Potential economic impact of a tanker spill on ocean-based industries in the North Coast Region, British Columbia

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Abstract

Ocean-based industries are estimated to directly employ about 10% of the population in the North Coast region. When indirect and induced values are considered, ocean-based industries provide employment for an equivalent of nearly 30% of the regional population. The comparatively high regional unemployment rate of 9.3%, in contrast to the provincial rate of 6.6%, suggests that ocean-based industries are critical to the regional economy and wellbeing of communities. This is one reason why there has been considerable concern by British Columbians about the possible impacts of a tanker spill.

The Enbridge Northern Gateway pipeline and tanker route, proposed by Enbridge Northern Gateway Pipelines Limited Partnership, would transport 525,000 barrels (bbls) per day of conventional light and heavy oil, synthetic oil and blended bitumen from Bruderheim, Alberta to Kitimat, British Columbia, for export via tankers. While the economic benefits of the project have been quantified by the proponents and the potential biophysical impacts of a hydrocarbon spill within the confined channel area (CCAA) of the Douglas Channel and open water area (OWA) of the Pacific Ocean have been assessed, the potential economic costs of a hydrocarbon spill from a tanker along the proposed shipping routes have not yet been quantified. In this study, economic values are expressed in terms of the value of total (i.e., direct, indirect and induced) economic effects on total output, employment and the contribution to gross domestic product (GDP). Ocean-based industries are estimated to currently contribute $1.1-$1.2 billion (2011 CAD) in total output value, 8,983-10,216 person-years (PYs) of employment and $667-$743 million to GDP each year.

The proposed Enbridge Northern Gateway project could produce total economic effects of $627 million in output, 4,521-8,577 PYs in employment and $293 million in GDP on the regional economy, in present value terms, over a 50-year period. Three potential spill scenarios are considered: no impact (no hydrocarbon spill), medium impact (a 10,000 m^3/63,000 bbl hydrocarbon spill at Ness Rock) and high impact (a 41,000 m^3/257,000 bbl hydrocarbon spill at Grenville Rock).

In the event of a medium impact tanker spill of 10,000 m^3 of hydrocarbons, the regional economy could suffer total losses of $41-$189 million in output, 399-1,314 PYs of employment and $23-$98 million in GDP over 50 years. This means that when the higher ends of the ranges of estimates are considered, under this scenario, 30%, 15% and 33% of the projected output value, employment and contribution to GDP of the Enbridge Northern Gateway Project would be lost to the spill.

If a high impact spill of 41,000 m^3 of hydrocarbons occurs, the North Coast region could experience total losses of $87-$308 million in output, 1,652-4,379 PYs of employment and $72-$205 million in GDP. Here, the percentages of the projected benefits from the Enbridge Northern Gateway project that would be lost to the spill are 49%, 51% and 70%, respectively.

The above projected percentage losses are high given the narrowness of the scope of the current valuation exercise and the conservative nature of our assumptions and estimates. Estimated losses are limited to market values of five ocean-based industries and do not include the cost of spill response, clean-up and litigation activities (estimated to be $2.4 billion CAD for a medium impact spill and $9.6 billion CAD for a high impact spill) as well as the economic value of social, cultural and environmental damages. If these costs are accounted for, all of the projected economic gains from the Enbridge Northern Gateway project could quickly turn into losses in the event of a tanker spill.

1. Introduction

The North Coast region of British Columbia (BC) encompasses coastal and inland areas and is bordered to the west by the Pacific Ocean and to the east by the Nechako region. The regional population of 56,145 (Statistics Canada 2012b) is distributed between the Skeena-Queen Charlotte and Kitimat-Stikine Regional Districts and includes the coastal communities of Kitimat (pop. 9,200) and Prince Rupert (pop. 12,900) on the mainland and Haida Gwaii (pop. 6,700), formerly known as the Queen Charlotte Islands. Economic activity is predominantly resource-based (BC Government 2011a) with significant commercial fishing and processing, a growing tourism sector and expanding industrial development.

Marine areas of the North Coast region are located within the boundaries of the Pacific North Coast Integrated Management Area (PNCIMA), one of five large marine planning regions in Canada (MacConnachie et al. 2007). PNCIMA also encompasses marine areas of the Central Coast region.

The economies of coastal and First Nations communities, including Kitamaat Village, Hartley Bay, Metlakatla, Lax Kw'alaams, Skidegate and Old Masset, are directly impacted by ocean-based activities. Inland areas are influenced by the marine environment, particularly through the relationship between freshwater salmon spawning and marine habitat, but are less dependent on the marine environment.

The Enbridge Northern Gateway pipeline and tanker route, proposed by Enbridge Northern Gateway Pipelines Limited Partnership (ENGP), would transport 525,000 barrels (bbls) per day of "conventional light and heavy oil, synthetic oil, bitumen blended with condensate and bitumen blended with synthetic oil" (ENGP 2010a) from Alberta to Kitimat, British Columbia, for shipment via tankers. A second pipeline would also be constructed to import 193,000 bbls per day of condensate (ENGP 2010b). Tankers departing the proposed terminal at the private Port of Kitimat will navigate a 290-kilometer route through the Douglas Channel before following either a northern route to access Asian markets (ENGP 2010c) or a southern route to access trade partners in the USA (ENGP 2010b). The majority of tanker traffic is expected to follow the northern route (ENGP 2010b).

Proponents expect the project to stimulate economic growth in northern and First Nations communities along the pipeline route and at the proposed Kitimat shipping terminal (ENGP website). While the economic benefits of the project have been quantified by the proponents (ENGP 2010d), and the potential biophysical impacts of a hydrocarbon spill within the confined channel area (CCAA) of the Douglas Channel and open water area (OWA) of the Pacific Ocean have been assessed (Stephenson et al. 2010, ENGP 2010e), the potential economic costs of a hydrocarbon spill in the OWA of the proposed shipping routes have not yet been identified. Gunton & Broadbent (2012) conducted a qualitative assessment on the potential impacts of a tanker spill on First Nations communities and Allan (2012) analyzed the broader impacts of the project on the Canadian economy resulting from an increase in the price of oil.

Public opinion polling has highlighted controversy surrounding the project. One poll suggested that 60.3% of B.C. residents oppose the ENGP project (Vanderklippe 2012), while a second indicates that 35% are in opposition, 7% are in support and 51% could be convinced to support the project if "economic and environmental considerations" could be addressed by project developers (Olivier 2012). BC Premier Christy Clark has suggested that additional compensation should be provided to the province to compensate for environmental and economic risks along the coastal shipping route (Hong 2012).

It is important to assess the potential economic cost of a hydrocarbon spill now so that the results can be included in the debate about potential costs and benefits of project implementation. These costs include social, environmental and economic externalities of the project that would be incurred by communities in the North Coast region. In order to adequately assess the benefits and costs of a hydrocarbon spill, it is critical to estimate these externalities. While some of the potential impacts can be assessed using existing market values, many require non-market valuation methodologies.

The *Exxon Valdez* oil spill (EVOS), which occurred in Prince William Sound (PWS), Alaska, in 1989 provides a case study from which to extrapolate information about the potential impacts of a tanker spill. PWS is located approximately 1,200 kilometres (km) north northwest of Prince Rupert, along the Gulf of Alaska coastline, and bears similar ecological, geographic, climatic and socio-political characteristics to the North Coast region. Both regions have coarse gravel beaches and sheltered rocky shores (NOAA 1997) and are regarded as wilderness tourism destinations due to their remoteness. They also share many of the same species of fish, birds and wildlife.

EVOS released 10.9 million gallons (350,000 bbls) of crude oil, primarily during the first 6 hours of the spill, and directly affected 1,100 miles (1,770 km) of coastline (NOAA 1992). Average values for duration and cost of impacts are also drawn from other major oil spills for comparison.

In this study, economic values are expressed in terms of total (i.e., direct, indirect and induced) economic effects on indicators (i.e., economic output, employment and gross domestic product, "GDP") of ocean-based industries. The scope includes economic activity that is generated within the region, undertaken by local residents as well as visitors, and economic activity in other jurisdictions that results from ocean-related activities within the North Coast region.

The potential impact of a tanker spill was estimated based on assumed (i) durations of marine area closures; and (ii) market recovery times, by industry. Three potential spill scenarios are considered: no impact (no hydrocarbon spill), medium impact (10,000 m^3/63,000 bbl hydrocarbon spill at Ness Rock in Camaaño Sound) and high impact (41,000 m^3/257,000 bbl hydrocarbon spill at Grenville Rock). In the absence of independent estimates, regional economic benefits were calculated using projected employment and project-related expenditures reported by ENGP (2010f).

2. Background

2.1. Existing industries

2.1.1. Commercial fishing

North Coast commercial fish stocks include 49 species of salmon (*Oncorynchus* spp.: Chinook, chum, coho, pink and Sockeye salmon), herring (*Clupea pallasii*: roe, spawn-on-kelp), rockfish (*Sebastes* spp.), halibut (*Hippoglossus stenoleptis*), sablefish (*Anoplopoma fimbria)*, lingcod (*Ophiodon elongatus*), spiny dogfish (*Squalus acanthias*), arrowtooth flounder (*Atheresthes stomias*), southern rock sole (*Lepidopsetta bilineata*), shellfish (e.g. Dungeness crab, red and green sea urchin, geoduck, sea cucumber, shrimp, prawn) and skates (*Raja* spp.: big, black and longnose). Commercial fishing occurs within the Department of Fisheries and Oceans Canada (DFO) Management Areas 1-6 (near shore) and 101-106 and 140 (offshore).

Industries indirectly impacted by the commercial fishing sector include seafood processing, marketing, transportation, wholesale, retail and services. The seafood processing sector in Prince Rupert, in particular, has undergone considerable changes within the past two years. Most recently, the closure of the J.S. McMillan Ltd. processing plant in October 2011, the merger of Ocean Fisheries Ltd. and Canadian Fishing Company Ltd. (Canfisco) in June 2011 and the subsequent closure of the Ocean Fisheries Ltd. processing plant in May 2012 has reduced the volume of seafood processed in the North Coast region and shifted processing activities south, to the Lower Mainland of British Columbia. Because the value of seafood processing is indirectly linked to commercial fish catch within the North Coast region, the value that is generated in other jurisdictions is traced back to the original source (i.e., the North Coast), where the fish are caught.

Aquaculture

DFO (2012a) lists six aquaculture license holders in the North Coast region, four of which are developing facilities and do not currently produce a commercial harvest. The two producing facilities are located on Porcher Island, near Prince Rupert, and in Skidegate Inlet, on Haida Gwaii. The Porcher Island facility produces Littleneck clam (*Protothaca staminea*), Manila clam (*Venerupis philippinarum*), Pacific oyster (*Crassostrea gigas*) and Western blue mussel (*Mytilus trossulus*), while the Skidegate Inlet facility produces Pacific oyster (*Crassostrea gigas*) and Pacific scallop (*Patinopecten* sp.). Both facilities are small-scale and employ fewer than 10 full-time staff.

The Haida Nation and Metlakatla Band have invested in the development of shellfish aquaculture facilities, with inaugural harvests expected in 2013 and extending through 2023. The Haida Nation is anticipating initial production of 10 million scallops per year at its site, ramping up to 40 million scallops per year with the potential to diversify into geoduck cultivation (John Disney, personal communication, June 29, 2012). Coastal Shellfish Corp., based in Prince Rupert, has partnered with the Metlakatla Band to establish a facility to produce Pacific scallop, Manila clam, Geoduck clam (*Panopea abrupta*) and Pacific oyster near Prince Rupert. The Metlakatla Band is also developing sites to produce Pacific scallop and Japanese scallop (*Patinopecten yessoensis*) at Stephen's Passage and Wolfe Island.

Due to the small-scale nature of aquaculture operations currently producing shellfish on the North Coast, the value of aquaculture has not been included in this study; however, the economic contribution of aquaculture is expected to grow considerably over the coming decades.

Hatchery production

DFO operates a salmon and trout hatchery at the mouth of the Kitimat River, which releases approximately 8.5 million juvenile Chinook, coho, chum, steelhead and cutthroat trout each year (Watson 2010). A second hatchery, located at Marie Lake on Graham Island, Haida Gwaii, is operated jointly by DFO and the Old Masset Village Council and targets annual production of 300,000 Chinook and coho smolts (DFO 2012b). While trout are released into the freshwater environment, a portion of the salmon released from the hatchery is caught by commercial and recreational fishermen in the region. Thus, the value of the Kitimat hatchery is captured in the current study through its effect on commercial fisheries and recreational fishing.

Monitoring and enforcement

DFO employs 80 staff in Prince Rupert and 10 on Haida Gwaii; the Canadian Coast Guard employs 19 staff at its Prince Rupert location and eight staff on Haida Gwaii (Gardner Pinfold Consulting 2010; MIEDS 2011). The Haida Fisheries Program employs an additional 12 part-time and 25-30 full-time staff.

Research, monitoring and enforcement related to fisheries are indirectly linked to commercial and recreational fishing activities. It should be noted that the value of research, monitoring and enforcement is not included in this study.

Food, social and ceremonial fisheries

While not a market-based industry, fishing provides many First Nations communities in the region with a source of food and holds spiritual and cultural significance. The legal right of First Nations to fish for food, social and ceremonial (FSC) purposes was enshrined by the Supreme Court of Canada in 1992 (Robinson Consulting & Associates 2012). FSC fisheries have priority over commercial and recreational fisheries and are managed jointly by DFO and First Nations in the North Coast region, including the Haisla (Kitamaat Village) and Haida (Old Masset Village Band and Skidegate Band Council) Nations and four of seven bands of the Tsimshian First Nation (Lax Kw'alaams, Metlakatla, Gitxaala and Gitga'at Nation). The traditional territory of the Kitasoo/Xaisxais Band encompasses a portion of the North Coast region, but the community is physically located on the Central Coast.

FSC catch databases are maintained independently by each First Nation and data is shared with DFO; however, this information is highly sensitive to First Nations and DFO recognizes that reported data is of limited accuracy. DFO provides annual FSC salmon catch for sockeye, Chinook, coho, chum and pink salmon and on its website (DFO 2012c) and maintains some records of thirteen additional species including rockfish, sablefish, halibut and lingcod (DFO 2012d). A detailed assessment of FSC catch is available for only the Gitaga'at Nation (Hartley Bay). This study details average annual catch of 45 species (Gregory et al. 2011), with listed annual catch for salmon species more than four times greater than those reported in DFO salmon catch estimates for the Gitga'at Nation (DFO 2012e).

The results of the Gitga'at FSC catch cannot be used to estimate catch for other First Nations due to considerable variation in the species composition and proportions between traditional use areas (Bruce Watkinson, personal communication, June 26, 2012). Additionally, the value of FSC catch cannot be estimated using methods applied to commercial catch (e.g. ex-vessel prices) because of the many social, cultural, educational and other benefits associated with FSC fishing (Bruce Watkinson, personal communication, June 26, 2012). First Nations Councillors and Fisheries Managers within the North Coast assert that FSC fishing is invaluable to the health and well-being of their communities (Bruce Watkinson, personal communication, June 26, 2012; Ellis Ross, personal communication, June 25, 2012; Bill Shepert, personal communication, June 27, 2012) and that the educational, social and cultural values of FSC fishing activities are irreplaceable (Bruce Watkinson, personal communication, June 26, 2012). In the absence of adequate valuation methods to account for these benefits, it is only possible to conclude that in one year, the Gitga'at (pop. 155) (BC Stats 2012) catch approximately 200,000 pieces of fish and other seafood, and that nearly 10,000 members of the Haisla, Haida and Tsimshian First Nations are similarly dependent on marine resources within the North Coast region.

2.1.2. Port activities

The North Coast region hosts two of the three most active ports in British Columbia at the publicly-owned Port of Prince Rupert and the private port at Kitimat.

The Port of Prince Rupert includes five shipping terminals as well as the Northland Cruise Terminal (InterVISTAS 2012), which serves as a port-of-call for cruise ships and smaller "pocket cruises" en route between Seattle or Vancouver and Alaska (Robinson Consulting 2012). The number of calls by cruise ships varies considerably between years, with competition for cruise traffic shared by the Port of Victoria.

The private port at Kitimat is currently used exclusively by Rio Tinto Alcan and employment, revenue and GDP information associated with shipping operations are combined with data for plant operations and considered proprietary (Paul Henning, personal communication, June 20, 2012). The port was used by Methanex Corp. to ship methanol and ammonia until 2005 and by West Fraser Timber's Eurocan pulp and paper mill until 2010 (Schreier 2012). The Methanex site has been purchased by Royal Dutch Shell and the Eurocan site by Apache Canada Ltd., EOG Resources Canada Inc. and Encana Corp., which own Kitimat LNG. Redevelopment of the Kitimat LNG site began in 2012 (Schreier 2012). These industries are expected to contribute significantly to the local economy through export of liquefied natural gas (LNG), primarily to Asian markets, but are not currently operational and are excluded from this analysis.

2.1.3. Ferry transportation

British Columbia Ferry Services Inc. (BC Ferries), the public ferry service provider throughout British Columbia, operates three routes within the North Coast region, between Port Hardy and Prince Rupert (Route 10), Prince Rupert and Skidegate (Route 11) and Skidegate and Alliford Bay (Route 26). The service provides transportation for local residents as well as a considerable number of tourists during summer months (May-September).

2.1.4. Marine tourism

Marine recreation encompasses activities undertaken by both residents and non-residents (i.e., tourists) (Robinson Consulting 2012). Expenditure by residents produces an induced effect on the tourism industry, while tourism expenditure can be considered an export of goods and services resulting in direct economic impact. Only tourism activity produces a gain or loss in the local economy, while recreation by residents creates a transfer of revenue within the region but no associated gain or loss. Thus, the present analysis is limited to tourism-based activities.

Recreational fishing

A literature scan (MIEDS 2011; Gregory et al. 2011) and review of local tourism websites and guides indicates at least 74 fishing charter operators within the areas of Haida Gwaii (8), Prince Rupert (51) and Kitimat (13). The majority of these businesses operate seasonally and are owner-operator based, with few or no additional staff. Nevertheless, the cumulative effects of these operations contribute to the local economy and draw in revenue from outside the region. Recreational fishing activities support and are supported by the existence of eleven harbour authorities or public wharves, two marinas and four marine fuel service stations within the region (BCMCA 2012). Visitor Centre Statistics from Tourism BC (2012) suggest a positive average annual rate of growth in number of visitors for Prince Rupert (+8.41%) during the period 2003-2011, negligible tourism growth in Kitimat (-0.07%) and negative growth in Haida Gwaii (-3.05%).

Other activities

Other activities by non-residents that occur in the marine environment include recreational boating, beach activities, whale and wildlife watching, kayaking, sailing tours and mothershipping tours (Cisneros-Montemayor & Sumaila 2010). There is evidence of recreational diving activity within the region; however, only a few operators offer tours. Gardner Pinfold Consulting (2010) reports 37 businesses in the marine tourism sector and an additional eight businesses that provide marine transport on Haida Gwaii, including kayak mothershipping, kayak tours, powerboat tours and sailboat tours. Business size ranges from very small (i.e., one owner/operator) to large, with activity largely seasonal. Some tourism operators generate additional revenue through marine transportation, which presents a challenge when allocating employment by marine sector. Indirect employment and revenues related to the sector are received by transportation providers, local retailers and the hospitality industry.

Many tourism operators within the North Coast region are based in other areas of British Columbia, Alaska, Washington, or elsewhere in the USA. The direct economic output enjoyed by these operators is included in this study because the initial value is generated within the North Coast region.

There is little evidence of formal ocean-based tourism activity near Kitimat beyond periodic boat charters for wildlife viewing. Only one privately-owned dock, M.K. Marina, operates near Kitamaat Village, outside Kitimat. The absence of a public dock limits recreational boating opportunities. Kayaking in the Douglas Channel, near Kitimat, can be unsafe due to north-south winds and waves (Marc-André de Launière, personal communication, July 3, 2012). Gregory et al. (2011) report that at least eight sailing tour companies and three fishing lodges operate within the traditional territory of the Gitga'at Nation, around Hartley Bay. The Haisla Nation is currently working to develop tourism within the region, and offers some guided cultural tours in traditional canoes (Gregory et al. 2011). Between 200 and 250 participants, including local residents, participate in traditional canoe tours each year (Gregory et al. 2011). The Haisla Nation maintains a list of tour guides who are employed casually, as needed. Based on this information, it is reasonable to conclude that recreational boating contributes to the economy within Gitga'at Territory and near Kitimat.

If approved, the Enbridge Northern Gateway project will boost port activities in the North Coast region and provide additional output, employment and GDP.

ENGP (2010f) estimates that project construction, including the Kitimat Terminal (i.e., tank and marine terminals), tunnels and pipelines, will provide 4,025 PYs of employment in coastal British Columbia, of which 2,235 PYs will be supplied by regional businesses. Project proponents expect indirect and induced employment during construction to generate 585 PYs and 245 PYs of employment, respectively.

Operations are expected to provide 104 direct jobs[1] in the Kitimat area to operate pipelines, pump stations and the Kitimat Terminal and to provide project-related goods and services (ENGP 2010f). Expenditures on wages and benefits will amount to $3.6 million per year (ENGP 2010f). Project proponents expect 60 indirect jobs and 40 induced jobs to result from operations (ENGP 2010f). Marine operations, including support services, cleaning, maintenance and security at the Kitimat Terminal, emergency response staff, tug operators and pilots, are expected to provide an additional 134 jobs, 11 indirect jobs and 35 induced jobs in the region (ENGP 2010f). Expenditures on wages and benefits for these positions are estimated at $19.4 million per year (ENGP 2010f).

[1] Operations figures are provided by ENGP (2010f) as number of jobs, instead of person-years.

Capital and operating expenditures, excluding wages and benefits and including purchases of goods and services, will generate economic benefits both inside and outside the North Coast region. ENGP (2010f) estimates the value of contracted goods and services expenditures within coastal British Columbia at $381.2 million (ENGP 2010f). Approximately 71% the total contracted goods and services will be supplied by regional businesses, resulting in a regional output of $270.7 million (ENGP 2010f). ENGP does not provide an estimate of operating expenditures in coastal British Columbia other than total wages and benefits.

2.2. Tanker spill impacts

Tanker spills create a broader range of economic costs per unit spilled than spills from pipelines or refineries and result in relatively more costly impacts. In general, hydrocarbon spills in open marine environments tend to produce relatively lower economic impacts than spills in sensitive coastal areas (Advanced Resources Int'l 1993). In addition to environmental effects, hydrocarbon spills can cause extensive socio-economic, psychological and cultural impacts, including effects on industries (e.g. commercial fisheries, port activities) and public health (Sumaila et al. 2012; Skinner & Reilly 1989).

The duration of spill effects is influenced by both ecological and market recovery times. Ecological recovery is determined by the type of hydrocarbon, duration of exposure, water temperature and seasonal conditions, type of ecosystem, degree of weathering, adequacy and efficacy of spill response, ontogenetic stage of the individual and species-specific life history traits (e.g. mobility, feeding and reproductive patterns) (Sumaila et al. 2012; Skinner & Reilly 1989; Impact Assessment Inc. 1990; Palinkas et al. 1993) and is measured by how quickly individuals and populations of species that occupy different ecological niches return to pre-spill conditions. Market recovery is based on the time for market conditions in affected industries to be fully restored and is influenced by the duration of marine area closures (e.g. commercial fisheries, recreational fisheries), public perceptions of seafood safety, the degree of seafood tainting (i.e., visual, taste or smell) (Moller et al. 1989) and perceived impacts to the aesthetic quality of the environment.

The 1989 *Exxon Valdez* oil spill (EVOS) in Prince William Sound, Alaska, released 10.9 million gallons (350,000 bbls) of crude oil, primarily during the first 6 hours of the spill, and directly affected 1,100 miles (1,770 km) of coastline (NOAA 1992). The diversity of shoreline characteristics and influence of tides profoundly affected clean-up of EVOS. Surface oil reached the coastline of Prince Williams Sound within hours or days, but didn't reach the shores of Kenai Fjords National Park for nearly two weeks, giving park managers an opportunity to protect areas of critical salmon spawning habitat by deploying booms at the mouths of rivers and lagoons (National Park Service 1999). Stranded oil on sheer rock faces or coarse-grained, rocky beaches presented serious challenges to spill responders (NOAA 1992). Migration of surface oil due to tidal activity had effectively ceased by mid-summer 1989, allowing clean-up crews to focus on existing oiled shoreline areas (NOAA 1992). Significant weathering of surface oil had occurred by 1990; however, subsurface oil remained in a liquid state (NOAA 1992). The National Oceanic and Atmospheric Administration (NOAA) monitoring studies to evaluate the effectiveness of clean-up efforts between September 1989 and February 1990 determined removal rates for surface oil on exposed shorelines (90%) and sheltered shorelines and those with intermittent energy (70%) (NOAA 1992). The sub-surface oil removal rate was approximately 55% (NOAA 1992; Wolfe et al. 1994) and varied with the depth of the sub-surface oil impacts.

While weathering and transport of spilled oil during the first 12 months following the spill occurred according to projections, Peterson et al. (2003) conclude that unexpected persistence of sub-surface oil in sediments and chronic exposures continued to affect wildlife through delayed population reductions, indirect effects and trophic interactions 14 years beyond the acute phase of the spill (Peterson et al. 2003).

The EVOS spill fouled coastal areas used for subsistence fishing, hunting and gathering by local communities (EVOSTC 1994). Damage to valued subsistence resources contributed to feelings of "cultural dislocation", psychological stress and disruption of social infrastructure related to on the part of some native communities (EVOSTC 1994). Subsistence resource harvesting by local communities was banned during 1989 (EVOSTC 1994) and did not return to pre-spill levels until 2003 (EVOSTC 2009).

An official list of resources and services impacted by EVOS within the affected area was compiled in November 1994 by the EVOS Trustee Council (EVOSTC) to assist in monitoring and evaluation of restoration efforts (EVOSTC 2010). EVOSTC publishes updates detailing the recovery and condition of impacted resources and services every three to four years; the most recent update was released in 2010. EVOSTC defines "recovery" of resources and services as the "return to conditions that would have existed had the spill not occurred" (EVOSTC 1994).

Several studies have examined the economic impacts of EVOS, including losses to the recreational fishing (Carson & Hanemann 1992; Mills 1992) and tourism (McDowell Group 1990) sectors. Cohen (1993) determined that total wages in the community of Valdez, Alaska, during 1989 increased by 300% over the previous year; however, economic benefits of the short-term boom were not evenly distributed (Cohen 1993). Impacts to passive use values were evaluated by Brown (1992), Carson et al. (1992) and Carson et al. (2003). Impacts of EVOS on labour market opportunities were studied by Hore & Carrington (2011).

Additional damages from EVOS included losses of wildlife (i.e., sea otters, seals, eagles, seabirds and shorebirds) and non-use values (i.e., option, bequest, existence and other values). Marine mammals and seabirds are at elevated risk from surface oil due to routine contact with oiled ocean surfaces resulting in loss of insulating capacity of feathers and fur, ingestion, smothering and drowning (Peterson et al. 2003). The spill killed an estimated 250,000 seabirds, 2,800 sea otters, 300 harbour seals, 250 bald eagles and up to 22 killer whales (National Park Service 2009). Brown (1992) estimated the cost of damages to wildlife at $53.9 million (1993 USD) and Carson et al. (2003) assessed Americans' perceived impacts to non-use values at $31 per capita, or $3 billion (1993 USD). Sea otter populations have recovered more slowly than expected, at an estimated rate of 4% per year (Bodkin et al. 1999).

Impact Assessment Inc. (1990) observed three broad social impacts of EVOS across communities in the affected area: i) fundamental disruptions in usual ways of being; ii) experiences of the loss of personal and community control over daily events; and iii) displacement of usual and expected actions, plans and resources for spill response and clean-up. Impact Assessment Inc. (1990) and Palinkas et al. (1993) documented several social and psychological impacts of EVOS on local communities including a 90% increase in each of general anxiety disorder, post-traumatic stress disorder and depression; increased substance abuse, domestic violence and social conflict; and lower measures of health status one year after the event. Short- and long-term impacts of EVOS to subsistence, or FSC, fishing have been documented in Fall et al. (2001), Gill & Picou (1997) and Endter-Wada (1992). None of these impacts are accounted for within the industry-focused scope of this study.

Exxon Mobil paid a total of $3.8 billion (1990 USD) in damages and clean-up costs (Miller & Spoolman 2008). This was equivalent to $3.26 billion CAD in 1990, and worth approximately $21.3 billion CAD in 2011. A 1994 court ruling awarded damages of $5 billion (1994 USD) to fishers, cannery workers and landowners for punitive damages; however, this amount was reduced to $510 million USD ($481 million CAD) by the U.S. Supreme Court in 2008 (Miller & Spoolman 2008).

2.2.1. EVOS impacts: Commercial fishing

Oiling of subsurface cobbles and gravels along spawning streams led to elevated mortality of pink salmon embryos through 1993, with recovery in 1994 (Murphy et al. 1990). Commercial fisheries for salmon, herring, crab, shrimp, rockfish and sablefish were closed in 1989 (EVOSTC 2009). Shrimp and salmon fisheries in portions of the affected area remained closed in 1990 (EVOSTC 2009). Populations of pink salmon (*Oncorhynchus gorbuscha*) recovered more quickly than sockeye salmon (*Oncorhynchus nerka*) over a matter of years, while herring populations crashed in 1993, the first year that individuals spawned in 1989 would have recruited (EVOSTC 1999, 2009; Haggarty et al. 2003). Herring, a commercially and ecologically valuable species, has still not fully recovered; the fishery has been closed for 13 of the past 19 years (EVOSTC 2009). However, the causes of herring population changes are poorly understood, and some studies suggest that the decline may have been caused by changes in ocean conditions rather than EVOS (Williams & Quin 2000; Pearson et al. 1999). Groundfish, crab and halibut landings in Alaska do not appear to have been significantly affected by EVOS (Impact Assessment 2011). Due to the disruptive nature of high-pressure hot water washing of sediments, EVOS clean-up crews avoided mussel beds in favour of natural weathering. High concentrations of hydrocarbons remained in mussel beds in affected areas six years after the initial impact (Carls et al. 2001). Local fishermen have speculated that EVOS led many fishermen to exit the industry but also increased efficiency across the remaining fleet (Impact Assessment 2011).

2.2.2. EVOS impacts: Port activities

The authors of this report are unaware of any reported impacts of EVOS on freight shipping. Had EVOS occurred near a major port-of-call, disruption or delays of port activities could have occurred while response crews were operating in the area and cruise ships could have been rerouted to avoid the area, resulting in decreased cruise-related tourism expenditures.

2.2.3. EVOS impacts: Ferry transportation

The authors of this report were also unable to find any reported impacts of EVOS on ferry transportation. Reductions in tourism would likely decrease revenue to ferry service providers; however, this effect would be offset, to some degree, by increased ferry traffic from spill clean-up crews.

2.2.4. EVOS impacts: Marine tourism

EVOS also affected all recreational activities within both the affected and surrounding areas (EVOSTC 1994). Impacts to tourism occurred due to spoiling of aesthetic quality and disruptive activities of clean-up crews (EVOSTC 1994). Closures, fear of contamination, unavailability of boats and congestion at sites outside the affected area resulted in a decline in recreational fishing in the affected area (EVOSTC 1994).

Recreational fishing

EVOS led to access restrictions in recreational fishing areas in the affected region (Oxford Economics 2009) and, during 1989, the number of non-resident recreational fishing days fell by 25% from the projected value for that year.[2] Tourism businesses in the affected area reported declines in business of up to 50% in 1992, compared to pre-spill conditions, with larger tour companies recovering more quickly than smaller ones (EVOSTC 1994).

The total number of angler days (resident and non-resident) rose in areas outside the affected region, by 10.8% in Southeast Alaska and 2.7% in the Western Alaska (Arctic-Yukon-Kuskokwim), and fell by 5.7% in the affected area of Southcentral Alaska (Carson & Hanemann 1992). In 1989, the number of non-resident angler days within the affected area increased by 15% and the number of non-resident anglers increased by 1% (Mills 1992). Changes in patterns of recreational use are attributed to increased activity in the affected area by non-resident clean-up crews, decreased activity by residents and tourists and displacement of resident fishing activity from affected regions to neighbouring areas (Carson & Hanemann 1992). Between 1989 and 1997, the number of sportsfishers increased by 65% in Prince William Sound, 25% in the Kodiak Region and 15% in the Kenai Peninsula region (EVOSTC 1999).

EVOS clean-up and restoration activities provided increased average wages and economic opportunities for some local businesses and commercial fishers who provided services to non-resident crews or participated in clean-up operations (Impact Assessment 1990; Hore & Carrington 2011). However, the influx of non-residents also imposed a socioeconomic burden on local communities through increased health care demands, higher crime rates, labour shortages and competition for labour and conflicts between local residents and "outsiders" (Impact Assessment 1990). A review of annual earnings by economic sector suggests that economic activity due to clean-up activities was limited to 1989, after which time annual earnings rejoined the pre-spill trend (Impact Assessment 2011).

[2] Expected Number of Days Fished was estimated using regression analysis. The reduction in fishing days was calculated based on the difference between the expected Number of Days Fished and the actual number of fishing days reported for 1989.

Other activities

EVOS reduced tourism in the affected area partly because services previously available to tourists were occupied by spill response crews (McDowell Group 1990). Labour shortages affected the service industry, including tour companies, lodges and resorts (McDowell Group 1990). Visitor centre inquiries fell by 55% during the following year (Oxford Economics 2009). The proportion of business generated by vacation and pleasure tourism fell by 17% in Southcentral Alaska and by 27% in Southwest Alaska (McDowell Group 1990). Tourism impacts of EVOS were reported to occur over a period of 25 months (Oxford Economics 2009). Visitor spending during the summer of 1989 fell by 8% in south-central Alaska and 35% in southwestern Alaska from 1986 levels (McDowell Group 1990). Fewer effects on visitor patterns are reported to have occurred during 1990 (McDowell Group 1990; Advanced Resources Int'l 1993); however, oil persisting on some areas of the coastline remained a concern for recreational users (EVOSTC 2009). Kayakers and campers reportedly continued to avoid some beaches in Prince William Sound through 1999 due to residual oil; oil was not reported to be of concern to recreational users in other affected coastal areas (EVOSTC 1999).

Habitat restoration efforts in Kenai Fjords National Park increased human activity on remote beaches and led to the discovery of several new archaeological sites, providing new information about human habitation but also exposing these sites to disturbance (National Park Service 2009). The number of visitors to Alaska, including the spill areas, nearly doubled between 1989 and 1997 (EVOSTC 1999). Tourism has increased despite residual impacts to populations of important natural features, such as killer whales and harbour seals (EVOSTC 1999).

2.2.5. Northern Gateway tanker spill modeling

The transport and fate of diluted bitumen in the marine environment is different than that of conventional oil, suggesting that rates of dispersion evaporation and the relative proportions of surface and subsurface hydrocarbons present in the water column following a spill along the proposed Northern Gateway tanker route may differ from those of EVOS. Additionally, weathering and transport will be affected by prevailing conditions (i.e., wind, current, tides, temperature) at the time of the spill and during the ensuing response and clean-up. Independent evaluations of the fate and biophysical impacts of spilled hydrocarbons have been conducted for multiple spill scenarios within the North Coast region. Experts have also suggested that, if the *Exxon Valdez* had been constructed using a double-hulled design similar to that proposed for tankers using the Northern Gateway shipping route, the amount of oil spilled would have been reduced by half (EVOSTC 2009). For these reasons, among others, the impacts of a hydrocarbon spill along the Northern Gateway tanker route are likely to differ from those of EVOS; however, the EVOS case study provides an important starting point to estimate potential impacts.

Stephenson et al. (2010), on behalf of Stantec Consulting, assessed the potential environmental impacts of three summertime spill scenarios in the CCAA: at the Kitimat terminal (250 cubic metres/2,130 bbls of diluted bitumen; 250 cubic metres of condensate) and in Wright Sound (36,000 cubic metres/307,000 bbls of diluted bitumen) (Stephenson et al. 2010). Calculations were based on properties of three of the four types of hydrocarbons proposed for transport: Syncrude synthetic light oil (SYN), CRW condensate (CRW) and MacKay River Heavy bitumen diluted with synthetic oil (MKH) (Stephenson et al. 2010).

Belore (2010a), for SL Ross Environmental Research Ltd., also investigated the properties and fate of three potential hydrocarbon spill sizes – 10,000 cubic metres (m^3) and 36,000 m^3 – during the winter, spring, summer and fall at four locations: Emilia Island, Principe Channel, the Kitimat (Marine) Terminal and Wright Sound. The study assumed spreading of hydrocarbons at a rate of 0.25 to 1.0 metres per second (Belore 2010a).

In addition to evaluating impacts within the CCAA, Belore (2010b) assessed the potential fate and biophysical impacts of a hypothetical spill of 10,000 m^3 (63,000 bbls) in October for two locations within the OWA: Butterworth Rocks and Ness Rock. The return periods of spills of 20,000 m^3 and 40,000 m^3 are reported to be 2,800 years and more than 15,000 years, respectively, assuming all proposed spill mitigation measures are in place (ENGP 2010b). Both scenarios assume an initial discharge of 1,900 m^3 (12,000 bbls) of hydrocarbons during the first hour of the incident, followed by 675 m^3 (4,245 bbls) per hour of discharge over the following 12 hours (Belore 2010b). Twelve hours after the spill, the maximum time estimated prior to arrival of spill responders, the densities of the three hydrocarbons are expected to be 0.892 g/mL (CRW), 0.909 g/mL (SYN) and 0.994 g/mL (MKH) (Belore 2010b). Only MKH is expected to emulsify following contact with the marine environment, becoming more dense and viscous (Belore 2010b). While not expected to sink, the MKH is predicted to remain below the surface of the water. Eighty percent of the total spilled volume is expected to remain on the surface of the water 120 hours after the incident has occurred; only CRW is expected to completely evaporate (Belore 2010b).

The work of Stephenson et al. (2010) and Belore (2010a, 2010b) was informed by hydrocarbon mass balance estimates developed using methodologies later published by Stronach (2011), for Hay & Company Consultants, to inform spill response at the Kitimat Terminal (250 m^3 bitumen; 250 m^3 condensate), Emilia Island (10,000 m^3 synthetic light oil), Principe Channel (10,000 m^3 diluted bitumen), Wright Sound (36,000 m^3 diluted bitumen), Ness Rock in Camaaño Sound (10,000 m^3 diluted bitumen) and Butterworth Rocks in North Hecate Straight (10,000 m^3 light synthetic oil) (Stronach 2011).

Third-party modeling of spill migration and fate has also been conducted by Triton Consultants Ltd. (2007) for the Living Oceans Society (Triton 2007). Model outputs have been converted into a set of interactive maps and web-based visualizations of hypothetical tanker spill scenarios occurring in January and July at Fin Island in Wright Sound (1,600 m^3/10,000 bbls), Ness Rock in Camaaño Sound (41,000 m^3/257,000 bbls) and Grenville Rock (41,000 m^3/257,000 bbls).[3]

All of the hydrocarbon spill models assume that no spill response is conducted; however, this situation is not expected to occur based on spill response plans submitted by ENPG (2011), which have been developed to manage a hydrocarbon spill of maximum size 36,000 m^3 (226,000 bbls).

3. Methods

3.1. Values of existing ocean-based industries

The values generated by commercial fishing, port activities, ferry transportation and marine tourism (i.e., recreational fishing, recreational boating, beach activities, whale and marine-based wildlife watching, kayaking, sailing tours, mothershipping tours) in the North Coast region are characterized using the indicators of total revenue (value of total output), employment (in person years, ‘PYs’) and contribution to GDP (value of total output less cost of intermediate inputs, ‘GDP’). Profit was not included as one of the indicators because of the lack of published, publicly-available data regarding operating costs for several of the industries. A time period of 50 years was modeled to represent a reasonable time horizon for project evaluation. The three indicators - total output, employment and contribution to GDP - are evaluated using methods previously employed by Cisernos-Montemayor and Sumaila (2010), Dyck and Sumaila (2010), Harper et al. (2010) and Sumaila et al. (2012). Total economic effects on these indicators are classified as ‘direct’, ‘indirect’ and ‘induced’.

For each of the economic indicators, we calculate the (i) direct; (ii) indirect; and (iii) induced effects of economic activities. Direct effects measure the economic activities of businesses operating within the industries studied. Indirect effects encompass the economic contribution of these industries in the form of total revenue from goods and services purchased from businesses in other related industries (BC MoE 2007). The commercial fishing industry, for example, supports firms involved in seafood processing, marketing, distribution and retail. Induced effects result from expenditure of income and wages earned through direct and indirect employment by ocean-based industries (BC MoE 2007).

[3] The web-based oil spill model is available on the Living Oceans Society website: http://www.livingoceans.org/initiatives/tankers/oil-spill-model

Due to significant changes in the regional economy over the past decade (e.g. growth of the tourism sector, expansion of port activities) average output from the most recent three to six years has been employed for each industry included in this study. The value of total output was calculated as the product of ex-vessel price and catch in the case of commercial fisheries and the product of average daily per capita expenditure, average duration of stay in the region, proportion of total tourism and average reported annual tourism participation for marine tourism.

The value of total output, employment and contribution to GDP for port activities are estimated from previous studies (InterVISTAS Consulting 2012). The value of total revenue was previously reported for ferry transportation (BC Ferries 2010; 2011). Employment and contribution to GDP in commercial fishing are estimated using the Provincial Input-Output multiplier for fishing, hunting and trapping published by Statistics Canada (2012c).

Indirect and induced values of commercial fishing and ferry transportation are estimated using Provincial and National Input-Output multipliers, respectively, published by Statistics Canada (2012c, 2012d). In the case of marine tourism, total economic effects on employment and GDP are estimated using multipliers derived from Tourism BC (2004).

A detailed description of analytical methods is included by industry in Appendix I. A list of sources used during the analysis is provided in Appendix II.

3.2. Value of the proposed Enbridge Northern Gateway project

Economic benefits resulting from the Enbridge Northern Gateway shipping route within the North Coast region, including direct output during both the construction and operations phases of the project and total economic effects on employment, are provided in ENGP (2010f) within an area defined as "Coastal British Columbia" (ENGP 2010f). This area encompasses those portions of the North Coast region which are located on the mainland and includes the Kitimat Terminal as well as nearly 200 km of the proposed Enbridge Northern Gateway pipeline.

Distribution of employment during the construction phase was estimated using a summary of the estimated peak quarterly construction workforce requirements and a summary of total employment, provided by ENGP (2010f). Annual employment figures for the operations phase are provided by ENGP (2010f) but are reported in terms of jobs rather than PYs; sensitivity analysis was conducted to estimate employment if all operations-related jobs were assumed to be i) part-time; or ii) full-time.

The authors of this study are unaware of any other detailed estimates of project-related output, employment or GDP at the time of publication. Thus, the analysis relies on projections provided by ENGP (2010f) to estimate the economic contribution of the proposed Enbridge Northern Gateway project.

While the project will employ workers from both within and outside the North Coast region, employment will generate positive total economic effects within the region because workers will reside within the region during the course of their employment and participate in the regional economy.

Annual output was calculated based on total construction expenditure for the Kitimat Terminal in the coastal region ($271 million CAD), plus the value of wages and benefits paid to employees during project operations, reported in ENGP (2010f). Construction expenditure was assumed to be distributed evenly across the five-year construction period. Indirect and induced output was calculated using input-output multipliers provided by Statistics Canada (2012) for British Columbia (direct and indirect effects) and Canada (direct, indirect and induced effects) for "48A: Other Transportation" with medium aggregation (Statistics Canada 2012c, 2012d).

Contribution of construction and operations in the North Coast region, including the Kitimat Terminal, pump stations and pipelines, to GDP was estimated using output and the direct value multipliers provided by Statistics Canada (2012a) for "230: Construction" and "48A: Other Transportation", respectively, for British Columbia. Indirect and induced economic impacts were estimated using input-output multipliers provided by Statistics Canada (2012a, 2012b) for British Columbia (direct and indirect effects) and Canada (direct, indirect and induced effects) with medium aggregation.

The present values of economic impacts attributed to the project were modeled for a 50-year time period, during which time the project is assumed to be active for only 30 years (2013-2043). The construction phase is expected to occur from 2013-2017 and the operations phase from 2018-2043.

3.3.Economic impact of a tanker spill

Three potential spill scenarios are considered: no hydrocarbon spill, a large hydrocarbon spill at Ness Rock in Camaaño Sound (10,000 m^3/63,000 bbls) and a major hydrocarbon spill at Grenville Rock (41,000 m^3/257,000 bbls). These scenarios were chosen to provide a projected baseline for economic activity as well as medium and high estimates of potential impacts to the regional economy from a tanker spill associated with the proposed Enbridge Northern Gateway project.

The "no impact" scenario presents a 50-year baseline for projected industry development in the absence of a tanker spill, against which to compare potential tanker spill impacts. Average annual growth rates were used to project future conditions for each economic indicator.[4]

The "medium impact" scenario is based on spill modeling results reported by Stronach (2011) for a 10,000 m^3 diluted bitumen spill during the winter. Movement of diluted bitumen was modeled for a 15-day period, during which time hydrocarbons are predicted to reach the western coastlines of Dewdney, Trutch, Pitt and Banks Islands. The spill was modeled to occur during the year 2020 as a possible spill scenario. Impacts to commercial fisheries were estimated based on DFO Management Area closures and reduced catch in Areas 5, 6, 105 and 106. Activities at the Port of Prince Rupert, including cruise ship tourism, were assumed to experience no disruption. Reduced annual tourism revenue, resulting from a decrease in the number of tourists, was estimated for BC Ferries Route 10 (Port Hardy-Prince Rupert). Recreational fisheries in the Kitimat area were assumed to be affected, as were other tourism activities within Gitga'at territory. The number of days fished recreationally by non-resident clean-up crews could increase near Kitimat in the event of a spill in a similar manner to that observed after EVOS; however, the number of tourists was assumed to decline.

The "high impact" scenario is based on spill modeling results reported by Triton Consultants (2007) for a 257,000-bbl crude oil spill during the winter. The spill was modeled to occur during the year 2020 as a possible spill scenario. Oil transport and fate was modeled for a 15-day period, during which time hydrocarbons are projected to cover 52 kilometers of coastline along northern Haida Gwaii, Stephens Island and Porcher Island. Because tankers along the Northern Gateway shipping route are expected to transport a mixture of conventional light and heavy oil, synthetic oil, bitumen blended with condensate and bitumen blended with synthetic oil (ENGP 2010a), mass balance modeling outcomes for a crude oil spill offer an imperfect approximation of spill behaviour for this scenario. Impacts to commercial fisheries were estimated based on closures and reduced catch in DFO Management Areas 1, 4, 101 and 104. Port of call stops by cruise ships were assumed to be impacted due to reduced quality of tourism activities; however, shipping activities at the Port of Prince Rupert were assumed not to be impacted. Reduced annual tourism revenue, resulting from a decrease in the number of tourists, was estimated for BC Ferries Routes 10, 11 and 26. Marine tourism activities in the areas of Prince Rupert and Haida Gwaii were assumed to be affected. A decline in marine tourism in Prince Rupert and on Haida Gwaii similar to EVOS was assumed.

[4] Regression analysis was also used to assess trends by industry for commercial fishing, ferry transportation and tourism and extrapolate future predictions about economic indicators; however, the number of data points (i.e., <10) for each regression was insufficient to provide reasonable results.

Impact modeling assumed an average annual growth rate of -0.05% for commercial fisheries and -2.47% for ferry transportation. Based on Visitor Centre statistics for 2009-2011 (Tourism BC 2012), marine tourism is assumed to be growing at an annual rate of 8.41% in Prince Rupert, -0.07% in Kitimat and -3.05% in Haida Gwaii.

As far as the authors of this study are aware as of the date of this publication, only two economic impact assessments have been conducted for the Prince Rupert Port Authority (InterVISTAS Consulting 2010, 2012). During the three-year period covered by these reports, the average annual rate of growth of output from port activities was calculated to be 32.5%. Such a high short term rate of growth in economic output is unlikely to continue over the long run, thus a more modest annual growth rate of 4% was assumed based on the average national rate of GDP growth from 2002-2011 (Industry Canada 2011).

Rates of economic growth, by industry, are applied to initial annual industry output value, employment and GDP estimates for the year 2011 using the following equation:

$$N_{i,t} = N_{i,o} (1 + r)^t$$

Where *i* represents the indicator (i.e., output, employment, or GDP) and t = 0...49. Annual values for direct, indirect and induced employment, output and GDP are calculated for the period 2013-2063.

Methods for analyzing spill impacts were based on those used by Sumaila et al. (2012). All scenarios employ ex ante forecasting of growth for each industry over a 50-year time period.

Potential impacts of a tanker spill were modeled numerically using market recovery times, by industry and species, where applicable, based on market recovery times listed in Table 1. Ecological recovery times, while independent from market recovery times and not reported in this study, are nonetheless relevant; for example, ecological recovery is one factor that affects how quickly markets for seafood goods recover after a hydrocarbon spill. Species-specific impacts to commercial harvests are estimated based on impacts experienced during EVOS (EVOS Trustee Council 2002, 2010; Impact Assessment, Inc. 2011; Cohen 1995), with the exception of mollusc and invertebrate impacts. Because several mollusc and invertebrate species harvested in the North Coast region are not commercially fished in Alaska (e.g. geoduck, sea urchin, sea cucumber, hard shell clams) and because several shellfish fisheries in the EVOS area were closed during 1989 due to issues unrelated to the spill (Cohen 1995), potential market impacts to these fisheries were estimated based on mollusc and invertebrate market recovery times reported in Sumaila et al. (2010). Tourism-related impacts to port activities, ferry transportation and marine tourism were modeled based on impacts to the number of tourists, and subsequently average tourism revenues, resulting from EVOS, reported in McDowell Group (1990), Mills (1992) and Oxford Economics (2009).

Table 1. Assumed industry growth rates, spill impacts and market recovery times.

Industry	Baseline annual growth rate	Segment	Market impact	Impact duration
Commercial fishing	-0.05% (catch)	All	Closure of all affected areas in Year 1	1-7 years[5,6]
		Diadromous	-60% in Year 2[7] (catch)	1-4 years[8]
		Pelagic	-50% in Year 4, closure in Year 5 (herring catch)[9]	No recovery, fishery closed
		Groundfish	No reported impact[10]	No reported impact
		Finfish	No reported impact	No reported impact
		Mollusc	-100% in Year 1 (catch)	1-6 years[11]
		Invertebrate	-50% in Year 2 (catch)	1-2 years[12]
Port activities	+4% (output)	Cruise ship tourism	-20% in Year 1 (tourism expenditure)	1-5 years[13]
Ferry transportation	-2.47% (operating revenue)	Tourism	-20% in Year 1 (tourism expenditure)	1-5 years[14]
Marine tourism	+8.41%, -0.07%, -3.05%* (# of tourists)	Recreational fishing	-25% decrease in Year 1 (# of fishing days)	1-2 years
		Other activities	-20% in Year 1 (tourism expenditure)	2-8 years[15]

* Average annual growth rates for Prince Rupert, Kitimat and Haida Gwaii, respectively.

[5] EVOS Trustee Council (2002).
[6] EVOS Trustee Council (2010).
[7] Impact Assessment Inc. (2011).
[8] EVOS Trustee Council (2010).
[9] EVOS Trustee Council (2010).
[10] Cohen (1995).
[11] Sumaila et al. (2011).
[12] Freese & O'Clair (1995).
[13] Oxford Economics (2009).
[14] Oxford Economics (2009).
[15] Oxford Economics (2009).

It should be noted that spill scenarios do not address hypothetical response and clean-up activities, which will occur at a cost and vary widely based on weather and spill conditions. The costs of spill response and clean-up activities were excluded from this study, resulting in a conservative estimate of the economic impact of a spill. Economic activity generated by spill response and clean-up activities was not estimated. An actual spill may also affect a smaller area than that projected by models, due to spill response activities and containment, or a larger area, due to transport across larger distances over a longer duration than the modeling period.

Real (i.e., inflation-adjusted) ex-vessel prices, BC Ferries fares and tourism expenditures are held constant and impacts are assumed to diminish following a linear impact gradient (e.g. over a four-year recovery period, impacts will diminish by 25% each year). Only existing industries are included in the analysis; potential impacts to proposed projects or projects currently under development in the North Coast region are excluded.

Commercial fisheries closures are assumed to represent the geographic extent of spill impacts and to impact only Canadian fisheries within the affected management areas; however, many marine species engage in daily and seasonal, small- and large-scale migrations (Sumaila et al. 2012). Individuals may be directly physically exposed to contaminants as well as indirectly impacted via degradation of spawning and nursery habitats and food chain interactions (Sumaila et al. 2012). Thus, the impacts of a spill are likely to extend beyond closed areas.

The present values of the economic indicators (*i*) for the five ocean-based industries (α) and the proposed Enbridge Northern Gateway project under each of the three spill scenarios were calculated over time (*t*), expressed as:

$$PV_i = \sum_{t=0}^{T} d^t X_{i,\alpha,t}$$

where $X_{i,\alpha,t}$ represents the value of the economic indicator *i* (i.e., output, GDP), $\forall i \neq$ employment, α denotes the industry, *t* = 0…49 and the parameter *d* is the discount factor determined using the appropriate rate of discount applicable to the region. The value of these indicators was calculated for a 50-year time period (i.e., 2013-2063) using a real discount rate of 3.0%, which is a rate considered reasonable for environmental projects (Heal 2000; Sumaila & Walters 2005). Economic impacts associated with the large and major tanker spill scenarios are calculated and reported as the difference between present values of total economic effects on indicators under the three spill scenarios.

4. Results

4.1. Values of ocean-based industries

The economic indicators for the five ocean-based industries (i.e., commercial fishing, port activities, ferry transportation and marine tourism) analyzed in this study and total (i.e., direct, indirect, induced) economic effects are reported in the following sections.

Table 2 reports the estimated current economic indicators for ocean-based industries within the North Coast region.

Table 2. Current annual economic indicators for ocean-based industries in the North Coast region.

Industry	Value of output (2011 CAD, millions)	Employment (PYs)	Contribution to GDP (2011 CAD, millions)
Commercial fishing	155 - 190	863 - 1,061	74 - 91
Port activities*	800	4,550	420
Non-tourism activities	*780*	*4,436*	*410*
Cruise ship tourism	*20*	*114*	*10*
Ferry transportation**	46	451	34
Non-tourism activities	*29*	*284*	*21*
Ferry tourism	*17*	*167*	*13*
Marine tourism	120 - 181	2,922 - 4,352	139 - 198
Recreational fishing	*52 - 89*	*1,128 - 1,920*	*56 - 95*
Other activities	*68 - 92*	*1,794 - 2,432*	*83 - 103*
TOTAL	1,121 - 1,218	8,983 - 10,216	667 - 743

* Figures were reported in (InterVISTAS Consulting 2012). A range of values was not provided.

** Estimates were generated based on operating revenue reported in (BC Ferries 2004-2011). A range of values was not provided.

These estimates indicate that ocean-based industries contribute a total of $1,121-$1,218 million CAD in output value, 8,983-10,216 PYs of employment and $667-$743 million in GDP each year to the regional economy. Based on a proportion of working age individuals of 69% and a regional unemployment rate of 9.3% (BC Government 2011a), ocean-based industries are estimated to directly employ 10%-11% of the regional population. When indirect and induced values are also considered, ocean-based industries provide employment for an equivalent of 25%-28% of the regional population. The comparatively high regional unemployment rate, in contrast to the provincial rate of 6.6% (BC Government 2011b), suggests that ocean-based industries are critical to the regional economy and wellbeing of communities.

As demonstrated in the following sections, these estimates are consistent with the results of previous analyses of ocean-based industries in the region.

4.1.1. Commercial fishing

Results from Gislason & Associates (2004) indicate employment in the North Coast region of 1,025 person-years (PYs) generated by fishing, 220 PYs by recreational fishing and 480 PYs by seafood processing. Gardner Pinfold Consulting (2010) estimates that commercial fisheries provide 115 direct jobs on Haida Gwaii and 250 indirect jobs in seafood processing, but do not estimate person-years of employment. Monitoring, research and enforcement associated with fisheries and the marine environment by organizations, including DFO and the Haida Fisheries program, provides 58 jobs on Haida Gwaii alone. Previous estimates from GSGislason & Associates (2002) suggest that commercial fisheries in the North Coast region provided 1,000 PYs of employment, of which 105 PYs occurred on Haida Gwaii.

Gardner Pinfold Consulting (2009) estimates the total direct value of commercial landings within PNCIMA at $218-$232 million (CAD) per year for 2002-2006 and the total number of jobs at 1,260, with an additional 185 jobs in fish processing.

The present analysis suggests comparatively lower employment in the commercial fishing sector than previous estimates, and offers a very conservative estimate of total employment based on average annual catch. This likely reflects limitations associated with the use of commercial catch data by area for the North Coast region due to reporting restrictions (i.e., three-party rule) and limited access to DFO catch data.

Indirect and induced values reflect the relatively greater contribution of commercial fishing to the regional economy per unit output in contrast to other industries due to output, employment and GDP generated in the seafood processing, transport, distribution, marketing and sales sectors.

4.1.2. Port activities

Port activities support indirect employment related to forklift operation and loading, storage (warehousing), freight forwarding, trucking, construction, security (marine, rail, road, customs), maintenance and repairs, logistics, banking, cleaning, management and administration (InterVISTAS Consulting 2006). Many of the existing marine tourism operators based in Prince Rupert supplement revenues by providing marine transport services to vessels associated with the port.

InterVISTAS Consulting (2012) reports the combined economic impacts of shipping and cruise ship traffic at the Port of Prince Rupert. A study by Scarfe (2011) suggests negative net economic impacts of cruise ship traffic on the City of Victoria, a port-of-call for cruise ships on Vancouver Island, British Columbia. The study reports that cruise ship tourism has a net negative impact on Victoria of approximately $4 million per year due to social and environmental costs associated with marine effluents, atmospheric emissions, traffic congestion, traffic noise and infrastructure related costs. As of the date of publication, the authors of this study are unaware of any assessment of these impacts in Prince Rupert. Additionally, this study focuses on the impacts of industry and does not attempt to evaluate environmental costs. A relevant finding for this study is that home port cities, such as Seattle, reap greater benefits from tourism than port-of-call cities, such as Prince Rupert (Scarfe 2011).

4.1.3. Ferry transportation

Gardner Pinfold (2009) estimates that BC Ferries provides 250 jobs within PNCIMA.

Output from ferry transportation suggests a modest contribution to the regional economy. Due to low ridership and passenger revenues during non-summer months, these three routes return negative average annual net revenues and rely on large provincial and federal government subsidies to provide essential services to regional communities. Government subsidies act to redistribute revenue from other regions of the province and country to activities within areas serviced by ferry transportation.

4.1.4. Marine tourism

Recreational fishing

Gislason & Associates (2004) reported 245 PYs of employment at fishing lodges on Haida Gwaii shared between 520 individuals at 18 lodges, representing a portion of the indirect impacts of recreational fishing by non-residents of the region. Due to ownership and management of fishing lodges by non-residents of the region, only 50 PYs of employment were held by 115 local individuals. Gardner Pinfold Consulting (2010) reported 625 jobs in recreational fisheries on Haida Gwaii. Gardner Pinfold Consulting (2009) estimates direct expenditures on saltwater fishing at $137-$180 million (CAD) per year during 2002-2006.

Comparison of the current findings with previous estimates suggests that this study provides a conservative estimate of total employment. Visitor centre traffic statistics are based on the number of visitors who speak to a representative at each Tourism BC Visitor Centre and offer a very conservative estimate of annual tourism; actual participation in tourist activities is likely much higher.

Other activities

Employment related to recreational boating was previously estimated by The Economic Planning Group (2003) at 100 PYs on Haida Gwaii and 120 PYs elsewhere in the North Coast region. Gardner Pinfold Consulting (2010) reported 182 jobs related to marine tourism on Haida Gwaii and Misty Isles Economic Development Society (2011) reported 480 jobs in the marine tourism rector, including sport fishing and guiding. Gardner Pinfold Consulting (2009) estimates direct expenditures on coastal tourism at $50 million (CAD) during 2006.

Results of the current analysis appear consistent with jobs and employment estimated for other marine tourism activities within the region.

4.2. Value of the proposed ENGP project

ENGP (2010f) reports that the project will generate $318 million in construction-related expenditure between 2013 and 2017, 71% of which will occur in coastal British Columbia. The project is also expected to generate 2,235 PYs of direct employment, 585 PYs of indirect employment and 245 PYs of induced employment during the four-year construction phase (ENGP 2010f).

During project operations, ENGP (2010f) reports that annual output will decrease to $3.6 million CAD and annual employment will decrease to 104 jobs (direct), 60 jobs (indirect) and 40 jobs (induced).

Table 3 reports the expected annual economic impacts of the proposed Enbridge Northern Gateway project within the North Coast region during the construction and the operations phases. Estimates of output and GDP have been adjusted for inflation to 2011 CAD.

Table 3. Total economic effects of the proposed Enbridge Northern Gateway project (annual).

Project phase	Value of output (2011 CAD, millions)	Employment (PYs)	Contribution to GDP (2011 CAD, millions)
Construction*			
Direct	*46*	*447*	*18*
Direct and Indirect	*69*	*593*	*30*
Total	*103*	*655*	*49*
Operations*			
Direct	*4*	*52 - 104*	*1*
Direct and Indirect	*6*	*82 - 164*	*2*
Total	*8*	*102 - 204*	*4*

*Estimated based on figures reported in (ENGP 2010f). A range of values was not provided. Sensitivity analysis was used to determine a range of values for employment based on all jobs being i) part-time; or ii) full-time.

Based on the combined current values of ocean-based industries presented in Table 2 and the economic values of construction and operations presented in Table 3, during the construction and operations phases, the proposed Enbridge Northern Gateway project could contribute 9% (construction) and 0.07% (operations) of total output; 6% (construction) and 1.1%-2.2% (operations) of total employment; and 8.1% (construction) and 0.5% (operations) to total GDP annually to ocean-based industries in the North Coast region.

Table 4 reports the present values of the economic effects of the proposed Enbridge Northern Gateway project over a 50-year period.

Table 4. Present value of economic effects of the proposed Enbridge Northern Gateway project (50 years).

Type of Impact	Value of output (2011 CAD, millions)	Employment (PYs)	Contribution to GDP (2011 CAD, millions)
Direct	*281*	*3,587 - 4,939*	*107*
Direct and Indirect	*420*	*4,422 - 7,230*	*180*
Total	*627*	*4,521 - 8,577*	*293*

*Estimated based on figures reported in (ENGP 2010f). A range of values was not provided.

Assuming that the project is decommissioned after 30 years, the Enbridge Northern Gateway project could generate total economic effects of $627 million CAD in output, 4,521-8,577 PYs of employment and $293 million in GDP over a 50-year period.

4.3. Economic impact of a tanker spill

4.3.1. Low impact

The no impact scenario provides a baseline for evaluation of the economic contribution of the project and identification of long-lasting economic impacts of a tanker spill beyond the project lifespan. Under this scenario, the North Coast economy will gain all of the projected benefits in terms of output, employment and GDP of the existing ocean-based industries plus those associated with the proposed Enbridge Northern Gateway project.

4.3.2. Medium impact

A spill of this size and at this location would impact portions of DFO Management Areas 5, 6, 105 and 106, leading to reduced catch by commercial fisheries within these areas. Commercial fisheries closures would reduce revenues to local fishermen for the duration of market and result in negative ecosystem impacts. Due to its direct reliance on the health and quality of marine resources, the commercial fisheries sector is expected to experience the most severe losses of all industries in the event of a tanker spill.

A spill is assumed not to significantly impact operations at the Kitimat Terminal or along the Enbridge Northern Gateway shipping route within the North Coast region in this scenario due to the distance (>100 km) of the spill location from the Kitimat Terminal and the potential to re-route tankers away from the affected area.

Tourism impacts are expected to be limited to the affected area, which includes Gitga'at territory. No impacts on the cruise ship sector in Prince Rupert are expected; however, reduced tourist traffic on BC Ferries Route 10 is expected to translate into lost revenues.

Table 5 reports the projected present value of losses to ocean-based industries in the North Coast region in the event of a large (10,000 m^3) hydrocarbon spill at Ness Rock in Camaaño Sound over a 50-year period.

Table 5. Present value of losses to ocean-based industries in the North Coast region (50 years).

Type of Impact	Value of output (2011 CAD, million)	Employment (PYs)	Contribution to GDP (2011 CAD, million)
Commercial fishing			
Direct	*78 - 326*	*19 - 69*	*8 - 42*
Direct and Indirect	*136 - 568*	*30 - 153*	*14 - 71*
Total	*247 - 1,032*	*35 - 177*	*17 - 87*
Port activities			
Direct	*11 - 31*	*1 - 2*	*0.3 - 1*
Direct and Indirect	*15 - 41*	*1 - 3*	*1**
Total	*21 - 59*	*2 - 5*	*1 - 3*
Marine tourism			
Direct	*2 - 3*	*39 - 67*	*1.3 - 1.5**
Direct and Indirect	*3 - 6*	*79 - 137*	*3 - 4*
Total	*5 - 6*	*131 - 223*	*5 - 8*
TOTAL			
Direct	*21 - 74*	*128 - 423*	*10 - 45*
Direct and Indirect	*35 - 162*	*231 - 746*	*17 - 76*
Total	*41 - 189*	*399 - 1,314*	*23 - 98*

The present value of total losses to output resulting from a tanker spill in this scenario is in the range of $41-$189 million CAD, compared to an expected increase in output of approximately $627 million associated with the project. While 399-1,314 PYs of employment could be lost due to a spill, the project could generate approximately 4,521-8,577 PYs of employment within the region. The present value of lost GDP is expected to be in the range of $23-$98 million, compared to an increase of $293 million in GDP resulting from the Enbridge Northern Gateway project. The upper estimate of economic losses is due in part to long-lasting impacts to the herring fishery, which is assumed to have a minimum market recovery time of one year and an infinitely long maximum market recovery time (i.e., the resource never recovers). While economic benefits of the proposed Enbridge Northern Gateway project are assumed to be limited to the 30-year project lifespan, long-lasting economic impacts, such as those to the herring fishery, could continue to accumulate far into the future.

4.3.3. High impact

A tanker spill of this size at this location would impact portions of DFO Management Areas 1, 4, 101 and 104. Under this scenario, the Port of Prince Rupert is expected to receive fewer cruise ship tourists, resulting in lower tourism revenues. Fewer tourists on all of BC Ferries' regional routes (i.e., 10, 11 and 26), as well as to recreational fisheries and marine tourism destinations within the affected area between Prince Rupert and northern Haida Gwaii, are also assumed to reduce revenue in these industries, in accordance with the durations of market impacts reported in Table 1.

Table 6 reports the projected present value of losses due to a 41,000 m^3 hydrocarbon spill from a tanker at Grenville Rock over a 50-year period.

Table 6. Present value of losses to ocean-based industries in the North Coast region (50 years).

Type of Impact	Value of output (2011 CAD, million)	Employment (PYs)	Contribution to GDP (2011 CAD, million)
Commercial fishing			
Direct	*20 - 96*	*85 - 463*	*9 - 43*
Direct and Indirect	*33 - 155*	*148 - 807*	*15 - 71*
Total	*38 - 179*	*268 - 1,465*	*19 - 88*
Port activities			
Direct	*2 - 33*	*10 - 182*	*1 - 17*
Direct and Indirect	*2 - 41*	*16 - 288*	*1 - 22*
Total	*3 - 48*	*21 - 374*	*2 - 25*
Ferry transportation			
Direct	*1 - 2*	*14 - 42*	*0.4 - 1*
Direct and Indirect	*2 - 4*	*19 - 56*	*1 - 2*
Total	*2 - 6*	*27 - 80*	*2 - 5*
Marine tourism			
Direct	*21 - 38*	*389 - 751*	*10 - 18*
Direct and Indirect	*33 - 59*	*802 - 1,521*	*26 - 46*
Total	*43 - 75*	*1,063 - 2,463*	*50 - 88*
TOTAL			
Direct	*45 - 170*	*498 - 1,436*	*21 - 79*
Direct and Indirect	*70 - 259*	*986 - 2,670*	*43 - 141*
Total	*87 - 308*	*1,652 - 4,379*	*72 - 205*

* Low and high estimates converge when rounded.

The present value of losses to commercial fisheries resulting from fisheries closures and impacts to commercial species under this scenario is greater than those experienced under the medium impact scenario. The location of the high impact spill is expected to result in losses to cruise ship tourism revenues. The recreational fishing sector is expected to experience slightly smaller losses than under the medium impact scenario; however, due to the presence of a more developed and diverse marine tourism industry in the affected geographical area of the high impact spill, losses to this industry are expected to be greater than under the medium impact scenario.

The present value of losses to output is in the range of $87-$308 million CAD, a figure more than double that of comparable losses under the medium spill scenario, yet still smaller than the regional economic output of approximately $627 million associated with the proposed Enbridge Northern Gateway project. A spill of this size, at this location, is expected to cause employment losses of 1,652-4,379 PYs, compared to approximately 4,521-8,577 PYs of employment within the region attributed to the proposed Enbridge Northern Gateway project. GDP losses could amount to $72-$205 million, compared to gains of $293 million resulting from the Enbridge Northern Gateway project.

5. Discussion

Ocean-based industries are estimated to directly employ about 10% of the population in the North Coast region. When indirect and induced values are also considered, ocean-based industries provide employment for an equivalent of nearly 30% of the regional population. The comparatively high regional unemployment rate of 9.3% (BC Government 2011a), in contrast to the provincial rate of 6.6% (BC Government 2011b), suggests that ocean-based industries are critical to the regional economy and well-being of communities.

The proposed Northern Gateway project is estimated, using data provided by ENGP (2010f), to generate total (i.e., direct, indirect, induced) economic effects of $627 million in output, 4,521-8,577 PYs of employment and $293 million in GDP, in present terms, over a 50-year period.

In the event of a medium impact tanker spill of 10,000 m^3 of hydrocarbons, the regional economy could suffer total losses of $41-$189 million in output, 399-1,314 PYs of employment and $23-$98 million in GDP over 50 years. This means that when the upper ends of the ranges of estimates are considered, under this scenario, 30%, 15% and 33% of the projected output value, employment and contribution to GDP from the proposed Enbridge Northern Gateway project could be lost to the spill.

If a high impact spill of 41,000 m^3 of hydrocarbons occurs, the North Coast region could experience total losses of $87-$308 million in output value, 1,652-4,379 PYs of employment and $72-$205 million in GDP. Here, the percentages of the projected benefits from the Enbridge Northern Gateway project that could be lost to the spill are 49%, 51% and 70%, respectively.

The above projected percentage losses are high given the narrowness of the scope of the current valuation exercise and the conservative nature of our assumptions and estimates. For instance, if the cost of spill response, clean-up activities and litigation processes for damage compensation, as well as the value of spilled hydrocarbons, are accounted for, all of the projected economic gains from the Enbridge project will simply turn into losses. These costs will vary with spill conditions, volume and location, among other factors, but would impose considerable expenses on the project proponent; local, provincial and federal governments; industry groups; local businesses; and local communities. Wright Mansell Research (2012) estimates clean-up costs of $15,000/bbl (2010 CAD) plus punitive damages of $22,500/bbl in the event of a tanker spill along the Enbridge Northern Gateway shipping route. When these estimates are applied to the spill scenarios presented in this analysis, total damages amount to $2.4 billion CAD for a medium impact spill and $9.6 billion CAD for a high impact spill. To put these costs in perspective, Exxon Mobil paid a total of $3.8 billion USD in damages and clean-up costs for EVOS (Miller & Spoolman 2008), worth approximately $3.26 billion CAD in 1990 and $21.3 billion CAD in 2011.

Several factors have influenced the accuracy and completeness of the results provided in this study. The values presented in the study provide a very conservative estimate of total output, employment and contribution to GDP resulting from ocean-based activities within the North Coast region. In particular, where tourism estimates are applied, actual annual expenditure is likely much higher than reported. The actual value of commercial fishing activities is also believed to be higher than reported due to limited availability of commercial catch data.

The contribution of FSC fishing by First Nations communities cannot be accurately evaluated due to the unavailability of reliable catch data and existing deficiencies in current valuation approaches for non-market values related to social, educational and cultural values and well-being. First Nations Councillors and Fisheries Managers have expressed a very high perceived value associated with FSC fishing and consider FSC fishing opportunities to be irreplaceable to their communities.

As noted in Sumaila et al. (2012), the input-output analysis method employed in this study has been subject to criticism, including that of Christ (1955), Grady & Muller (1988) and de Mesnard (2002). Pitfalls of this approach include the inability to include the effects of changing prices on impacts, the isolation of impacts and failure to address interactions at the aggregate level and the reliance on the stability of technical coefficients over time and across industries. By assuming constant prices, this study has not examined the potential impacts of a tanker spill on ex-vessel prices to be received by commercial fishermen or the value of tourism expenditures. Decreases in prices resulting from diminished product quality (i.e., seafood, tourism experience) could lead to further impacts to present value of the regional economy in the event of a tanker spill.

While this study provides a highly conservative first estimate of the potential economic impacts of a tanker spill in the North Coast region of British Columbia, several potential impacts to valued ecosystem services were not assessed. These include social, cultural and ecological values to residents and non-residents of the region. Additional investigation of these values, including those related to FSC fishing, would provide a more complete estimate of the total economic value related to the ocean in the North Coast region and support informed decision-making for industrial developments, such as the Enbridge Northern Gateway project.

Potential impacts on emerging ocean-based industries, including the shellfish aquaculture industry currently being developed by the Haida Nation and Metlakatla Band, have also not been assessed. Shellfish are known to be particularly sensitive to hydrocarbon contamination through bioaccumulation (EVOSTC 1999), resulting in considerable lost economic opportunity in the event of a hydrocarbon spill. With four fledgling aquaculture projects expected to become operational over the next 10 years in the North Coast region, a spill could have devastating effects on project investors, of which the majority are local First Nations.

Analysis of the present future values of existing ocean-based industries was conducted using historical growth rates and does not address potential future growth in existing ocean-based industries, such as commercial fishing and tourism. For example, organizations such as the Coastal First Nations, T. Buck Suzuki Foundation, North Coast Skeena First Nations Stewardship Society and Ecotrust Canada are working toward more profitable and sustainable management of commercial fisheries in North Coast region, which could increase catch and revenues to commercial fishermen and processors.

This study focuses on market values generated by five ocean-based industries and, therefore, only addresses a small portion of the total economic impacts of the proposed project and the potential impact of a tanker spill. There remains a need to address information gaps in methodologies for assessing and quantifying social, cultural and ecological values and integrating these values into assessment of present economic values.

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Appendix I: Analytical methods

1. Commercial fishing

Each of the indicators (i.e., total output "*x*", employment "*y*", GDP "*z*") is assumed to be related to total commercial catch (*C*) as follows:

$$x = C \bullet p$$

$$y = x \bullet M_{1,2,3}$$

$$z = x \bullet M_{4,5,6}$$

where *p* is the ex-vessel price per tonne and $M_{1,2,3}$ and $M_{4,5,6}$ represent the economic impact multipliers for direct, indirect and induced employment ($M_{1,2,3}$) and GDP ($M_{4,5,6}$) related to fisheries (Statistics Canada 2012c; 2012d). It should be noted that provincial multipliers are used for direct impacts and National multipliers are used for indirect and induced impacts.

Several data-related limitations resulted in the need to derive a range of catch values, reported as "low" and "high". Catch data for species with coast-wide licenses, including shellfish, sablefish and groundfish trawl, are only publicly available from DFO for the whole of the British Columbia coast. While catch data for some other species, such as salmon, are reported by DFO by area for near shore Areas 1-6, data are not provided for offshore Areas 101-106 and 142. Commercial catch data by area are available by formal request under the Freedom of Information and Protection of Privacy Act, but the data may not be available for several months. Catch from fisheries operated by fewer than three vessels cannot be disclosed by DFO as per the "three-party rule" (Laurie Biagini, personal communication, April 5, 2012).

"Low" catch data were compiled for the years 2008-2011 from commercial catch data provided in reports from the International Pacific Halibut Commission (Greenaert et al. 2011) and by DFO Management Area (Areas 1, 2, 101, 102 and 142) previously requested under the provincial *Freedom of Information and Protection of Privary Act*. Average catch per unit area, by species and per square kilometer, was calculated for near shore (i.e., Areas 1-6) and open water (Areas 101-106, Area 142) areas. The size of each DFO Management Area within the North Coast region was calculated and average values were used to extrapolate average catch for areas where data was unavailable but fisheries are permitted and known to occur. Actual and extrapolated catch data were used to calculate three-year average catch values by species for each DFO Management Area within the region.

“High” annual catch estimates by fishery were developed using catch per DFO Management Area or per vessel reported in Nelson (2011a), commercial catch data provided in DFO fishery management plans (DFO 2010a, 2010b, 2006, 2011a, 2011b, 2011c, 2011d, 2011e, 2011f) and post-season fishery reviews (DFO 2011g, 2011h, 2011i, 2012c, 2012d, 2012e, 2012f), reports from the International Pacific Halibut Commission (Greenaert et al. 2011) and groundfish catch data reported in GSGislason & Associates (2011). Three-year average catch values were applied where data was available; otherwise, data from the most recent year was applied.

Ex-vessel prices were calculated based on total landings and landed values reported for 2008-2010 by the British Columbia Ministry of Environment (BC MoE 2011). Clam prices for 2005-2010 were reported by DFO (2010a). Ex-vessel prices, adjusted to 2011 CAD using the Consumer Price Index (CPI) for British Columbia (Statistics Canada 2012b), were applied to low and high catch estimates to calculate values.

Employment figures, as well as indirect and induced economic impacts of the commercial fishing sector, were estimated using input-output multipliers provided by Statistics Canada (2012c, 2012d) for British Columbia (direct; direct and indirect effects) and Canada (direct, indirect and induced effects) with medium aggregation.

2. Port activities

Direct, indirect and induced output, employment and GDP attributed to shipping and cruise ship traffic were reported by InterVISTAS Consulting (2012). The study employed a survey-based approach including twenty on-site and off-site businesses that comprise the majority of direct port-related employment. The authors used Statistics Canada economic multipliers for British Columbia from the 2008 Interprovincial Input-Output model, updated with Consumer Price Indices to account for inflation, to estimate indirect and direct economic effects of port activities. The scope of the study by InterVISTAS Consulting (2012) included shipping and cruise ship operations and supporting businesses, as well as induced expenditures by employees of these businesses.

The contribution of cruise ship tourism to the total value of port activities was also assessed independently of the total value of port activities. Direct, indirect and induced employment and output were provided in InterVISTAS Consulting (2012). The total contribution of cruise ship tourism to GDP was calculated based on multipliers applied to cruise ship tourism in InterVISTAS Consulting (2009).

3. Ferry transportation

BC Ferries publishes Annual Reports to the British Columbia Ferry Commissioner, which are available on the British Columbia Ferry Commission website. Total operating revenues for each of the three North Coast routes for 2009-2011 (BC Ferries 2010, 2011) were used to calculate three-year average output for BC Ferries. Employment and GDP were estimated using output and the direct value multipliers provided by Statistics Canada (2012a) for British Columbia. Indirect and induced economic impacts of the ferry transportation were estimated using input-output multipliers provided by Statistics Canada (2012a, 2012b) for Transit and Ground Passenger Transportation in British Columbia (direct and indirect effects) and Canada (direct, indirect and induced effects) with medium aggregation.

The contribution of tourism to the total value of ferry transportation was also assessed independently of the total value of port activities. First, monthly BC Ferries passenger and vehicle revenues were calculated as the product of the number of passengers or vehicles and the appropriate fare using Traffic and Fare information provided by BC Ferries (2012a, 2012b). A typical passenger profile of 70% adults, 15% children and 15% seniors was assumed. In order to obtain a conservative estimate of vehicle revenues, all vehicles were assumed to be "Underheight Vehicles", which belong to the lowest vehicle fare class. Tourism revenue during 2011 was estimated for each of Routes 10, 11 and 26 as the difference between average revenue during the tourism season (May to September) and the off-season (October to April). Direct employment and GDP as well as indirect and induced economic impacts of ferry tourism were estimated using input-output multipliers provided by Statistics Canada (2012a, 2012b) for Transit and Ground Passenger Transportation in British Columbia (direct and indirect effects) and Canada (direct, indirect and induced effects) with medium aggregation.

4. Marine tourism

Because tourism affects multiple sectors (e.g., transportation, retail, hospitality), goods (e.g., souvenirs, clothing, electronics) and service providers (e.g., airlines, tour companies), total output is most easily and accurately estimated using average daily per capita tourism expenditure. This approach eliminates the need to evaluate the relative contributions of tourists versus local residents to each business or sector individually.

4.1. Recreational fishing

Each of the indicators (i.e., total output "x", employment "y", GDP "z") is assumed to be related to average daily client expenditure (E) as follows:

$$x = E \bullet (n \bullet r) \bullet d$$

$$y = x \bullet M_{7,8,9}$$

$$z = x \bullet M_{10,11,12}$$

where n is the total average number of tourists per year, r is the participation rate in recreational fishing and d is the average length of stay. $M_{7,8,9}$ and $M_{10,11,12}$ represent economic impact multipliers for economic effects on employment ($M_{7,8,9}$) and GDP ($M_{10,11,12}$) derived using a ratio of client spending to employment and GDP, respectively, for the tourism sector based on data reported in (Tourism BC 2004), adjusted to 2011 CAD. Where the number of anglers per year is known, this figure replaces the product of n and r in the equation for total output.

Low ($133.42) and high ($353.30) daily per capita expenditures for non-resident anglers on Haida Gwaii were obtained from Tourism BC (2003). Non-resident anglers were assumed to visit Haida Gwaii for an average of ten days and comprise 23.8% of all tourism participants (Tourism BC 2003).

Low ($254.04) and high ($340.84) daily per capita expenditures for non-resident anglers in Prince Rupert, including accommodations, were obtained from Counterpoint Consulting (2008) while average ($261.40) daily per capita expenditure was obtained from Tourism BC (2008). An average of 5.8 tourism days per angler, including 3.1 fishing days, and a total of 15,003 anglers per year was assumed (Tourism BC 2008).

Based on similarities between participation rates in non-resident recreational fishing for Haida Gwaii (8.1%) and Prince Rupert (7.9%), to be conservative, an average participation rate of 7.9% was assumed for Kitimat. The total average number of tourists per year was estimated based on three-year average traffic statistics for the Kitimat and Sandspit and Queen Charlotte (Haida Gwaii) visitor centres for 2008-2011 (Tourism BC 2012). Average daily per capita expenditure was assumed to be similar to Prince Rupert ($261.40).

Total output attributed to non-resident recreational fishing was calculated using the average number of anglers per year (Prince Rupert) and by multiplying the total average number of tourists per year by participation rates for recreational fishing (Haida Gwaii and Kitimat) and multiplying this figure by the average length of stay in the region and low, average and high daily per capita expenditures. Per capita expenditures for Haida Gwaii, Prince Rupert and Kitimat were adjusted to 2011 CAD.

Employment, in person-years (PYs) was estimated based on a ratio of client spending to employment calculated for the tourism sector using data reported in Tourism BC (2004) and adjusted to 2011 CAD. Indirect and induced economic impacts were estimated using multipliers for output, employment and GDP generated based on the results from Tourism BC (2004).

4.2. Other activities

Indicators for other activities are estimated using the methods outlined above for the recreational fishing sector, which is accounted for independently due to availability of specific regional data.

Low ($133.42) and high ($353.30) per capita daily expenditures for tourism on Haida Gwaii were obtained from Tourism BC (2003). Length of stay on Haida Gwaii was assumed to be an average of ten days (Tourism BC 2003). All expenditures are inclusive of tax, thereby reflecting combined private and public revenues. The number of visitors to Haida Gwaii was estimated based on three-year average traffic statistics from the Queen Charlotte visitor centre for 2009-2011 (Tourism BC 2012) and the proportions of visitors participating in beach activities, kayaking and boating were obtained from Tourism BC (2003). Visitor centre traffic statistics represent a very conservative estimate of annual tourism because they are based on the number of visitors who speak to a representative at each Tourism BC Visitor Centre; actual participation in tourism activities is likely much higher.

Total participation in “overnight leisure” tourism, participation rates of overnight leisure travellers in wildlife viewing, kayaking and canoeing and recreational boating and average ($201) daily per capita expenditure for overnight leisure travellers to Prince Rupert was obtained from Tourism BC (2008).

Average annual person-days of recreational boating, average expenditure per person per sailing tour operator and average annual revenues for sailing tours within Gitga’at Territory were provided in Gregory et al. (2011).

All low, average and high daily per capita expenditures were adjusted to 2011 CAD. Total output from other marine tourism activities for Haida Gwaii, Prince Rupert and Gitga'at Territory was calculated as the product of total visitors, the participation rate for each ocean-based activity, the average daily per capita expenditures and the average length of stay in the region.

Employment, in person-years (PYs), was estimated for each of the activities included in the analysis based on a ratio of tourism expenditure to employment calculated based on findings reported in Tourism BC (2004) and adjusted to 2011 CAD. Contribution to GDP was calculated using a multiplier developed based on total client spending and total GDP reported in Tourism BC (2004).

Indirect and induced economic impacts were estimated using multipliers for output, employment and GDP generated based on the results from Tourism BC (2004).

Appendix II: Data sources

Source types are: (1) peer-reviewed publication; (2) government agency report; (3) government agency website; (4) Independent consultant report; (5) NGO report; (6) newspaper; (7) commercial or public website.

Industry	Source	Source type (1-7)
Commercial fishing	BC Ministry of Environment, 2011. British Columbia Seafood Industry - 2010 Year in Review. Retrieved on June 13, 2012 from http://www.env.gov.bc.ca/omfd/reports/YIR-2010.pdf.	2
	DFO, 2006. Pacific Region Integrated Fisheries Management Plan – Euphausiids. January 01, 2007 to December 31, 2012. Retrieved on July 5, 2012 from http://www.dfo-mpo.gc.ca/Library/329395.pdf.	2
	DFO, 2010a. Pacific Region Integrated Fisheries Management Plan – Intertidal Clams. January 1, 2010 to December 31, 2012. Retrieved on July 5, 2012 from http://www.dfo-mpo.gc.ca/Library/338991.pdf.	2
	DFO, 2010b. Pacific Region Integrated Fisheries Management Plan – Crab by Trap. January 1, 2011 to December 31, 2011. Retrieved on July 5, 2012 from http://www.dfo-mpo.gc.ca/Library/342457.pdf.	2
	DFO, 2011a. Pacific Region Integrated Fisheries Management Plan – Geoduck and Horse Clam. January 1 to December 31, 2012. Retrieved on July 5, 2012 from http://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/2012/geoduck-panope-2012-eng.pdf.	2
	DFO, 2011b. Pacific Region Integrated Fisheries Management Plan – Prawn and Shrimp by Trap. May 1, 2011 to April 30, 2012. Retrieved on July 5, 2012 from http://www.dfo-mpo.gc.ca/Library/343253.pdf.	2
	DFO, 2011c. Pacific Region Integrated Fisheries Management Plan – Sea Cucumber by Dive. October 1, 2011 to September 30, 2012. Retrieved on July 5, 2012 from http://www.dfo-mpo.gc.ca/Library/344264.pdf.	2
	DFO, 2011d. Pacific Region Integrated Fisheries Management Plan – Red Sea Urchin. August 1, 2011 to July 31, 2012. Retrieved on July 5, 2012 from http://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/red_urchin_2011-12.pdf.	2
	DFO, 2011e. Pacific Region Integrated Fisheries Management Plan – Shrimp by Trawl. April 1, 2011 to March 31, 2012. Retrieved on July 5, 2012 from http://www.dfo-mpo.gc.ca/Library/343050.pdf.	2

Commercial fishing (cont'd)	DFO, 2011f. Pacific Region Integrated Fisheries Management Plan – Pacific Herring. November 7, 2011 to November 6, 2012. Retrieved on July 5, 2012 from http://www.dfo-mpo.gc.ca/Library/344588.pdf.	2
	DFO, 2011g. 2011 Post Season Review. Salmon. North Coast Areas 1-6 & Central Coast Areas 7-10. Retrieved on July 5, 2012 from http://www.pac.dfo-mpo.gc.ca/northcoast/post-seasonreview/docs/2011/2011-Salmon_Post_Season_Review.pdf.	2
	DFO, 2011h. Final Hook and Line Summary Report, 2009-2010. Retrieved on July 5, 2012 from http://www.pac.dfo-mpo.gc.ca/fm-gp/commercial/ground-fond/docs/2010-2011_Hook_Line_Catch_Summary_Report.pdf.	2
	DFO, 2011i. 2011 Post Season Review. Salmon. North Coast Areas 1-6 & Central Coast Areas 7-10. Retrieved on July 5, 2012 from http://www.pac.dfo-mpo.gc.ca/northcoast/post-seasonreview/docs/2011/2011Salmon_Post_Season_Review.pdf.	2
	DFO, 2012a. Current Valid British Columbia Shellfish Aquaculture License Holders. Retrieved on July 25, 2012 from http://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/shell-conch-processors-transformateurs-eng.pdf.	2
	DFO, 2012b. Yakoun River, Marie Lake Hatchery Project. Retrieved on July 25, 2012 from http://www.pac.dfo-mpo.gc.ca/sep-pmvs/projects-projets/cedp-pdec/Yakoun-eng.htm.	2
	DFO, 2012c. Salmon Catch Statistics & Logbook Reports. Commercial Salmon Catch Statistics by Year (Provided by Fisheries Management). Retrieved on July 5, 2012 from http://www.pac.dfo-mpo.gc.ca/fm-gp/species-especes/salmon-saumon/fisheries-peches/stats-donnees-eng.htm.	2
	DFO, 2012d. Preliminary Summary Commercial Statistics. Retrieved on July 5, 2012 from http://www.pac.dfo-mpo.gc.ca/stats/comm/summ-somm/index-eng.htm.	2
	DFO, 2012e. FSC catch data, Areas 1-6. Requested under the Freedom of Information and Privacy Act. Information Request #6626, submitted by Sean Broadbent. Response received from Laurie Biagini, Manager, Regional Data Services Unit, DFO on August 23, 2011.	2
	DFO, 2012f. Final Hook and Line Summary Report, 2010-2011. Retrieved on July 5, 2012 from http://www.pac.dfo-mpo.gc.ca/fm-gp/commercial/ground-fond/docs/2010-2011_Hook_Line_Catch_Summary_Report.pdf.	2

Commercial fishing (cont'd)	DFO, 2012g. Commercial catch data, Areas 1, 2, 101, 102 and 142. Requested under the Freedom of Information and Privacy Act. Information Request #6627, submitted by Sean Broadbent. Response received from John Davidson, Regional Data Services, DFO on April 18, 2012.	2
	Geernaert, T., Clark, B., Gilroy, H., 2011. Commercial halibut catch and effort for IPHC statistical areas on the B.C. coast (Regulatory Area 2B). International Pacific Halibut Commission. Retrieved on August 10, 2012 from http://www.iphc.int/documents/commercial/bc/2B_WPUE_1980-2010.pdf.	2
	GSGislason & Associates, 2011. Economic Impacts from a Reduced BC Groundfish Trawl Fishery in British Columbia. BC Ministry of Environment. Retrieved on August 23, 2012 from http://www.env.gov.bc.ca/omfd/reports/groundfish-trawl-fishery-economic-impacts.pdf.	2
	Nelson, S., 2011a. Pacific Commercial Fishing Fleet: Financial Profiles for 2009. Prepared for Fisheries and Oceans Canada, Pacific Region. Pacific Commercial Fishing Fleets Financial Profiles Series, 2011-4. 160 pp. Retrieved on August 7, 2012 from http://www.dfo-mpo.gc.ca/Library/343762.pdf.	2
	Nelson, S., 2011b. West Coast Fishing Fleet: Analysis of Commercial Fishing Licence, Quota, and Vessel Values. Prepared for DFO, Pacific Region. Retrieved on August 7, 2012 from http://www.pac.dfo-mpo.gc.ca/fm-gp/picfi-ipcip/docs/2011-value-valeur.pdf.	2
Port activities	InterVISTAS Consulting, 2010. Port of Prince Rupert Economic Impact Study, Version 2. Prepared for the Prince Rupert Port Authority. Retrieved on September 6, 2012 from http://www.rupertport.com/media/Port_of_Prince_Rupert_Economic_Impact_Study.pdf.	4
	InterVISTAS Consulting, 2012. Port of Prince Rupert Economic Impact Study Update - Final Report. Prepared for the Prince Rupert Port Authority. Retrieved on September 6, 2012 from http://www.rupertport.com/documents/economic-impact-study-2012/pdf(http://www.rupertport.com/media/Port_of_Prince_Rupert_Economic_Impact_Study.pdf.	4

Ferry transportation	BC Ferries, 2004. 2003/04 Annual Report to the British Columbia Ferry Commissioner. 79 pp. Retrieved on June 13, 2012 from http://www.bcferrycommission.com/wp-content/uploads/2011/annual_reports/BCFSReport_to_Commiss0304.pdf.	2
	BC Ferries, 2005. 2004/05 Annual Report to the British Columbia Ferry Commissioner. 71 pp. Retrieved on June 13, 2012 from http://www.bcferrycommission.com/wp-content/uploads/2011/annual_reports/BCFSReport_to_Commiss0405.pdf.	2
	BC Ferries, 2006. 2005/06 Annual Report to the British Columbia Ferry Commissioner. 76 pp. Retrieved on June 13, 2012 from http://www.bcferrycommission.com/wp-content/uploads/2011/annual_reports/BCFSReport_to_Commiss0506.pdf.	2
	BC Ferries, 2007. 2006/07 Annual Report to the British Columbia Ferry Commissioner. 75 pp. Retrieved on June 13, 2012 from http://www.bcferrycommission.com/wp-content/uploads/2011/annual_reports/BCFSReport_to_Commiss0607_copy.pdf.	2
	BC Ferries, 2008. 2007/08 Annual Report to the British Columbia Ferry Commissioner. 79 pp. Retrieved on June 13, 2012 from http://www.bcferrycommission.com/wp-content/uploads/2011/annual_reports/BCFSReport_to_Commiss0708_copy.pdf.	2
	BC Ferries, 2009. 2008/09 Annual Report to the British Columbia Ferry Commissioner. 74 pp. Retrieved on June 13, 2012 from http://www.bcferrycommission.com/wp-content/uploads/2011/annual_reports/BCFSReport_to_Commiss0809.pdf.	2
	BC Ferries, 2010. 2009/10 Annual Report to the British Columbia Ferry Commissioner. 78 pp. Retrieved on June 13, 2012 from http://www.bcferrycommission.com/wp-content/uploads/2011/05/asp/BCFSReport_to_Commiss0910.pdf.	2
	BC Ferries, 2011. 2010/11 Annual Report to the British Columbia Ferry Commissioner. 92 pp. Retrieved on June 13, 2012 from http://www.bcferrycommission.com/wp-content/uploads/2011/04/BCFS-FY2011-Annual-Report-to-BCFC.pdf.	2
	BC Ferries, 2012a. Traffic Statistics. Retrieved on August 7, 2012 from http://www.bcferries.com/about/traffic.html.	2
	BC Ferries, 2012b. Fares Archive. Retrieved on August 7, 2012 from http://www.bcferries.com/travel_planning/fares/archive.html.	2

Marine tourism	Counterpoint Consulting, 2008. Skeena Economic Dimensions 2008. Retrieved on July 5, 2012 from http://www.psf.ca/edswsf.pdf.	4
	The Economic Planning Group, 2003. Economic Impact Analysis of Outdoor Recreation on British Columbia's Central Coast, North Coast and Queen Charlotte Islands/Haida Gwaii. Outdoor Recreation Council of British Columbia. Retrieved on August 25, 2012 from http://torc.linkbc.ca/torc/downs1/CoastRecReport.pdf.	4
	Tourism BC, 2003. Value of the Queen Charlotte Visitor Centre Study Results. Retrieved on August 24, 2012 from http://www.jti.gov.bc.ca/research/ResearchByRegion/pdf/northern_bc/2002_-_Queen_Charlotte_City.sflb.pdf.	2
	Tourism BC, 2004. Economic Value of the Commercial Nature-Based Tourism Industry in British Columbia. Retrieved on August 24, 2012 from http://www.jti.gov.bc.ca/research/ResearchbyActivity/pdfs/land_based/Economic_Impacts_of_Commercial_Nature-Based_Tourism_Report.sflb.pdf.	2
	Tourism BC, 2008. 2007 Prince Rupert Visitor Study Findings. Retrieved on August 24, 2012 from http://www.jti.gov.bc.ca/research/ResearchByRegion/pdf/northern_bc/Final_Report_for_the_2007_Prince_Rupert_Visitor_Study.sflb.pdf.	2
	Tourism BC, 2012. Visitor Centre Network Statistics Program Year Over Year Report 2012. Retrieved on August 24, 2012 from https://www.networkstats.tourismbc.com/reportdefinition.aspx.	2
Enbridge Northern Gateway project	Enbridge Northern Gateway Pipelines, 2010d. Volume 2: Economics, Commercial, and Financing. Enbridge Northern Gateway Project. Sec. 52 Application. Retrieved on June 13, 2012 from https://www.neb-one.gc.ca/ll-eng/livelink.exe/fetch/2000/90464/90552/384192/620327/624798/619886/B1-4_-_Vol_2_%96_Gateway_Application_%96_Economics,_Commercial_and_Financing_(Part_1_of_1)_-_A1S9X7_.pdf?nodeid=619772&vernum=0.	4
	Enbridge Northern Gateway Pipelines, 2010f. Update to Sec. 52 Application Volume 6C: Environmental and Socio-economic Assessment (ESA) – Human Environment Section 4.4: Regional Social and Economic Effects (New Material). Retrieved on September 25, 2012 from http://www.northerngateway.ca/assets/pdf/application/Vol_6C_Sec_4_4Update.pdf.	2

Tanker spills	Cohen, M.J., 1993. The economic impact of an environmental accident: a time series analysis of the *Exxon Valdez* oil spill in southcentral Alaska. Sociol. Spectr. 13(1): 35-63.	1
	Exxon Valdez Oil Spill Trustee Council, 1999. *Exxon Valdez* Oil Spill Restoration Plan. Update on Injured Resources and Services. Retrieved on September 14, 2012 from http://www.arlis.org/docs/vol1/41089450.pdf.	2
	Exxon Valdez Oil Spill Trustee Council, 2002. *Exxon Valdez* Oil Spill Restoration Plan. Retrieved on September 14, 2012 from http://www.arlis.org/docs/vol1/50770994.pdf.	2
	Exxon Valdez Oil Spill Trustee Council, 2010. *Exxon Valdez* Oil Spill Restoration Plan. 2010 Update – Injured Resources and Services. Retrieved on September 14, 2012 from http://www.arlis.org/docs/vol1/C/768779147.pdf.	2
	Freese, J.L., O'Clair, C.E., 1995. *Exxon Valdez* Oil Spill: State/Federal Natural Resources Damage Assessment Final Report. Injury to Crabs Outside Prince William Sound. Fish/Shellfish Study Number 22. Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration. Retrieved on September 24, 2012 from http://www.evostc.state.ak.us/Files.cfm?doc=/Store/FinalReports/1992-FS22-Final.pdf.	2
	Impact Assessment, Inc., 1990. Economic, social and psychological impact assessment of the *Exxon Valdez* oil spill. Final report prepared for Oiled Mayors Subcommittee, Alaska Conference of Mayors. Author, La Jolla, CA.	4
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	Oxford Economics, 2009. Potential Impact of the Gulf Oil Spill on Tourism. Prepared for the U.S. Travel Association. Retrieved on September 7, 2012 from http://www.ustravel.org/sites/default/files/page/2009/11/Gulf_Oil_Spill_Analysis_Oxford_Economics_710.pdf.	4
	Stronach, J., 2011. Technical Data Report – Hydrocarbon Mass Balance Estimates: Inputs for Spill Response Planning. Enbridge Northern Gateway Project. Hay and Company Consultants. Retrieved on August 23, 2012 from http://www.ceaa.gc.ca/050/documents_staticpost/cearref_21799/2561/hydrocarbon.pdf. (Appendix C: Specific Trajectory Examples retrieved from http://www.ceaa.gc.ca/050/documents_staticpost/cearref_21799/2561/appc.pdf.)	4
	Triton Consultants Ltd., 2007. Oil Spill Model Development, Northwest Canadian Pacific Coast, Technical Background. Prepared for Living Oceans Society. Retrieved on September 10, 2012 from http://www.livingoceans.org/sites/default/files/tankers/TritonOilspillReport2007Aug14mrtV2.pdf.	4
	Watson, T., 2010. Marine Fisheries Technical Data Report. Triton Environmental Consultants Ltd. and Jacques Whitford Axys. Retrieved on September 10, 2012 from http://www.ceaa.gc.ca/050/documents_staticpost/cearref_21799/2424/marine_fisheries.pdf.	4