl, passerine birds, and pelagic birds.
			Reptiles and amphibians	Animals such as alligators, crocodiles, lizards, snakes, amphibians and turtles.
			Fish	Animals such as anadromous marine, resident, diadromous, estuarine, freshwater, and marine benthic or pelagic fishes.
			Invertebrates	Animals such as bivalves, cephalopods, crabs, echinoderms, gastropods, insects and lobster and crayfish.
		Areas	*Habitats and plants*	Ecological reserves or special habitats or communities such as algae beds, coral reefs, floating or submersed aquatic vegetation, kelp, and special or rare plants.
			Wetlands	Special/rare wetland plants, habitats, or worm beds.
			Coastal environments	Three established types: estuaries, beaches and coastal rocky zones; which are used to assess the environmental vulnerability associated to oil spill, using parameters such as conservation state, value for conservation (singularity), and resilience.
		Management	*Management areas*	Officially designated management areas, including designated critical habitats, national parks, state and regional parks, marine sanctuaries, wildlife refuges, and preserves and reserves set aside by various agencies and organizations.
			Special management areas	Other ecological sites that have special resource management status, such as UNESCO or RAMSAR sites.
			Species at risk	Endangered or threatened species such as plants, animals and microorganisms, protected by national legislation.

		Category	Description
Socio-economic	Human activities	*Aquaculture*	Activities related with extraction of resources from Hatcheries, ponds and pens, etc.
		Aboriginal commercial fishing	Activities related with extraction of resources from leased shellfish beds and near shore, shallow-water fisheries such as crabbing, shrimp harvest, lobster harvest, and estuarine fisheries performed by aboriginal people.
		Commercial fishing	Activities related with extraction of resources from leased shellfish beds and near shore, shallow-water fisheries such as crabbing, shrimp harvest, lobster harvest, and estuarine fisheries.
		Mining	Activities related with extraction of resources from Intertidal/sub tidal mining leases.
		Agriculture	Farming activities.
		Military	Military facilities on the shoreline.
		Industry	Industry related activities, not specified what type.
		Tourism	All tourism employment activities (even not directly related to the shoreline/marine tourism industry).
		Subsistence	Activities related with extraction of resources from designated harvest sites or hunting.
		Port	Activities related with cargo transportation.
		Fresh water	Activities related with the usage of industrial, drinking, or cooling water, and coastal population intake of freshwater.
		Coastal infrastructure	Infrastructures located within a predetermined coastal buffer (i.e. potentially vulnerable area which contain most of the vulnerable activities and is located near from the shoreline).
	Population	*Population*	Presence of towns or settlements in the shoreline.
		Education	Level of education of the coastal population.
		Income	Income level of the coastal population.
		Relationship with natural resources	Level of dependence on natural resource activities of the coastal population, such as fishing or aquaculture.
	Cultural	*Recreation*	Areas with recreational and sports usage, directly related with marine recreation such as, high-use recreational beaches, sport-fishing, windsurfing, sailing diving sites, surfing areas, and artificial reefs. Also boat ramps and marinas, which are both recreational sites and access points for response activities; and non-directly related with marine recreation but in the surrounding of coastal areas, such as sport fields.
		Heritage	Natural conservation areas adjacent to the coast, which are indicators of land that has particular value for recreational use or cultural sensitivity.
		Archaeological sites	Places or areas where tangible evidence of past human activity is located in situ on, below or above ground, or on lands under water, which have been formally recognized by an authority as having heritage value.
	Oil Spill management	*Oil booms efficiency*	Efficiency of safeguarding species with oil booms at close range.
		Accessibility	Degree of access from emergency locations to a shoreline segment.
		Operability	Operational limitations in the use of response methods in a shoreline segment.
		Crisis management	Analysis of the quality of local oil spill management plans, which are evaluated depending on different variables such as creation date, existence of vulnerability maps, available tools, and staff training.

Appendix C Metadata

Table C-1 Ecological indicators Metadata (Figures 4-4, 4-5, 4-6)

SHORELINE TYPE

Nº	Layer name	Description	Contact	Database
1	Mid-upper intertidal zone shoreline type	A combined morphology and substrate indicator; major indicator for oil spill retention and response	EC	ECSC
2	Lower intertidal zone material	Provides indication of material in lower half of the intertidal zone; useful in logistics planning	EC	ECSC
3	Lower intertidal zone form	Provides indication of morphology in the lower half of the intertidal zone; useful in logistics planning	EC	ECSC

CONSERVATION POTENTIAL

1. National Parks, Reserves of Biosphere

Nº	Layer name	Description	Contact	Database
2	T17 Ramsar Wetland Sites	Sites are listed under the convention on Wetlands of International Importance especially as Waterfowl Habitat, also known as the Ramsar Convention. The only obligation that the convention places on the managers of wetlands is not to allow activities that would alter or destroy the ecological character of the wetland.	DNR, Canadian Wildlife services	RLUL
3	T10 National migratory bird sanctuary	An area designated by the federal government for the protection of migratory waterfowl.	DNR, Canadian Wildlife services	RLUL
4	T9 National park and adjunts	National Parks are a country-wide system of representative natural areas of Canadian significance. By law, they are protected for public understanding, appreciation and enjoyment, while being maintained in an unimpaired state for future generations.	Parks Canada	RLUL

2. Marine Reserves, Natural Parks

Nº	Name	Description	Contact	Database
1	T12B Natural watershed Municipal Surface Water Supply Areas	Natural surface watershed areas upstream of municipal surface drinking water supply intake points.	DEL, Water & Waste	RLUL
2	T1 Designated Provincial Parks and Park Reserves	(c367 RSNS 1989 - The Provincial Park Act) - Crown land set aside for outdoor recreational opportunities or to preserve rare or significant elements of the natural environment and historic resources of the province.	DNR, Parks	RLUL
3	T3 Protected beaches under the Beaches Protection Act	(c367 RSNS 1989 - The Provincial Parks Act) - Crown land set aside for outdoor recreational opportunities or to preserve rare or significant elements of the natural Environment and historic resources of the province.	DNR, Parks	RLUL

3. Nature Reserves, important bird areas

Nº	Name	Description	Contact	Database
1	T18 Eastern habitat Joint Venture Lands	Lands acquired by the Crown through the North American Waterfowl Management Plan. These sites provide key nesting, staging, and wintering habitat for migratory shorebirds.	DNR, Wildlife	RLUL
2	T13A Operational Non-designated Parks and Reserves	Provincial Crown Lands identified for future Park designation.	DNR, Parks	RLUL
3	T15 Nature Conservancy of Canada Lands	Nature Conservancy of Canada works with local and community organizations (including municipal government) work to identify and protect important natural areas. Securing and providing adequate conservation in areas of significance for migratory birds, rare plants, interesting geology and diverse marine life is the primarily goal of all concerned.	Nature Conservancy of Canada	RLUL

Nº	Layer name	Description	Contact	Database
4	T6A Provincial Wildlife management areas	(c504 RSNS 1989 - The Wildlife Act) - An area designated to control, preserve, maintain or enhance wildlife population habitat.	DNR, Wildlife	RLUL
5	T6B Provincial Game Sanctuaries	(c504 RSNS 1989) - An area designated to preserve and protect a wildlife population habitat.	DNR, Wildlife	RLUL
6	T4 Wilderness Areas	(c27 SNS 1998, Wilderness Area Protection Act) - An area of land, set aside for protection, which may be outstanding, unique, rare, valuable or a representative example of a natural landscape or ecosystem.	DEL, Protected Areas	RLUL

4. Protected landscapes, fisheries reserves

Nº	**Name**	**Description**	**Contact**	**Database**
1	T29 Canadian Heritage Rivers	Recognized to ensure that long-term management will conserve their outstanding heritage resources and promote their sustainable recreational potential.	-	RLUL
2	T19 Trail Act Lands	These lands recognize trails on Crown and privately owned lands and over watercourses for recreational use and enjoyment and to reduce the liability of the owner or the occupier of privately owned lands where consent is given to designate a trail.	DNR, PARKS	RLUL
3	T5B Sites of ecological significance under moratorium	Areas where a moratorium on development has been imposed; most were previously identified under the International Biological Program (IBP).	DEL, Protected Areas	RLUL
4	T5A Areas under the Special Places Act	Provide for the preservation, protection, regulation, exploration, excavation, acquisition and study of archaeological and historical remains, paleontological sites, and ecological sites which are considered important parts of the natural or human heritage of the Province.	DEL, Protected Areas	RLUL

Table C-2 Social indicators Metadata (Figures 4-4, 4-5, 4-6)

CULTURAL

1. Bathing beaches

Nº	Name	Description	Contact	Database
1	Beaches	Beaches part of the layer ParkRecreationFeatures: An inventory of HRM owned and maintained playgrounds	HRM	HRMCD
2	Level beaches	Beaches identified by EC database	EC	EC

2. Leisure and Sport Marinas

Nº	Name	Description	Contact	Database
1	Wharf and Boat Launch	Wharfs and boat launchers part of the layer ParkRecreationFeatures: An inventory of HRM owned and maintained playgrounds	HRM	HRMCD

3. Coastal and Marine Archaeological sites

Nº	Name	Description	Contact	Database
1	Archaeological Buffers	Buffers around Archaeology sites provided by the NS Museum	NS Museum	HRMCD
2	T8NationalhistoricSitesandparks	Provide recognition of significant places, persons, and events in order to preserve our cultural heritage. All such designations are made by the Minister of Canadian Heritage on the advice of the Historic Sites and Monuments Board of Canada.	Parks Canada	RLUL

4. Urban Beaches and shoreline leisure

Nº	Name	Description	Contact	Database
1	T13bNonDesignatedRailCorridors	Abandoned rail corridors acquired by the Province. These corridors were acquired in consideration of their potential for future development and management as public recreational trails, and for additional linear public uses where such uses can be demonstrated to be compatible with existing or potential recreational trail use.	DNR, Parks	RLUL
2	Recreation Features	DALO (Scenic lookout); DART (Racetrack); DAGC (Golf course), part of the layer Designated Areas	HRM	HRMCD
3	Sport fields	Sport fields, such as Basketball hoop and Court, General playground; Playfield;Football; Soccer; Tennis; Baseball; trailhead. Part of the layer Park recreation Features	HRM	HRMCD
4	Parks	An inventory of HRM owned and maintained parks.	HRM	HRMCD

Table C-3 Economic indicators Metadata (Figures 4-4, 4-5, 4-6)

COASTAL INFRASTRUCTURE SENSITIVITY

1. Cooling water basin power stations

Nº	Name	Description	Contact	Database
1	Cooling water	Power station using water for cooling purposes contained within HRM database	HRM	HRMCD

2. Defence and military infrastructures, Mainly naval bases

Nº	Name	Description	Contact	Database
1	Defence and military	Department of National Defence and DFO infrastructures contained within EC database	EC	ECSC

3. Commercial ports

Nº	Name	Description	Contact	Database
1	Port infrastructure	Ports contained within EC database	EC	ECSC

4. Bathing and tourist beaches

Nº	Name	Description	Contact	Database
1	Beaches	Beaches part of the layer ParkRecreationFeatures: An inventory of HRM owned and maintained playgrounds	HRM	HRMCD
2	Level beaches	Beaches identified by EC database	EC	ECSC

5. Marine aquaculture facilities, marine fishing and facilities

Nº	Name	Description	Contact	Database
1	Small Craft Harbours	Core-fishing and non-core fishing harbours. The georeferenced information was taken from the DFO Small Craft Harbours (SCH) program website: http://www.dfo-mpo.gc.ca/sch-ppb/maps/map-eng.asp?c=a	DFO	None
2	Shellfish Harvest areas	Shellfish harvest areas identified in EC database	EC	ECSC
3	Fishing areas	Fishing areas identified in EC database	EC	ECSC

6. Commercial and industrial areas in which the spill does not affect their immediate activities

Nº	Name	Description	Contact	Database
1	Industrial and commercial areas	Industrial and commercial areas, including pits, storage areas and business and industrial parks.	HRM	HRMCD

PRODUCTION VALUE

1. Fishing industry

Nº	Name	Description	Contact	Database
1	Small Craft Harbours	Core-fishing and non-core fishing harbours. The georeferenced information was taken from the DFO Small Craft Harbours (SCH) program website: http://www.dfo-mpo.gc.ca/sch-ppb/maps/map-eng.asp?c=a	DFO	None
2	Shellfish Harvest areas	Shellfish harvest areas identified in EC database	EC	ECSC
3	Fishing areas	Fishing areas identified in EC database	EC	ECSC

2. National Defence

Nº	Name	Description	Contact	Database
1	Defence and military	Department of National Defence contained within EC database	EC	ECSC

3. Fisheries and Oceans				
Nº	**Name**	**Description**	**Contact**	**Database**
1	Defence and military	DFO infrastructures contained within EC database	EC	ECSC

4. Port of Halifax				
Nº	**Name**	**Description**	**Contact**	**Database**
1	Port infrastructure A	Port infrastructure which belongs to Port of Halifax (Halifax Port Authority)	EC	ECSC
2	Port infrastructure B	Port infrastructure which belongs to Port of Halifax (Halifax Port Authority)	HRM	HRMCD

5. Shipbuilding and boat building, marine construction, marine manufacturing and aquaculture				
Nº	**Name**	**Description**	**Contact**	**Database**
1	Marine construction A	Shipbuilding, marine construction facilities contained within HRMCD database	HRM	HRMCD
2	Marine construction B	Naval shipbuilding	EC	ECSC

6. Ocean tourism				
Nº	**Name**	**Description**	**Contact**	**Database**
1	Beaches	Beaches part of the layer ParkRecreationFeatures: An inventory of HRM owned and maintained playgrounds	HRM	HRMCD
2	Level beaches	Beaches identified by EC database	EC	ECSC

Appendix D Canada's Marine Oil Spill Pollution Preparedness and Response System for Ships

Table D-1 Roles and responsibilities related to three stages (pre-spill, during spill and post-spill), of government institutions which are part of Canada's Marine Oil Spill Pollution Preparedness and Response System for Ships.

Institution		Roles and responsibilities	Spill		
			Pre	During	Post
TC		Lead regulatory / governance agency for all ship-source spills and the overall response regime	X	X	X
TC		Lead for international matters concerning marine policy (i.e. shipping policy, vessel safety and ship-source pollution prevention) and is the national administration to which many international maritime conventions refer	X		
TC		Lead department representing Canada and providing overall co-ordination for Canada's relations at the International Maritime Organization (IMO), and represents Canada on any negotiations related to the Oil Pollution Preparedness and Response and Cooperation (OPRC) Convention	X		
TC		Lead Agency for salvage of vessels during a pollution incident		X	
TC		To certify ROs and evaluate their activities that include, but are not limited to, auditing, inspection, response plans, exercise and training	X		
TC		To ensure vessels operating in waters under Canadian jurisdiction have a Ship Oil Pollution Emergency Plan (SOPEP) and an arrangement with a certified RO	X		
TC		To ensure oil tankers of 150 tonnes gross tonnage or more and vessels of 400 gross tonnes or more that carry oil as cargo or fuel have the appropriate documentation as required by CSA 2001	X		
TC		To ensure amendments to fees charged by an RO in relation to an arrangement with an OHF or vessel are applied in an appropriate and transparent manner through a User Committee	X		
TC		To implement and oversee the National Aerial Surveillance Program	X	X	
TC		To appoint Regional Advisory Committee (RAC) Members in six Regions, and provide logistical and Secretariat support for each Committee	X		
TC		To oversee RO User Committees	X		
TC		To implement and oversee the National Advisory Council (NAC) and provide logistical support to the NAC	X		
TC		To conduct on-board investigation of ship source pollution occurrences			X
TC		To investigate discharges of oil that occur during transfers between vessels and OHFs			X
DFO	DFO	Lead agency for all operational joint contingency plans developed with foreign countries	X		
DFO	DFO	Provides its spill response expertise for the review and updating, as required, of the ER Regulations and Response Organization standards	X		
DFO	DFO	Maintains the Marine Pollution Incident Reporting System (MPIRS) and shares data and analysis with TC		X	X
DFO	DFO	Responsible for the Marine Advisory Boards across the country	X		
DFO	DFO	To provide technical expertise to CCG with respect to the ship and ship's onboard activities (e.g. lightering) in the event of a marine spill or threat of a spill		X	
DFO	CCG	Lead federal agency responsible for ensuring an appropriate response to ship source spills in waters under Canadian jurisdiction		X	X
DFO	CCG	Acts as either the federal monitoring officer, by monitoring the polluter's response to spills or as the on-scene commander, by managing the response to spills. If the polluter is unknown or is unwilling or unable to take on all or some response obligations; declines to continue the management of the response; or responds in a matter that, in the opinion of the Coast Guard, is inadequate, the Coast Guard assumes the management of the pollution incident		X	X
DFO	CCG	Lead on international fora dealing with operational service matters		X	
DFO	CCG	In the event of an international incident, provides available response resources to countries, which are signatory to the International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC).		X	
DFO	CCG	To take measures to repair, remedy, minimize or prevent pollution damage from a ship or OHF, as stated in CSA 2001		X	X
DFO	CCG	To provide competent and qualified CCG ER personnel to act as the Federal Monitoring Officer/On-Scene Commander (FMO/OSC) or to support the activities of the FMO/OSC	X	X	X
DFO	CCG	To ensure an adequate number of trained Environmental Response personnel on Response Management System (RMS)	X		
DFO	CCG	To provide competent and qualified Environmental Response personnel as Pollution Response Officers (PROs) appointed by the Minister of Fisheries and Oceans	X	X	X
DFO	CCG	To provide operational oversight and maintenance of: (1) CCG National Response Plan and Regional Chapters. (2) Canada/United States Joint Contingency Plan (CANUS JCP) and Regional / District Annexes with the United States Coast Guard (USCG)	X		
DFO	CCG	To exercise the Regional District of the CANUS JCP Annexes on a biannual basis	X		
DFO	CCG	To provide services relating to the National Support Team	X		
DFO	CCG	To maintain the CCG as a center of excellence in marine spill response through research and development, training, exercising and national and international technical cooperation	X		
DFO	CCG	Responsible for all technical publications related to pollution response operations, including reporting and notification of pollution events			X
EC		Lead federal department for spills from federal facilities (including CCG and DND vessels) and for pollution incidents originating from the land	X	X	X
EC		Provides scientific, environmental and wildlife advice, with support from DFO	X	X	X
EC		To Chair the Environmental Emergencies Science Table in case of environmentally significant events to provides consolidated environmental and scientific advice		X	X
EC		To participate in the post mortem process and follow up on the lessons learned, within three months			X

Institution	Roles and responsibilities	Spill		
		Pre	During	Post
DND	Provide people, facilities, logistics, naval and airborne support and other resources		X	
AANDC	Provide advice about spills in the Arctic, and on or near Aboriginal lands, and about land claims agreements, cultural and other issues		X	
PSEPC	Provide support for a large-scale incidents requiring additional coordination of federal resources to support CCG's role of lead federal agency		X	
Provincial, territorial and municipal governments	Have laws, mandates and expertise that can contribute to the overall response. Aboriginal Groups may provide local knowledge, and can identify environments at risk.	X	X	X

Table D-2 Roles and responsibilities related to three stages (pre-spill, during spill and post-spill), of the industry which is part of Canada's Marine Oil Spill Pollution Preparedness and Response System for Ships.

Institution	Roles and responsibilities	Spill		
		Pre	During	Post
Vessels	To have an appropriate SOPEP	X		
	To have an arrangement with a certified RO	X		
	To have a Declaration which: - confirms an arrangement with a certified RO, - identifies the ship's insurer,- identifies the authorized person who implements the RO arrangement	X		
	To ensure that an appropriate SOPEP is kept on board the vessel and the captain and crew are well versed on its content	X		
	To ensure the SOPEP is exercised and tested on a prescribed basis	X		
	To ensure that ships are boomed during bunkering operations	X		
	To equip their vessels with enough boom to circle the vessel	X		
	To carry sorbent material when transiting in remote areas	X		
	To follow proper notification procedures when a spill occurs		X	
	To implement the SOPEP		X	
	To appoint an OSC for the management of the spill for which they are responsible		X	
	To mitigate, contain and control an oil discharge/spill through their own capacity (means) and/or in combination with a contractor and the invoking of the vessel's RO arrangement		X	
	To keep the CCG FMO apprised of all response activities and plans		X	
	To take financial responsibility for all reasonable costs associated with the response, recovery activities and monitoring costs of pollution incidents			X
	To participate in the post mortem process and follow up on the lessons learned within three months			X
Oil Handling Facilities	To ensure that their operations have the appropriate infrastructures, plans, equipment and trained personnel to manage an immediate and effective response during oil transfer Operations to or from a ship as per the legislative Requirements	X		
	To ensure that an appropriate OPEP is available and facility personnel are well versed in its content	X		
	To have an arrangement with a certified RO	X		
	To ensure the OPEP and OPPR are exercised and tested	X		
	To maintain a preparedness capacity (as per the legislative requirements)	X		
	To comply with the RO and OHF's Regulations	X		
	To follow proper notification procedures when a spill occurs		X	
	To implement the OPEP		X	
	To appoint an OSC for the management of the spill		X	
	To mitigate, contain and control the spill within the appropriate time allowances and by invoking their arrangement with a RO, through their resident capacity, or by the use of a contractor		X	
	To keep the CCG FMO apprised of all response activities and plans		X	
	To be financially responsible for all reasonable costs associated with the response, recovery activities and CCG monitoring costs			X
	To participate in the post mortem process and follow up on the lessons learned within three months			X
ROs	To submit to TC, an appropriate response plan and declaration to obtain a certificate of designation	X		
	To provide a proposed list of fees or amended fees with each application for certification	X		
	To maintain the availability of the resources, equipment and procedures as identified in the response plan	X		
	To ensure that the appropriate infrastructure, plans, equipment, and trained personnel are established to maintain their certification	X		
	To conduct exercises to validate their submissions for certification	X		
	To ensure the RO preparedness capacity identified in their submissions is kept in a constant state of operational readiness	X		
	To establish and maintain a Life Cycle Management Program for their preparedness capacity	X		
	To develop and maintain the appropriate logistic plans to allow for a response within the prescribed RO time standards	X		
	To ensure their preparedness capacity is located in the optimum locations considering the associated risk and adjusted as required within the prescribed legislative requirements	X		
	To advise in advance of any prospective changes to their certification submission	X		
	To establish RO User Committees to oversee fee amendments and advertise fee amendments through Canada Gazette	X		
	To activate the RO spill management team upon notification by the OSC		X	
	To deploy equipment and personnel for response operations as per the direction of the OSC		X	
	To ensure close adherence to response times when responding To oil pollution incidents within their Geographical Area of Response (GAR)		X	
	To invoke their mutual aid agreements as required		X	
	To co-ordinate all response activities and plans through the OSC and CCG FMO		X	
	To take financial responsibility and submit all costs associated with the response to the OSC			X
	To participate in the post mortem process and follow up on the lessons learned within three months			X

Figure D-1 Assessment method for prospective users, using an arbitrary scoring scheme based on two criteria regarding the Marine Pollution Preparedness and Response System for Ships: 1) its current state, and 2) recent recommendations for the Regime improvement, made by the Tanker Safety Panel Secretariat contained in its 2014 report *"A Review of Canada's Ship-source Oil Spill Preparedness and Response Regime — Setting the Course for the Future" Chapter 4 "Preparedness and Response".* TC, CCG and ROs were classified as certain prospective users, EC and provincial, territorial and municipal governments as probable users and the rest as unlikely prospective users. a. Scoring criteria. b. Criteria explanation. c. Scoring table. d. Prospective users' final scoring criteria for classification.

a)

Score	Level	Current state		Tanker Safety panel Secretariat recommendations
		A	B	N° 3 to N° 7, N°10, N° 11 and N° 20
+2	High	CEVIOS or related is stated as part of its mandate and responsibilities	Is a lead department or agency at the strategic or operational level	Is a CEVIOS or related recommendation that affects its role and responsibilities; or the stakeholder must be lead of a multi-stakeholder team to achieve the recommendation
+1	Medium	CEVIOS or related is not part of its mandate and responsibilities, but could use it as support for them	Is a support department/agency	Is a CEVIOS or related recommendation that has indirect repercussion (via another stakeholder) for its role and responsibilities; or the stakeholder must be part of a multi-stakeholder team to achieve the recommendation
0	Low	This information is not meaningful for this stakeholder	Is only subject to regulations	Recommendations do not have any implication
0	Not possible to assess	There is not enough information to determine it	There is not enough information to determine it	There is not enough information to determine it

b)

Code	Explanation
A	Level of relation with its role and responsibilities
B	Level of responsibility in the marine spill pollution preparedness system
N°3	Transport Canada should regularly review and update the national Risk Assessment for Marine Spills in Canadian Waters and make these results public
N°4	Transport Canada should designate new Areas of Response, based on the national Risk Assessment for Marine Spills in Canadian Waters
N°5	Using a consistent methodology, Transport Canada should perform regional risk assessments for each Area of Response and make the results public
N°6	Transport Canada, in collaboration with the Canadian Coast Guard, Environment Canada and Response Organizations, should develop a standardized process for risk-based Area Response Planning
N°7	The Canadian Coast Guard should lead the Area Response Planning process for each Area of Response, in collaboration with Transport Canada, Environment Canada and the Response Organizations operating within it
N°10	Transport Canada should require Response Organizations to develop detailed Geographic Response Plans to minimize potential spill impacts to key environmental and socioeconomic sensitivities. These Geographic Response Plans should include specific time standards and identify the response resources that would be maintained locally
N°11	Transport Canada should certify Response Organizations based on their Area Response Plans and Geographic Response Plans, which may include the use of alternative response
N°20	The Government should remove the legislative impediments for the use of alternative response techniques.

c)

Potential user	Current state		Tanker Safety panel Secretariat recommendations								Score
	A	B	N°3	N°4	N°5	N°6	N°7	N°10	N°11	N°20	
TC	1	2	2	2	2	2	1	1	2	0	**1.5**
DFO	1	1	0	0	0	0	0	0	0	0	**0.2**
DFO/CCG	1	2	1	1	0	1	2	1	0	1	**1**
EC	1	2	1	0	0	1	1	0	0	0	**0.6**
DND	0	1	0	0	0	0	0	0	0	0	**0.1**
AANDC	0	1	0	0	0	0	0	0	0	0	**0.1**
PSEPC	0	1	0	0	0	0	0	0	0	0	**0.1**
Provincial, territorial and municipal governments	1	1	0	0	0	0	0	0	0	2	**0.4**
Vessels	0	0	0	0	0	0	0	0	0	0	**0**
OHFs	0	0	0	0	0	0	0	0	0	0	**0**
ROs	1	2	0	1	0	1	1	2	1	1	**1**

d)