WHAT'S AT STAKE?

The Cost of Oil on British Columbia's Priceless Coast

RAINCOAST CONSERVATION FOUNDATION

www.raincoast.org

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About Raincoast Conservation Foundation:

Raincoast is a team of conservationists and scientists empowered by our research to protect the lands, waters and wildlife of coastal British Columbia. We use peer-reviewed science and grassroots activism to further our conservation objectives.

Our vision for coastal British Columbia is to protect the habitats and resources of umbrella species. We believe this approach will help ensure the survival of all species and ecological processes that exist at different scales.

Our mandate: Investigate. Inform. Inspire.

We Investigate to understand coastal species and processes.
We Inform by bringing science to decision makers and communities.
We Inspire action to protect wildlife and their wilderness habitats.

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Preface

Sockeye salmon in the Richmond Cannery, 1913. Until very recently, the ocean was viewed as an unlimited pool of resources, the exploitation of which measured the success of an enterprising economy. PHOTO: ROYAL BC MUSEUM ARCHIVES E-05033

A humpback whale feeds on BC's central coast. The return of some large whales to inside coastal waters gives us hope that actions to protect marine species and habitats can be successful. PHOTO: C.T. DARIMONT

The BC coast is a fragile labyrinth of geography and diversity. Woven between inlets, straits, channels and sounds, its beauty and abundance have captivated and sustained people for millennia, unfailingly offering spiritual and physical sustenance. The ocean, islands, and adjoining lands have formed the basis of survival for countless cultures, plants, and animals. Yet, over the last 200 years, Canada's Pacific coast has been modified by an economy that ignored the tapestry of ecology, or worse, viewed the environment as an obstacle to overcome.

For many, the exploitation of coastal ecosystems measured the success of an enterprising economy. Accordingly, our historic and contemporary activities have gradually altered the diversity, abundance, and resilience of the species, communities, and ecosystems that constitute and define our coast. The consequences of this transformation seemingly grow irreversible and unsolvable, underscoring the fragile nature of our environment.

Yet, in recent years awareness has grown of the fundamental conflict between unbridled commerce and healthy ecosystems.[1] Protecting and restoring habitats has become a matter of principle, unmistakably distinguished from matters of price. Many people now understand that, although the Pacific Coast is a shadow of what it once was, it remains full of potential.

We know that at least 27 species of marine mammals have been observed along the Pacific coast. Fourteen of them are found regularly, and for them our coastal waters serve a multitude of purposes – for breeding, foraging, resting, overwintering, or simply as a migratory corridor. Some species, such as killer whales and Pacific white-sided dolphins, range widely, but others, such as sea otters, are much more closely tied to specific areas of the coast.

"Hecate Strait is the most important body of water for seabirds on the Canadian Pacific Coast." Gary Kaiser, former population biologist for the Canadian Wildlife Service[2]

The silver wave. As one of the great, historically abundant and heavily exploited fishes of the North Pacific Ocean, Pacific herring still underpin much of the coastal foodweb. Each spring, their presence signals the end of winter for coastal birds and mammals who join this wave of migrating fish. Below, sooty shearwaters and humpback whales compete for herring along their route. PHOTOS: (ABOVE) G. MAZILLE, (BELOW) J. TOWER.

Marine birds rely on healthy oceans as well. Over 120 species of marine birds have been identified in BC's coastal waters, and while all return to land to nest, they spend much of their lives at sea. From flocks of tiny phalaropes spinning on the water's surface to the majestic soaring of giant albatross, they hold much fascination both for those who spend much time at sea, and those who observe it from shore.

Essential to the ocean's recovery, however, is reformed ocean and fisheries management. Conservation and restoration efforts have noticeably improved the status of some marine species. The results thus far have been limited but encouraging – especially for marine mammals such as sea otters, sea lions, and some whale species. The growing presence of these marine mammals offers no guarantee of the occurrence of other species, but inspires confidence and hope that recovery is possible.

Raincoast's goals are to restore, sustain, and enhance the coastal environment by defending against impending threats, while building on the conservation gains of recent years.

Although BC is shouldering a substantial ecological debt, Raincoast believes that we now have the promising opportunity to focus on prosperity without destructive growth, helping to ensure the future of our children without compromising the land and ocean that ultimately will sustain them.

To best ensure healthy coastal environments, ocean management must integrate ecosystem complexities with socio-economics and conservation principles. Accordingly, Raincoast continues efforts to conserve and protect marine birds, mammals, and fish in Canada's Pacific waters. Our research aims to improve our understanding of their biology, habitat and food requirements, and potential threats from human activities. Raincoast science is applied to management plans, policies and public education, which we hope will ensure the long-term survival of all species, including humans.

1. Why Survey for Marine Animals?

The lack of published information on the abundance and distribution of many whales, dolphins, porpoises, and sea birds spurred Raincoast to undertake five years of surveys. This information is critical to making informed decisions about the risks and costs of oil development on the BC coast. PHOTO: O. ANDREWS

Surveys continue through the evening on an unusually calm Hecate Strait. PHOTO: S. HEINRICH

The growing emphasis on BC's coast as an energy corridor has spurred substantial concerns from coastal communities and the public about the impacts and risks associated with large-scale oil operations and spills. Properly assessing these impacts requires a species inventory and knowledge of where each fits in the grand web of ocean processes and biological production. Generally, we lack this fundamental understanding of the functions and processes that underpin natural systems. But we need to start somewhere. At the most basic level, managing and protecting species requires two essential pieces of information: how many animals there are (abundance) and where they can be found (distribution).

Although information on animal distribution and abundance is integral to wildlife conservation and management, surprisingly few data have been collected on marine animal distribution and abundance in the waters of Canada's Pacific coast. Killer whales in this region are particularly well studied, but there is comparatively little information on other cetaceans (dolphins, porpoises and whales) many of which were heavily depleted by commercial exploitation.

Limited information often reflects the expense of collecting data, and generally, gathering data from marine environments is far more expensive than from land. Further, the value in collecting data for purposes of understanding populations lies in doing repeated surveys, which translates into additional costs.

Having information on distribution and abundance provides insight into why animals occur in certain places. These habitat preferences represent an important part of a "species niche" – in other words, where an organism fits in relation to other species in the food web. A shorthand definition of niche is how an organism makes a living. For example, humpback

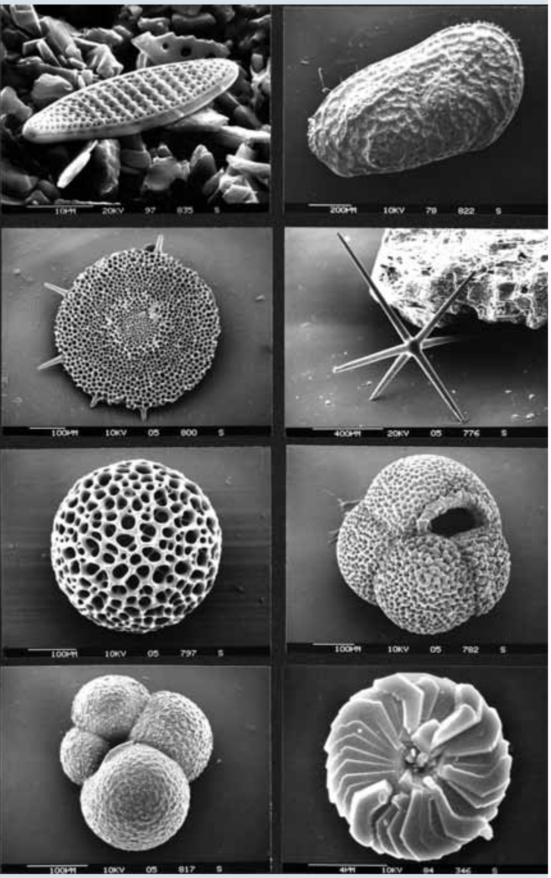
Killer whales surface. PHOTO: G. MAZILLE

whales, which are filter feeders, occupy a different niche than killer whales, which have teeth and eat salmon. Although a species' distribution may change in the short-term as local conditions change or food resources move, its niche is likely to remain unchanged.[3] Hence, an understanding of a species niche can be used to predict how it might react to changes in its local environment over time. Raincoast's goal is to build species models that help us understand the factors that determine marine mammal abundance and distribution.

Figure 1. Raincoast's Marine Survey Study Area. In 2004, we surveyed from the Strait of Juan de Fuca (BC-Washington border) to Dixon Entrance (BC-Alaska border). In 2005-2008, we focused our efforts in the Queen Charlotte Basin, surveying from Johnstone Strait to Dixon Entrance. Track lines and inlets were systematically assigned, yet randomly generated each year.[5]

In 2003, decisions to explore, develop, and move oil through BC's coastal waters were gaining momentum.[4] Yet, systematically collected information about the distribution and abundance of the marine animals and birds that would be put in jeopardy if these developments were approved was not available. Realizing that a properly informed debate over the future of BC's coast needed such information, Raincoast committed to going out and collecting these crucial data.

In 2004 we began five years of gruelling systematic line transect surveys, covering 14,000 kilometres (8,700 miles) of ocean track line, logging over 2,000 sightings of marine mammals and close to 15,000 sightings of marine birds. We weathered hurricane force winds along the proposed tanker routes, 18-hour days were common place, low budgets were a given, and high seas repairs part of the job. But we fell asleep to singing humpbacks, woke to the blows of killer whales in the dense fog, travelled the days with leaping dolphins, and watched the sun set on thousands of sooty shearwaters. Our experiences have instilled in us a deep understanding of the risks associated with oil tankers traversing our rocky waters and an unwavering commitment to protect this precious coast.



Major groups of phytoplankton (diatom, ostracod, radiolaria, sponge spicule, radiolaria, foraminifera (2), coccolith).
PHOTO: HANNES GROBE/CREATIVE COMMONS

A global context for marine research and conservation

Awareness is growing of the fundamental conflict that exists between our economic growth model and the ecological services, processes and features that underpin our economy. This conflict exists because as the economy grows (typically measured by GDP), natural capital is re-allocated from a physical habitat to the human economy.[6] Increasingly, the cost of this approach is seen in rising numbers of endangered species, loss of biodiversity, pollinator decline, climate change, limits to waste absorption, fisheries collapse, declining farmland and forest cover, and declining water and air quality.[7]

Globally, few places are immune from the ever-growing imprint of the human enterprise. Significantly, the human population worldwide and within Canada is concentrated near coasts – about 60% within 100 kilometres (62 miles). Moreover, a recent analysis suggests that although humans use about 8% of the primary production of the oceans, that fraction grows to more than 25% for upwelling areas and to 35% for temperate continental shelf systems.[8]

Although the north and central coasts of British Columbia sustained First Nation cultures for thousands of years, these regions still appear rugged and wild, seemingly untouched by the march of "progress." We are truly fortunate to have such a visibly pristine coastline. Yet, superficial appearances aside, it is not unmarked by the ravages of industry, and now lurking at its door is the unsustainable growth economy that has visibly consumed so much of the globe's coastlines and resources.

Shifting baselines

Canada's Pacific coastal waters have been changing for the last two centuries. Because none of us grew up knowing the abundance of whales, salmon, and herring before commercial exploitation, we are inclined to infer their current status relative to changes we have witnessed in our own lifetimes. This is also true for politicians and resource managers who think and work on very short timelines. The concept of *shifting baselines*[9], first described by marine scientist Dr. Daniel Pauly, refers to the incremental lowering of standards in which each new generation assesses environmental decline only in the context of their own lifetimes. More broadly, this idea explains our inability to recognize ailing ecosystems, as our only reference is what preceding generations left behind.

Cumulative impacts. The southern resident killer whale population numbers less than 100 whales. They are exposed to a wide range of stressors (reduced food supply, toxins that bioaccumulate, increased disturbance and underwater noise) that cumulatively may affect the ability of the population to grow.
PHOTO: G. ELLIS

Cumulative effects: The "tyranny of small decisions"[10]

Small, seemingly independent decisions or actions can accumulate into large, undesirable consequences over the long term.[11] In coastal waters, the incremental and combined effects of human activities are compiling. For example, the extraction of marine species, destruction of the seabed, persistent addition of airborne and aquatic pollution, introduced species and diseases, and increased inputs of carbon dioxide to the atmosphere and ocean have all created multiple lines of threats to marine ecosystems. Acting synergistically, their effect is to compromise ecological processes such as primary production and species interactions, which results in an altered coastal environment.

The importance of primary productivity

Through the processes of photosynthesis, primary production is the creation of energy from CO_2 in the air and the ocean. In the ocean, the primary producers are mostly phytoplankton, on land, they are vascular plants. All life on earth relies on them, both for food and CO_2 conversion. By far, most of the ocean's productivity occurs along the coasts. Our actions – from removing living creatures and altering the shoreline, to inputs of toxins and increasing CO_2 can affect the rate of primary production.

2. A Changing Ocean

A changing ocean: food supply. One of the ocean's primary roles is the regulation of the Earth's climate. As changes in temperatures influence wind and ocean circulation, this affects other ocean processes like the availability of nutrients to phytoplankton, or zooplankton availability to young fish and seabirds. The poor survival of some seabirds (particularly auklets, shown here) in Queen Charlotte Sound has been linked to the lack of food availability associated with warmer currents during El Nino years. The same may be true for juvenile salmon. PHOTO: KQED QUEST

The extraction of marine life

Many of the fisheries that capture marine productivity have focused on top predators such as salmon and tuna. Yet as catches decline, the focus of global fisheries is slowly shifting away from long-lived, high trophic level fish to shorter-lived, lower level fish. This "fishing down the food web" is sending signals that many of today's fisheries will in time collapse.[12] As of 2009, 63% of recognized marine fisheries were overexploited or already depleted, and showed a 32% decline in total biomass.[13]

BC's aquatic front yard has seen equally staggering statistics, as massive quantities of marine life have been extracted from BC's coastal waters since the 19th century. Hundreds of thousands of tonnes of whales, salmon, and herring have been removed from coastal waters just in the last 100 years, all of which have since experienced various forms of population declines. Similarly, the commercial exploitation of sea otters resulted in their disappearance during the 1800s. This dramatically altered the presence of the coast's kelp forests and their role as nursery and feeding grounds for fish.[14]

This serial removal of living organisms has likely had a profound effect on today's ocean. Evidence from past records in other areas suggests that major structural and functional changes have occurred in coastal food webs from such extraction.[15] These changes also appear to be altering the ocean's ability to recover from such perturbations.[16] Further, the loss of locally adapted populations and of genetic material within populations reduces the resilience of species and ecosystems.

Removing the ocean's components

Massive quantities of marine life were removed from BC's coastal waters over the 20th century.

- Between 10 and 50 thousand tonnes of baleen and sperm whales were processed annually from coastal and broader offshore waters until whaling ended in the 1960s and 1970s.[17]
- Roughly 100,000 tonnes of salmon and herring were extracted annually.[18]
- More than 295 tonnes of corals and sponges were reported as bycatch between 1996 and 2002.[19]

Exploitation on such a large scale decreases the potential for future fisheries and appears to be altering the way the ocean works and recovers.

Bycatch of non-target fish. In 1994, commercial marine fisheries around the world discarded 25 million tonnes of bycatch (non-target fish, invertebrates and other animals) annually, a quantity nearly one third as large as total landings of fish.[20] Since then, global attention and lower harvests have reduced bycatch levels (but direct comparisons are not possible). Trawl fisheries (i.e. draggers) for shrimp and ground fish account for more than 50% of global bycatch.[21]
PHOTO: NOAA

Changing the sea floor

Dragged along the sea floor, huge nets used in trawl fisheries can cause substantial damage to feeding and predator refuge areas for fish and invertebrates. Evidence suggests the loss of these structures and the churning of sediments and nutrients from the trawl is a contributing factor in decreasing oxygen levels[22] and the growing presence of harmful algae blooms.[23] This destructive practice is also creating serious bycatch issues and causing declines in species abundance.

Harmful algae blooms

Harmful algal blooms (HABs) are sudden increases in species of marine phytoplankton that produce harmful structures or chemicals. Although the existence of these blooms has long been recognized, they have spread widely in the past three decades.[24] Their increased frequency, extent, and duration in coastal areas suggest that human activity has affected the base, as well as the top, of marine food chains. Algal blooms are usually correlated with changes in temperature, nutrients,

Mud trails of draggers and trawlers visible from space
Close-up of landsat (satellite) image showing mud trails from bottom trawling off the Louisiana coast. One sediment trail can be traced for 27 km. Assuming a standard trawling speed of 2.5 knots, sediment from this trawl is visibly persistent for nearly 6 hours.[25] In 2006, the US banned bottom trawling in much of its Pacific coast waters. Canada has protected some of its important sponge reefs, but the destructive practice continues. PHOTO: NOAA

Pteropod (*Limacina helicina*)
The pteropods or sea butterflies, are an important group of zooplankton that are fed upon by many organisms including salmon. Unfortunately, pteropods may be one of the first marine organisms affected by ocean acidification as their shells are highly susceptible to increased acidity. PHOTO: NOAA

or salinity. Nutrients in coastal waters are often influenced by pollution inputs and changes in water flows.[26] Other factors such as introduced exotic algal species from ballast water and decline in the numbers of algae eaters might also be factors. HABs can cause fish kills via their toxins and by reducing oxygen levels; they also lead to paralytic and amnesic shellfish poisoning in humans.

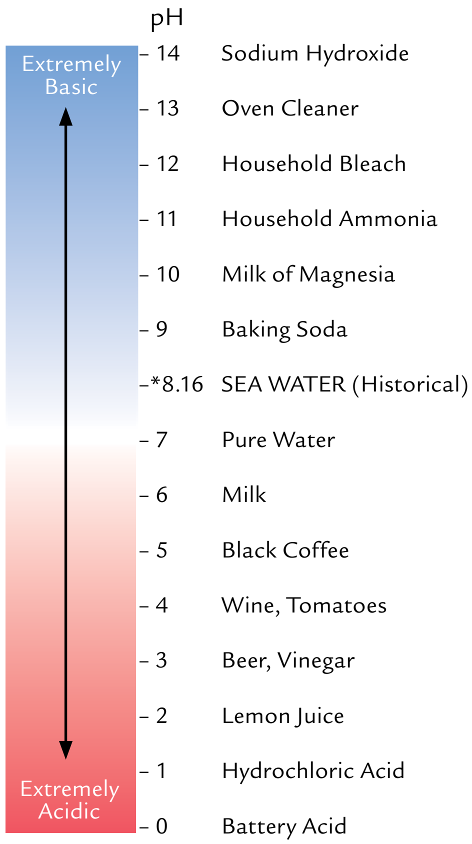
Increasing acidity of the oceans

One of the ocean's primary roles is the regulation of the Earth's climate. As carbon dioxide emissions have increased in the last century, the oceans have been picking up the slack, absorbing excess CO_2 from the atmosphere and dissolving it into seawater. Over the last 200 years, the oceans have taken up over 100 billion tonnes of CO_2, 43% of which has been absorbed in the last 20 years.[27] Although this has mitigated the effects of climate change, the carbon-based molecules formed in this process increase hydrogen ions (H), which increases the acidity of the water due to the production of carbonic acid. Plankton, corals, and other invertebrates such as shellfish often have shells or plates made from calcium carbonate, which are corroded by carbonic acid. As these animals form the basis of the food web, threats to their populations threaten other life in the oceans. Such threats to marine ecosystems will reverberate through our economy and food supply.

Implications of ocean acidification

Increasing ocean acidity has staggering implications for plankton, which serve as the biological engine of life in the oceans; life in the ocean, in turn, regulates life on the planet. The shells of plankton, along with those of many invertebrates, including corals and shellfish, will face increasing risk of corrosion. Just how this will impact their populations, and how those changes will transfer up the food web, is unclear, but will likely result in widespread changes to ocean ecosystems.[28]

The pH scale



A Sensitive Ocean
Human life and sea life have many things in common. One of them is pH. Both also have a very narrow pH range in which they can function. The pH range of human blood covers only 0.1 pH units – from 7.35 to 7.45. Illness occurs if the blood goes above or below this narrow range. Seawater also has a narrow pH range – from 8.1 to 8.3. Any level above or below that range can be harmful to its inhabitants. Over the last 200 years ocean pH is estimated to have decreased by 0.1 units, about a 30% change in acidity,[30] due to the increased uptake of carbon dioxide by the oceans. By the end of the century, forecasts suggest pH will drop another 0.3 -0.4 units lower, which translates to a 100–150% increase.[31] GRAPHIC: NOAA

Climate change

Climate change is creating novel problems for coastal and marine ecosystems that are already under pressure from other stressors. Patterns of wind and water circulation in the ocean environment have been altered. Such changes influence the vertical movement of ocean waters (i.e. upwelling and down-welling), increasing or decreasing the availability of essential nutrients and oxygen to marine organisms. These changes may have profound implications for the ecosystem services on which we and all other species rely.

The vexing problem with climate change is the difficulty in reliably predicting the direction and degree of impacts. Some species might respond favourably, whereas others might fail to adapt and become extinct. We believe the best strategy for tackling climate change is to support ecosystem resilience by working to keep all the interacting parts together.

Scientists with the Intergovernmental Panel on Climate Change (IPCC) have stated that in addition to greenhouse gas reductions, we need to reduce the non-climatic impacts that undermine species and ecosystem health (such as pollution, habitat destruction, etc). Doing so helps maintain their "resiliency," as it equips species and ecosystems with the best opportunity to cope/adapt to climate change.

Unexpected Consequences

The absorption of carbon dioxide by our seas may create noisier oceans.[29] When greenhouse gas reacts in the ocean it lowers pH, creating more acidic waters. The more acidic the water, the less that sound waves are absorbed. Keith Hester, a researcher with the Monterey Bay Aquarium Research Institute, predicts sounds will travel 70 percent further by 2050 because of increased carbon dioxide acidifying our oceans. A louder ocean will negatively affect marine animals, like whales and dolphins, which rely on sound to navigate, communicate, find food and avoid predators.

A plankton tow in the North Pacific gyre collects plastic. While scientists are learning more about the implications of debris ingestion by marine wildlife, little is known about plastic consumption by small filter feeders like krill at the bottom of the food web. Studies reveal there may be six times as much plastic as plankton in areas like the Central North Pacific Ocean.[35] This suggests that filter feeders most likely consume a great deal of plastic. PHOTO: ALGALITA MARINE RESEARCH FOUNDATION

Find out more about marine plastics on TED with Charles Moore.

Plastics

The scale of the marine debris problem has received recent attention with the discovery of a massive (estimates suggest the size of Texas) concentration of debris in the North Pacific Gyre between California and Hawaii. These are not large pieces of garbage, but small pieces that move with currents and winds and change in debris concentration.[32]

Much of the awareness of marine debris to date has focused on the thousands of marine animals that die annually from ingestion or entanglement associated with marine garbage.[33] Less studied, and of growing concern, are the toxic effects of plastics as they photodegrade and leach chemicals, such as bisphenol A and nonylphenols into ocean sediments. Plastics can also *attract* water-averse Persistent Organic Pollutants such as PCBs and flame retardants from their surrounding environment. These chemicals might later be transferred to animals that consume the plastics. Once inside mammals, all these chemicals can act as endocrine disruptors, which in sufficient concentrations can influence reproduction, immune systems, and the potential for cancer. Some studies have already shown a linkage between PCBs and cancer in sea lions.[34]

3. Five Years of Marine Mammal and Marine Bird Surveys

Angle board in platform
An angle board in the observer platform records the position of a marine mammal (relative to the ship) when it is first spotted. The true position is also recorded with GPS. Species, distance, behaviour (typically feeding or travelling) and queue (typically dorsal fin, breach or blow) are also recorded. Marine bird observers are seen on the bow. PHOTO: L. VICARI

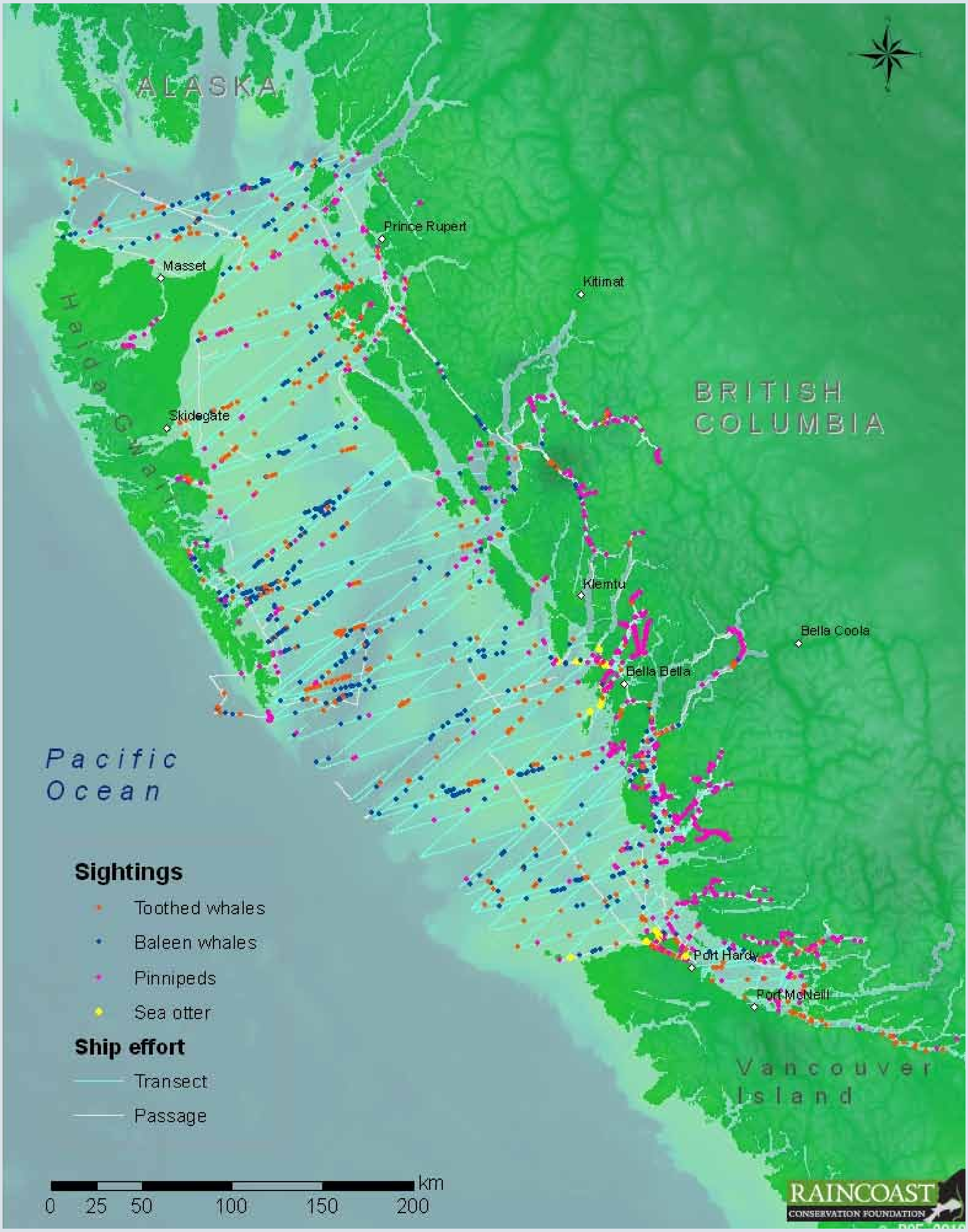
Observing and counting marine animals: methods

Between 2004 and 2008, we surveyed British Columbia's inner coast for marine mammals and birds using Raincoast's 22 m (68') research vessel *Achiever*. Most of our surveys were on the central and north coasts, but we also collected sightings as far south as Victoria. Figure 1 (Chapter 1) shows the study area.

The *Achiever* travelled at approximately 15 km/hr (8 knots) along systematically assigned transect lines.[36] Marine mammal observers scanned the transect line out to 90˚ on each side of the vessel, using the naked eye and binoculars. Sightings were also recorded opportunistically while the ship was in transit (passage) to transect lines. A single marine bird observer positioned on the bow scanned both sides of the transect line out to 90˚ on either side of the vessel. All sightings recorded along the transect line were analyzed using the software program Distance in order to obtain density and abundance estimates.

We used a second method, known as *Density Surface Modeling*[37] to estimate density and abundance of marine mammals. This method accounts for the fact that habitats are variable, and that animals can often be concentrated in "hotspots" that are associated with certain physical and environmental conditions, such as sea surface temperature and chlorophyll levels. The study area was divided into 5 kilometre (3.1 mile) grid squares, and the data within each square were analysed with respect to various environmental factors known to influence the presence of marine mammals.

Figure 2. Sightings of Marine Mammals (cetaceans and pinnipeds). Sightings of marine mammals recorded during Raincoast surveys on the BC coast between 2004 and 2008. Using two different methods, *Conventional Distance Sampling* and *Density Surface Modeling*, we derived population and density estimates for ten species of marine mammals. Abundance estimates varied from nine elephant seals to over 50,000 Pacific white-sided dolphins. We then used the results of *Density Surface Modeling* to identify likely hotspots for marine mammals on the BC coast.



What did we find? Marine mammal survey results

Surveying more than 14,000 kilometres (8,700 miles) of track line between 2004 and 2008, we collected 2,285 sightings of marine mammals. A "sighting" could range from one animal to 100 animals or more. After filtering these records for suitability, we were able to use 92% of the sightings for deriving our distribution and abundance estimates.

The results presented here (Chapter 3) are a summary of the full report on our marine mammal surveys. Predictive Marine Mammal Modeling for the Queen Charlotte Basin, British Columbia is available in our on-line supporting material.

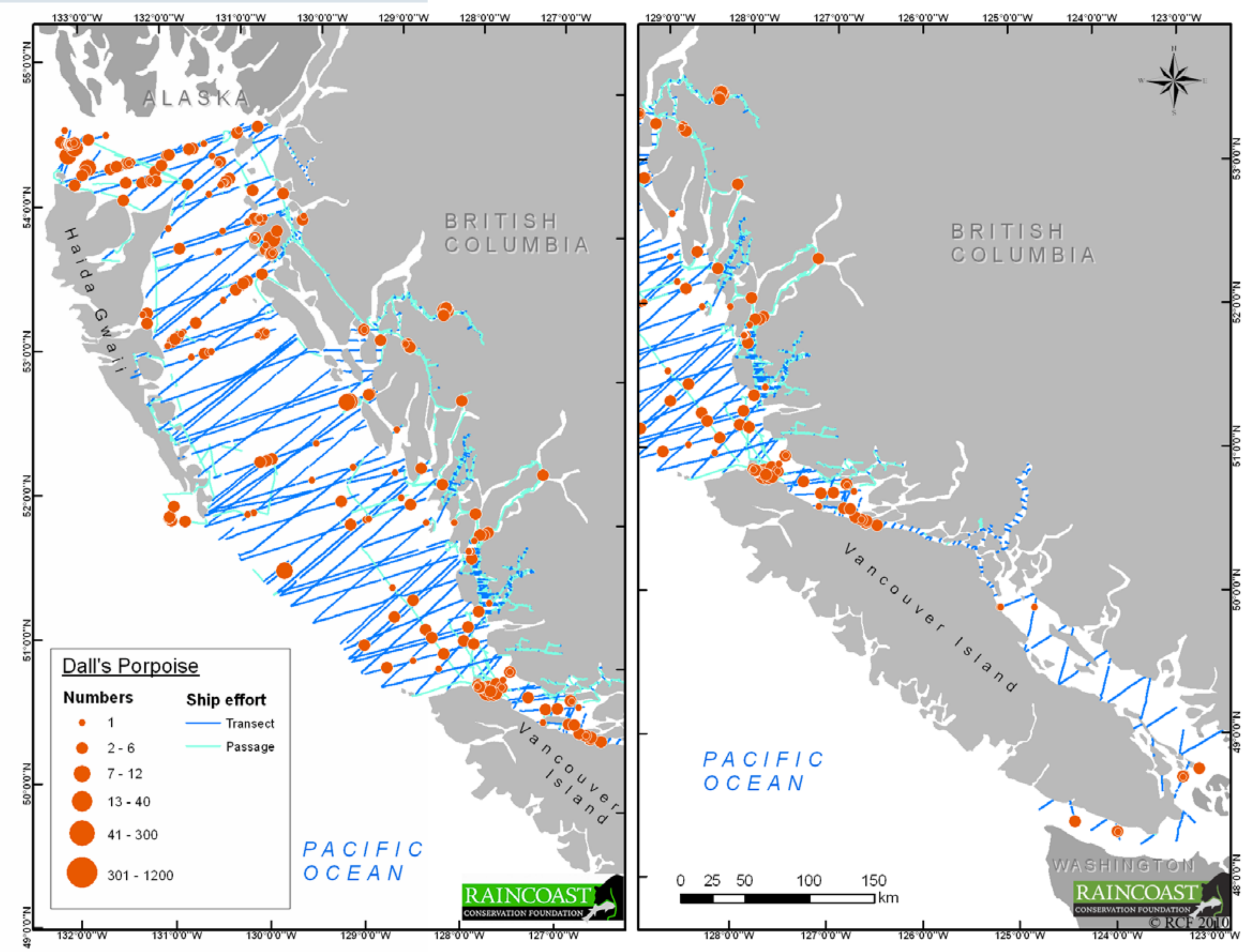
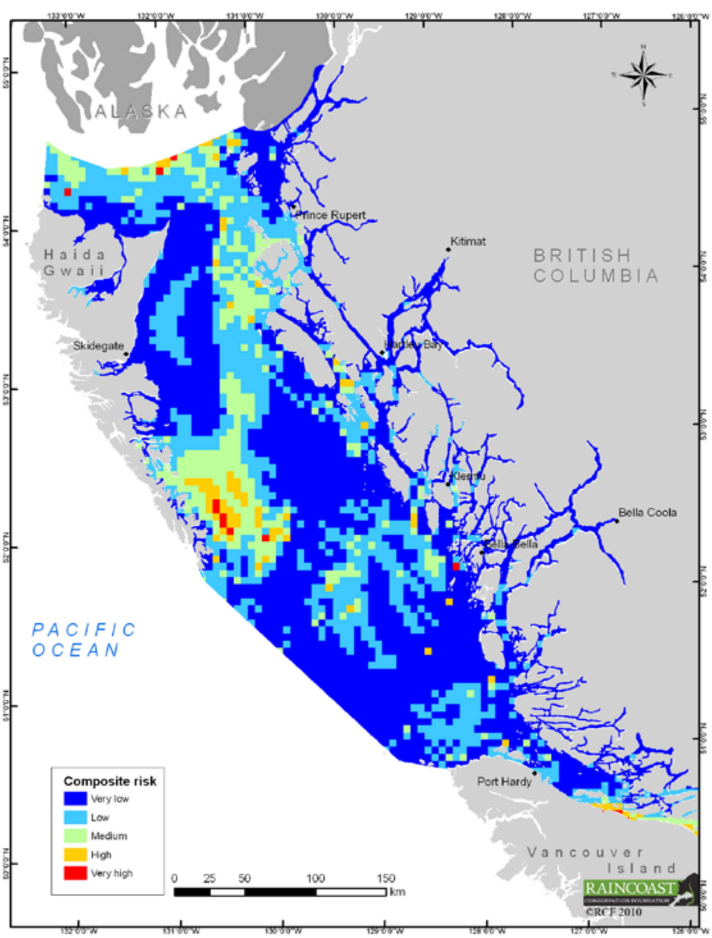


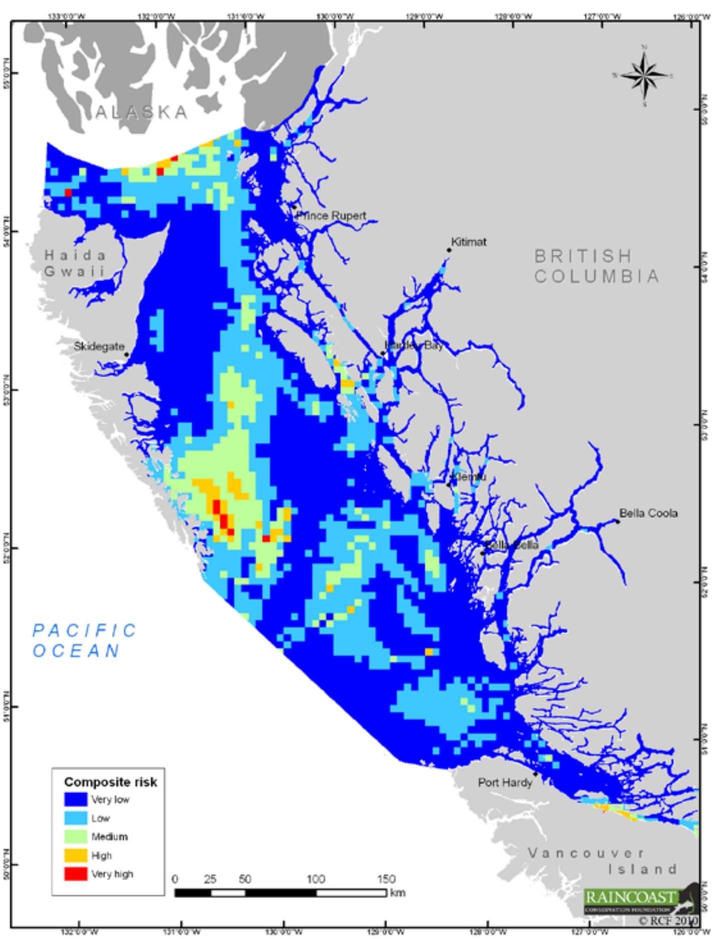
Figure 3. Sightings of Dall's porpoises from 2004-2008 throughout the study area. Results from our *Density Surface Modeling* analysis suggest a population size of approximately 5,300 animals (range 4,638-6,064). Individual maps for all recorded species are available in the on-line supporting materials.

Surveying presents special difficulties for biologists because marine mammals spend most of their time underwater. In order to use *Distance Sampling*, observers must ensure that they see all animals that surface in front of the vessel. Quick identification is required when whales, such as the minke (shown here), spend little time on the surface. PHOTO: R. WILLIAMS

Figure 4. *Density Surface Modelling* Results – Cetaceans and Pinnipeds. Risk areas for all marine mammals, based on the results of *Density Surface Modeling* analyses. Areas in red reflect the highest observed concentrations of animals along our transect lines. In the event of an oil spill these areas would be most at risk. The risk of a ship striking a marine mammal would also be higher in these areas. Dark blue reflects lower densities of marine mammals.

Figure 5. *Density Surface Modelling* – Cetaceans only. Risk areas for humpback, fin, minke and killer whales only, based on the results of *Density Surface Modeling* analyses. Areas shown in red reflect the highest observed concentrations of these species along our transect lines. These areas would be most at risk in the event of an oil spill and where the risk of ship strike is highest. Areas shown in dark blue reflect lower densities of marine mammals.





In addition to recording marine animals and birds, we also recorded garbage (n = 655). Most of our garbage sightings were forms of hard and soft plastics, which can have a big impact on marine life. Rather than biodegrade, this debris “photodegrades” meaning sunlight breaks it down into smaller and smaller pieces. For many animals, the floating plastic fragments are mistaken for food. This can eventually lead to starvation because the animal’s stomach is filled with items that cannot be digested.

Table 1. Status and abundance estimates for marine mammals from five years of surveys on BC’s north and central coast using *Conventional Distance Sampling* and *Density Surface Modeling.*[38]

Species	**Status* (Year status assigned)**	**Number of sightings between 2004 and 2008**	**Conventional Distance Sampling abundance estimates**			**Density Surface Model abundance estimates**		
			Population estimate (95% CI)	Distance to travel/ sighting	Density/ km (CV%)	Population estimate (95% CI)	Distance to travel/ sighting	Density/ km (CV%)
Harbour porpoise	Special Concern (2003)	128	6,631 (3,366-13,365)	3.7 km	0.272 (34.9)	8,091 (4,885-13,401)	10.3 km	0.097 (26.2)
Dall’s porpoise	Not At Risk (1989)	239	6,232 (4,165-9,324)	3.9 km	0.256 (20.0)	5,303 (4,638-6,064)	15.9 km	0.063 (6.8)
Pacific White-sided dolphin	Not at Risk (1990)	233	32,637 (20,087-53,029)	0.7 km	1.34 (24.6)	22,160 (16,522-29,721)	3.8 km	0.265 (15.1)
Killer Whale**	Threatened (2008)	29	308 (146-649)	76.9 km	0.013 (38.2)	371 v222-621)	250.0 km	0.004 (26.7)
Humpback Whale	Threatened (2003)	352	1,541 (1,187-2,000)	15.9 km	0.063 (12.9)	1,092 (993-1,200)	76.9 km	0.013 (4.8)
Fin Whale	Threatened (2005)	91	446 (263-759)	55.6 km	0.018 (26.4)	329 (274-395)	250.0 km	0.004 (9.3)
Minke Whale	Not at Risk (2006)	32	430 (259-712)	55.6 km	0.018	522 (295-927)	166.7 km	0.006 (29.9)
Harbour Seal – in water	Not at Risk (1999)	1018	17,454 (15,362-19,831)	1.4 km	0.717 (6.5)	24,916 (19,666-31,569)	3.4 km	0.298 (12.1)
Steller Sea Lion – in water	Special Concern (2003)	143	6,019 (3,056-11,853)	4.0 km	0.247 (35.3)	4,037 (1,100-14,815)	20.8 km	0.048 (74.3)
Elephant Seal	Not at Risk (1986)	20	65 (35-121)	333.3 km	0.003 (29.9)	9 (0-1.248)	10,000 km	0.0001 (2452.4)
Sea Otter	Special Concern (2007)	36	Due to their site fidelity, not suitable for DISTANCE sampling abundance estimation					

* As assessed by COSEWIC ** Northern resident and transient killer whales

Tufted puffins were one of the least frequently observed alcids during the surveys. They nest in burrows on slopes covered with grass, which makes them vulnerable to introduced predators such as rats.
PHOTO: C. FOX

What did we find? Marine bird survey results

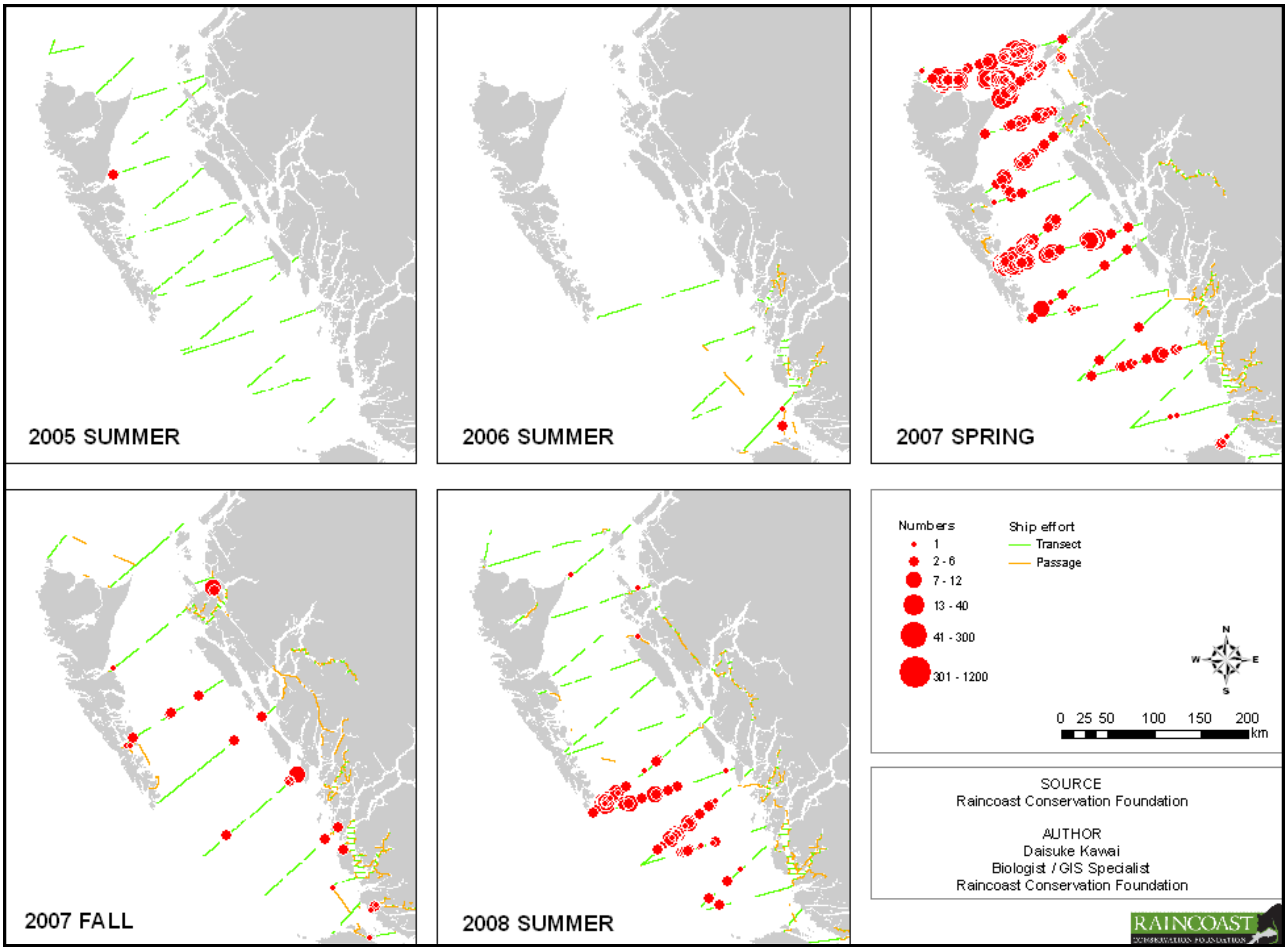
Beginning in 2005 we extended our surveys to include marine birds. By the end of 2008 we had surveyed more than 5,000 kilometres (3,100 miles) of trackline and detected over 14,000 sightings of marine birds, comprising 69 species. Individual maps for all 69 observed species are available in our on-line supporting materials.

Table 2. Number of sightings of marine bird groups during at-sea surveys of BC's central and north coasts between 2005 and 2008.

Group	Species	Number of Sightings
Seabirds		
Albatrosses	Black-footed Albatross, Laysan Albatross, Short-tailed Albatross	197
Fulmars and Shearwaters	Northern Fulmar, Pink-footed Shearwater, Buller's Shearwater, Flesh-footed Shearwater, Short-tailed Shearwater, Sooty Shearwater	2,377
Storm-petrels	Leach's Storm-petrel, Fork-tailed Storm-petrel	1,033
Cormorants	Brandt's Cormorant, Double-crested Cormorant, Pelagic Cormorant	
Jaegers, Kittiwakes and Gulls	Pomarine Jaeger, Parasitic Jaeger, Long-tailed Jaeger, Black-legged Kittiwake, Bonaparte's Gull, Mew Gull, California Gull, Herring Gull, Thayer's Gull, Glaucous-winged Gull, Sabine's Gull, Western Gull	1,979
Alcids	Common Murre, Pigeon Guillemot, Marbled Murrelet, Ancient Murrelet, Cassin's Auklet, Rhinoceros Auklet, Tufted Puffin, Horned Puffin	6,264
Shorebirds		
Sandpipers and Phalaropes	Whimbrel, Dunlin, Black Turnstone, Red-necked Phalarope	206
Oystercatchers	Black Oystercatcher	8
Marine Waterfowl		
Loons	Red-throated Loon, Pacific Loon, Common Loon, Yellow-billed Loon	833
Grebes	Horned Grebe, Red-necked Grebe, Western Grebe	311
Geese	Snow Goose, Brant Goose, Canada Goose	43
Ducks	American Wigeon, Mallard, Northern Shoveler, Greater Scaup, Bufflehead, Goldeneye	50
Sea ducks	Surf Scoter, White-winged Scoter, Black Scoter, Harlequin Duck, Long-tailed Duck, Hooded Merganser, Red-breasted Merganser	757
Marine Raptors	Osprey, Bald Eagle	337
Marine-Associated Birds	Great-blue Heron, Sandhill Crane, Belted Kingfisher, Northwestern Crow, Common Raven	158

Figure 6. Alcid sightings between 2005 and 2008. Alcids (murrelets, puffins and auklets) were the most abundant seabirds observed on Raincoast's surveys between 2005 and 2008. The sighting locations of Ancient Murrelets (ANMU), Cassin`s Auklets (CAAU), Marbled Murrelets (MAMU) and Pigeon Guillemots (PIGU) show that alcids were widely distributed through the study area.

Figure 7. Sightings of Ancient Murrelets (another alcid species) from 2005-2008 broken down by year and season. Individual maps for all observed species are available in our on-line supporting materials.



Pigeon guillemots, members of the alcid family, are one of the species that appear not to have recovered from the *Exxon Valdez* oil spill. However, the lack of baseline data makes this difficult to accurately assess. PHOTO: D.G. ROBERTSON

Short-tailed albatross. One of our more unusual sightings was that of a short-tailed albatross. Once the dominant albatross seen in BC, it was harvested to near extinction for the feather trade. Although nesting now on only two islands in the western Pacific, albatross are occasional visitors to our coastal waters. PHOTO: C. FOX

Salmon shark and *Mola Mola*. In addition to recording observations of marine mammals and birds, we also recorded giant sunfish, (*Mola mola* n=47) and sharks (spp. n= 107). Salmon sharks (above) are common in BC waters and juveniles do wash ashore. Both globally and locally, sharks have been severely persecuted. The slaughter of BC's basking sharks is an action from which they still have not recovered. PHOTO: N. DEBRUYN

Marine mammal surveys: Conservation applications

At a time when 36% of marine mammal populations are under threat globally,[39] monitoring their status is critically important in order to assess how they are being affected by human activities and climate change. Such information is essential for evaluating the impacts and risks associated with energy proposals in the Queen Charlotte Basin.

The primary goal of our five years of at-sea surveys was to provide baseline abundance and distribution information for the marine mammals and marine birds found in the Queen Charlotte Basin. The results presented here update those previously published from the first two years of survey work.[40] Additional data have improved the abundance estimates for all recorded species, by narrowing the ranges for these estimates (Table 1).

Distance Sampling is one of the most common methods of censusing populations, but here we show that *Density Surface Modeling*, while resulting in slightly different population estimates, almost always improves the confidence intervals.

Density Surface Modeling also identifies "hotspots" where animals are concentrated and takes into consideration the fact that the marine environment is far from uniform. In other words, where animals are found varies greatly in time and space. However there are locations where physical features and abiotic factors combine (like deep channels and upwelling) to create specific habitat conditions that attract certain species. Knowing where these hotspots are helps to identify areas of important habitat that should be of special concern to managers and decision makers when deciding if specific activities can occur within or near these sites. For example, assuming that conservation is a priority, industrial activities would be inappropriate in areas where high concentrations of marine mammals occur seasonally or continually.

Detecting trends in long-lived animals presents special problems, particularly for groups of animals like whales and

Sightings of Pacific white-sided dolphins in inshore waters in BC appear to have increased dramatically since the mid-1970s.[42] The reasons for this are unclear, but seem related to changing ocean conditions. PHOTO: N. DEBRUYN

Lessons from Alaska

One of the principal lessons learned from the *Exxon Valdez* oil spill in Alaska is the importance of collecting abundance and distribution data for non-commercially valuable species. Because this baseline information was lacking in Alaska, determining if and how the oil spill affected coastal wildlife was extremely problematic and of questionable reliability.

dolphins, which range widely.[41] For example, baleen whales are particularly long lived, with life spans of 50 to 100 years or more. The generation time for a killer whale is typically 25 years. The results of our surveys serve to provide baseline abundance estimates, which can form a foundation for comparison with future surveys. It will, however, be many years before we know whether these populations are stable, recovering, or declining.

In BC's coastal waters, Pacific white-sided dolphins were the most abundant cetacean (whale, dolphin or porpoise) observed, but Dall's porpoises were the most widely distributed (see sighting maps in on-line supporting materials). Neither of these populations is considered to be at risk, although their status has not been re-assessed in more than 20 years.

The two most frequently sighted baleen whales were fin whales and humpback whales. Historically, these animals were often observed in Hecate Strait and Queen Charlotte Sound, and occasionally in more protected waters. Both species were heavily harvested during the commercial whaling era.[43]

Our sightings of humpback and fin whales are consistent with increased observations of these species reported by others, suggesting that they may be reoccupying their historic habitat, or that there has been a demographic shift in their population.[44] Despite the historic presence of blue, sei, and sperm whales in coastal waters, we did not encounter any of these species in the five years of surveys. However, their known presence on the coastal shelf off Haida Gwaii and Vancouver Island makes us optimistic that given adequate protection from human caused disturbances (e.g. oil spills), these species can recover within their historic range.

Population estimates and confidence intervals

Surveys do not provide exact counts of individual animals. Therefore, high and low estimates known as "confidence intervals" are derived which, in theory, include the true number of animals within their range. The narrower the ranges of these estimates, the more certain scientists are that their estimates approximate the actual abundance of animals.

Common Murres were one of the most frequently observed alcids during the surveys and are widely distributed throughout Hecate Strait, Dixon Entrance and Queen Charlotte Sound.The common murre is the most frequent victim of bycatch in the commercial net fisheries operating along the BC coast.[45] It is also the species most frequently found oiled on beached bird surveys in the province.[46] PHOTO: M. YIP

Until very recently, sandhill cranes in coastal BC have been poorly studied. There is now growing attention on their use of outer and inner islands on the central and north coast for breeding. In addition to using bogs and forests for nesting, they rely on inter tidal habitats for foraging. PHOTO: D. BROWN

Marine birds surveys: Conservation applications

A unique, diverse, and often incredibly dense community of marine birds inhabits BC's coastal waters. Before 2004, systematically collected marine bird information on marine birds at sea in the Queen Charlotte Basin was largely lacking, which represented a major problem for conservation planning. Now, these surveys provide reliable information for determining their distribution in these waters. This information is a baseline against which future change can be compared. Specific sighting maps for all 69 species are available in our on-line supporting materials.

The most predominant group of seabirds observed during the surveys were alcids (murrelets, murres, and auklets). More than half the world's population of ancient murrelets nest on the islands of Haida Gwaii.[47] Despite their numerical abundance in our surveys, there are long standing conservation concerns for many of the alcids.

Alcids spend most of their lives at sea and are particularly vulnerable to catastrophic events such as oil spills. They constituted 32% of the proportion of oiled bird carcasses found following the *Exxon Valdez* oil spill.[48] In the aftermath of the spill, the lack of baseline data of marine bird communities considerably hindered population assessments for many species. We do know, however, that pigeon guillemot populations have still not recovered 20 years post spill.[49]

In Canada, ancient murrelets and marbled murrelets are considered as "species at risk". The status of Cassin's auklets is under review and of concern. More than 75% of the global

Ancient Murrelet chicks fledge at just two days of age. Adults then raise their flightless young at sea for several months. Our surveys encountered a number of families at sea in the summer of 2008. PHOTO: R. MERRILL

While ingestion of micro plastics is a growing concern for marine life, thousands of animals still die globally each year as result of entanglement in nets and lines. In BC, gill nets are the primary source of entanglement for dolphins and porpoises (like the Dall's porpoise shown here). Having abundance estimates for small cetaceans helps us understand the population impacts from these types of mortalities. PHOTO: NOAA

population of Cassin's breed on islands off the northwestern tip of Vancouver Island and forage in the waters off the continental shelf, and in Queen Charlotte Sound.

Of the species encountered, approximately 10% are considered at risk globally and nationally, although many have not been fully assessed. Where prior information is available, some species are showing evidence of recovery. The numbers of bald eagles, for example, are growing following declines that were largely due to DDT exposure before its market elimination.

Other populations show evidence of decline or are suspected to be decreasing. Both quantitative and anecdotal evidence suggest that marbled murrelet populations are declining in BC, although a lack of detailed survey information makes it impossible to determine the magnitude or rate at which populations are changing.[50]

Whereas the survey information only represents a series of "snap shots" of the at sea distribution and abundance of marine birds, it is crucial to filling in key knowledge gaps. The information's primary value, however, is that it provides a reference for carrying out repeated surveys over time from which population trends and status can be determined, ideally leading to more effective protection.

Marine debris

Much of the marine debris recorded on our survey was varying forms of plastic. Marine wildlife are increasingly being exposed to this debris. Plastics do not bio-degrade; rather they "photodegrade", meaning sunlight breaks them down into smaller and smaller pieces. For many seabirds and other animals, floating plastic fragments look like food, and are mistakenly eaten.[51]

Although birds naturally digest and regurgitate hard food items, the ingestion of plastics is believed to cause "intestinal blockage, a false feeling of satiation or reduced absorption of nutrients".[52] Plastics in the form of drinking cups and children's toys, as well as large pieces of fishing net, have been found within the stomachs of sperm whales.[53] In some cases, the undigested trash consumed by marine mammals can eventually lead to starvation and death. Marine mammals that have died as a result of ingestion of debris include a pygmy sperm whale, a northern elephant seal, and a Steller sea lion.[54]

It remains unclear to what extent these plastic fragments represent a source for accumulation of Persistent Organic Pollutants. However, more than 180 species have been documented to ingest plastic debris, and a positive correlation between the amount of ingested plastic and the PCB concentration in birds has been observed.[55] As plastics are known to accumulate PCBs in the environment, this correlation supports plastic-mediated transfer of contaminants up through the food chain.

An albatross carcass filled with plastic debris. PHOTO: ALGALITA MARINE RESEARCH FOUNDATION

4. A Coastal Labyrinth

The BC coast is only 900 km as the crow flies, but comprises 27,000 km of coastline. This geography makes the BC coast vulnerable. The isolation, and hence independent evolution of species on islands, means that their populations are not easily replaced if they disappear from these locations.
PHOTO: C.T. DARIMONT

The fragile biogeography of BC's coast

The interface between the land and the sea in coastal British Columbia has created a biological treasure, but one that is easy to spoil. BC's modest 900 kilometre north to south distance between Washington and Alaska contains 27,000 km of coastline that jogs around hundreds of islands and dozens of inlets to form a remarkable archipelago. Since the glaciers retreated over 10,000 years ago, this geography has yielded impressive diversity. But such diversity also comes with a cost. This configuration places coastal life forms at high risk and they can disappear in a (evolutionary) blink of an eye.

An archipelago environment blesses coastlines with biodiversity. We know from some of the most important biological studies ever conducted, notably Darwin's work on the Galapagos Islands, that islands foster diversity at the community, species, and genetic levels. Due to their isolation, animals and plants on islands diverge on their own evolutionary trajectories, creating novel adaptations to local environments. Research on BC's islands, including that done by Raincoast, has revealed tremendous diversity: from giant black bears on Haida Gwaii to "marine wolves" of the outer coast to endemic populations of lake fish.

These natural laboratories of biodiversity, however, bear a curse in today's world. The most rapid and severe human-caused extinctions our planet has ever witnessed have occurred on islands. The same isolation that allowed island populations to evolve on their own trajectory reduces their resilience to stressors. When island populations are stressed, the water barriers of channels and inlets slow down or prevent other individuals from coming to the rescue of dwindling populations.

Islands are fragile. But the possibility of a catastrophic oil spill compounds risks in many ways because spilled oil has a tendency to settle on shorelines and beaches. These serve as gateways or points of contact where oceanic resources (or pollutants) encounter much of the islands' diversity. The intertidal life, including foraging shorebirds, spawning herring, spawning pink and chum salmon, hauled-out marine mammals, and foraging maritime animals – all these utilize the interface between the land and the sea. Twenty-seven thousand kilometres of labyrinthine seaboard places this web of diversity much more at risk than a 900 km distance would suggest.

Terrestrial wildlife that forage extensively in intertidal habitats may be more accurately termed "maritime animals" due to their use and dependence on food from the sea. Coastal bears, for example, supplement their diet of salmon by foraging on mussels, barnacles, crabs, and amphipods. Opportunistic wolves eat river otters, ducks, seals, Humboldt squid, and whale carcasses, as well as salmon.[56] PHOTOS: (ABOVE) N. DEBRUYN, (BELOW) C.T. DARIMONT

Maritime animals: Terrestrial creatures that depend on the sea

Terrestrial animals are not the first to come to mind when assessing risks of oil and gas development in coastal marine environments. After all, these land-based species ought to be "terrestrial"; that is, squarely inhabiting and making their living on land. Yet, contemporary science has taught us that a previously regarded boundary between ocean and land is actually non-existent. In reality, the movements and food habits of many of these "maritime animals" span both environments. Consequently, many species we consider terrestrial can be acutely sensitive to everyday activities associated with oil and gas exploration, production, and transport, as well as the recurring catastrophic accidents that have stained the oil industry's reputation.

Many maritime animals forage extensively, and occasionally exclusively, in the intertidal. They serve as significant vectors of energy transfer from ocean to land. Not only mammals, but also terrestrial birds can be significant intertidal foragers. For example, individuals within coastal northern saw-whet owl and northwestern crow populations forage solely on intertidal prey and carrion.[57]

Raincoast's own work in coastal BC has demonstrated the importance of salmon and other marine resources to

Sea Wolves. Families of wolves, for example, commonly inhabit a group of islands and mainland areas and frequently swim among them as part of their home ranges.[61] Swimming distances can be significant. Areas colonized by wolves include islands up to 13 kilometres (8 miles) out at sea in Hecate Straight.[62]
PHOTO: R. CARPENTER

When all else fails – swim! Deer will cross channels and swim between islands to feed or escape predation by wolves. During a decade of fieldwork, Raincoast has documented more than 100 swimming events by large mammals such as grizzly bears, black bears, cougars, and deer.[66] Researchers in other areas have described similar swimming behaviour in these species.[67]
PHOTO: C.T. DARIMONT

carnivores. Wolves, particularly those living on islands, can make most of their living from oceanic resources.[58] In fact, during the fall, an entire population selected salmon over deer (usually their main prey).[59]

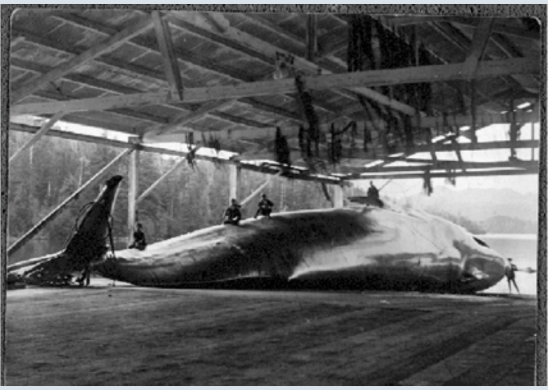
Similarly, coastal grizzly bears rely on salmon to maintain their population numbers. Examining populations in North America, US scientists showed strong and positive associations between the amount of salmon in the diet of grizzly bears and the productivity (fecundity, population density) of their populations.[60] This grizzly-salmon relationship is widespread in western British Columbia.

Grizzly bears as far inland as several hundred kilometres showed 20% or more contribution of salmon to their yearly diets, illustrating the importance of salmon as a food source. Coastal populations were almost exclusively dependent on this marine prey. Indeed, in similar work conducted by our team, grizzlies sampled from across the province were identified as either "interior bears" that were largely terrestrial or "maritime" bears, based on their diets. Maritime bears had diets that ranged from 13-61% "meat" consisting primarily of salmon but also including crabs and mussels.[63]

Salmon serve as a tremendously important marine subsidy for an extensive breadth of wildlife. Even riparian vegetation (herbs, shrubs, and trees) benefits from this marine-derived source of nitrogen and phosphorous that salmon carcasses provide.[64] In addition to benefiting from this bottom-up fertilization of the food web, organisms as varied as invertebrates, amphibians, birds, and mammals either directly or indirectly receive sustenance from salmon. So far 138 terrestrial species have been identified that rely to some extent on salmon.[65]

5. Populations Returning from the Edge of Extinction

Whaling in Georgia Strait, 1908. Captain Larsen at the harpoon gun on the *St. Lawrence* in the Strait of Georgia in 1908. A whaling station operated there from October 1907 to February 1908, processing 98 humpback whales before it was closed. PHOTO: D-03820 ROYAL BC MUSEUM ARCHIVES



Blue whale on the slip at Rose Harbour. A blue whale on the slip at the whaling station in Rose Harbour, Haida Gwaii (formerly Queen Charlotte Islands). Between 1905 and 1967 more than 24,000 whales were slaughtered as part of BC's commercial whaling efforts. PHOTO: E-05033 ROYAL BC MUSEUM ARCHIVES

By their very nature, marine mammal populations are vulnerable to overexploitation and other human generated threats. Marine mammals are generally long lived, but have low reproductive rates. Consequently, recovery from significant population reductions can take many years. However, by controlling destructive human behaviour, the declining trajectories of some marine mammal populations have been reversed.

Return of the whales

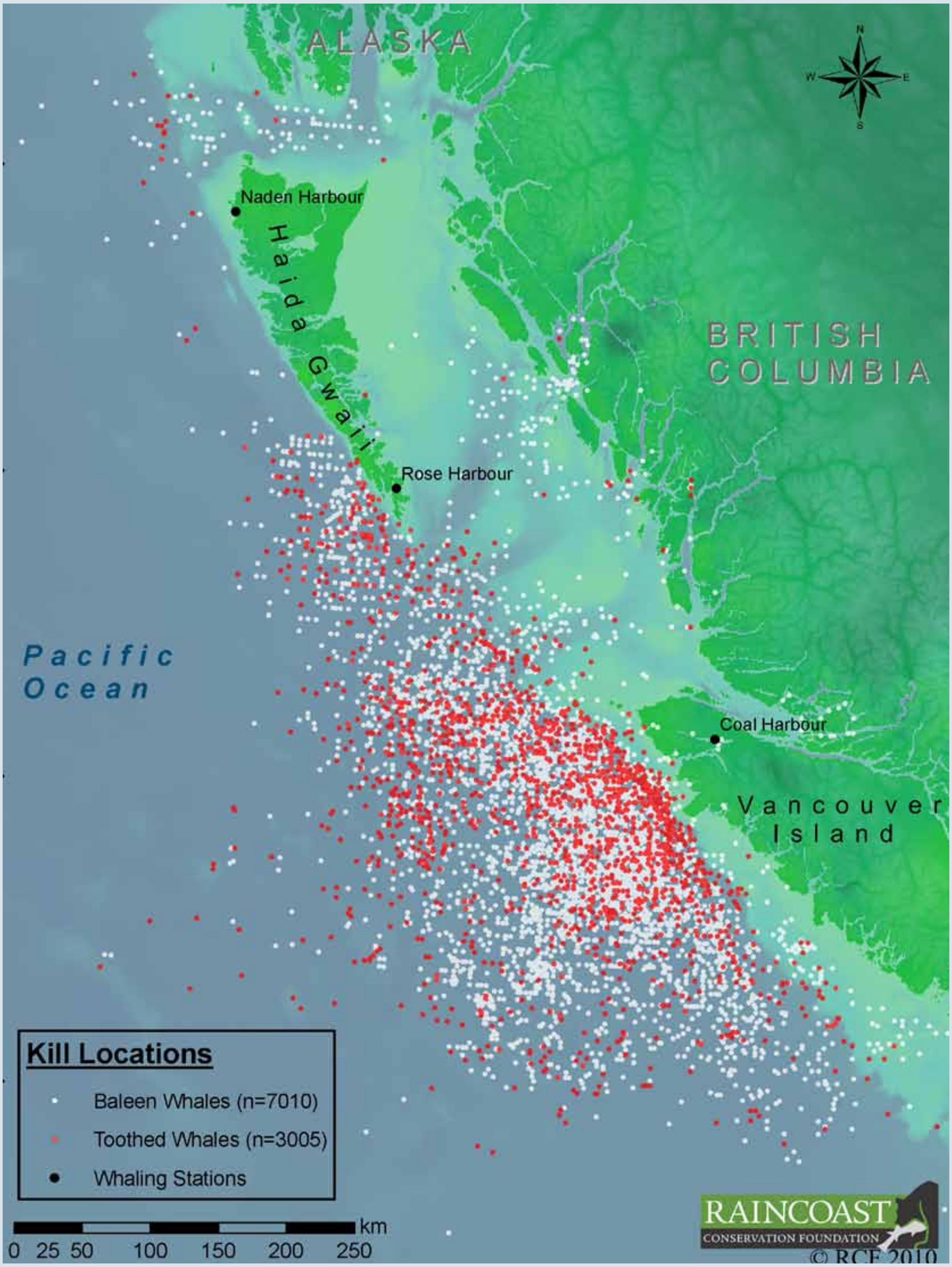
After a 40 year reprieve from whaling, these gentle giants are slowly returning to the coast. In the 1840s, large whales (such as sperm, blue, fin, humpback, grey and right whales) were so abundant in the Pacific Northwest that they became the target of whalers on sailing ships. By 1848, there were 292 sailing ships hunting whales in the region. By 1865, fewer than 20 years later, grey whales and right whales were commercially extinct.[68]

The introduction of steam powered vessels opened up the oceans to a second round of intense harvesting of whales. Here in BC, between 1905 and 1967 more than 24,000 large whales were taken from the BC coast. Six shore-based whaling stations were constructed, including two on Haida Gwaii (at Rose and Naden Harbours) and a third, the largest, at Coal Harbour, on northern Vancouver Island.

Over time, whalers targeted different species, driving each to commercial extinction before shifting their focus to other species. In the early part of the century, primarily humpback whales were taken. In later years, faster swimming fin whales and sperm whales dominated the catch.

Whales were afforded protection from commercial slaughter in 1968, which has led to the gradual return of humpback

Figure 8. Kill locations of whales hunted on the BC coast between 1905 and 1967. Known locations where whales were harvested by BC whalers between 1905 and 1967. This map represents roughly 40% of the whales actually harvested in BC. Grey and right whales were already commercially extinct on the coast before land based whaling stations were constructed.[69] Targeted whales between 1905 and 1967 were primarily humpback, fin, and sperm whales. Individual species maps are available in our on-line supporting materials. Data for these maps were complied by the Cetacean Research Program, Pacific Biological Station, Fisheries and Oceans Canada.



and fin whales to portions of the BC coast. In addition, the numbers of grey whales appear to have returned to the levels that preceded whaling. We have yet to see any signs of significant population recovery in sei whales and right whales.

Where's your passport? Steller sea lions do not recognize international boundaries. The largest breeding rookery for the eastern population of sea lions is just north of the British Columbia – Alaska border on Forrester Island, where this sea lion was born and branded by Alaska Fish and Game in 2001. It has since travelled more than 300 km to the Caamaño Sound area, where it was observed in the fall of 2006.

A stellar story of decline and recovery

Steller sea lions are one of the most studied marine mammals in the North Pacific. This is because the western population in Alaska (west of 144° W) has experienced population declines of 80% since the 1970s. The species is now considered "endangered" in the US.[70] Causes for the decline are the focus of much research and debate. Nutritional stress caused by changes that reduced the availability or quality of their prey seems the most likely explanation for the decline, although this theory remains controversial.[71]

The eastern population of Steller sea lions (east of 144° W and extending down into BC and California) was given Special Concern status in Canada, but at present the population remains at historically high levels. When listed in 2003, only 3 breeding rookeries were found in the province.[72] Canadian government biologists recognized that sea lions were sensitive to disturbance while on land, and expressed concern that the precipitous decline observed in the western population could spread.

The abandonment and recovery of the Sea Otter group as a sea lion rookery[73] In 1913, the rocky islets comprising the Sea Otter group was a small breeding rookery for Steller sea lions on BC's north coast. However, between 1923 and 1939, fishery officers used to visit the rookery near the end of the pupping season, using machine guns to shoot adults from their patrol boats. Then, they would then go ashore and kill the pups, which were generally too young to escape. As a result, the number of animals that returned to the rookery each year declined exponentially and the sea lions eventually abandoned the site, although a few animals were occasionally seen using it as a haul out. When sea lions were given protected status in 1970, they slowly began returning to the Sea Otter group. By 2006 enough animals had returned to breed that the islands were given official rookery status once again. PHOTOS: P.C. PAQUET

Steller sea lions: voracious salmon predators? The evidence from their scats (faeces) says no. Scats are collected from haul out sites and rookeries and then washed in a special machine called an elutriator. Only the hard parts remain (bones, eye lenses, squid beaks etc.), which can often be identified to species. Analyses of these hard parts reveal that Steller sea lions prey primarily on small and medium sized schooling fish that are seasonally abundant and/or accessible, such as herring, hake, sandlance, salmon, dogfish, eulachon, and sardines. Salmon constitute only 10% of their summer diet based on preliminary analysis of scats collected at Cape St. James.[76] In winter, sea lions prey primarily on herring.[77] PHOTO: M. CARWARDINE

Steller sea lion numbers have only recovered in BC since they were afforded protection from culling in 1970. Between 1913 and 1968, approximately 49,000 sea lions were culled and 5,700 were killed in commercial hunts, reducing the breeding population to about 30% of its previous size.[74] These kills generally took place while the animals were on shore, near the end of the breeding season. The primary reason the hunts were carried out was because sea lions were perceived as competitors for salmon. We now know that salmon are a relatively small proportion of the sea lions diet.

While Steller sea lions were being intensely culled in British Columbia, a population breeding on a small rookery on Forrester Island in southeast Alaska began to increase.[75] In 1929 there were less than 100 animals on Forrester Island and by 1945 there were an estimated 350. By 1961, when the first aerial surveys were flown, more than 800 pups were counted. Forester Island is now the largest Steller sea lion rookery in the world. More than 4,400 pups were counted in 2005.

More seals, more seal eaters. An increase in the abundance of transient (mammal-eating) killer whales coincides with a dramatic increase in the number of harbour seals, their primary prey.[78] Between 1879 to 1968 more than half a million harbour seals were killed in British Columbia. In 1970, they received protection from culling.[79] Since then, the harbour seal population has grown and stabilized at approximately 110,000 animals coast wide.[80] PHOTOS: K. HEISE/L.BARRETT-LENNARD

6. Lessons from Alaska

1 barrel
= 42 US gallons
= 35 Imperial gallons
= 159 litres
1 tonne
= 1,000 kg
= 7 barrels

At 42 million litres, the Exxon spill would fill 17 Olympic swimming pools.

***Exxon Valdez* grounded on Bligh Reef, Prince William Sound** The *Exxon Valdez* spilled more than 40 million litres of oil into Alaskan waters in 1989 when the supertanker went aground on Bligh Reef. Although one of the world's most famous and best-studied oil spills, it does not even rank among the top 50 largest spills. An overview of the *Exxon Valdez* Oil Spill and the lingering impacts can be viewed here (EVOS Trustee Council).
PHOTO: NOAA.

The *Exxon Valdez* oil spill

The story lives on, but began just after midnight on March 24, 1989 when the 300 metre (984 feet) supertanker *Exxon Valdez* ran aground on Bligh Reef, 50 kilometres from the port of Valdez, Alaska. In its hull were 220 million litres (53 million US gallons) of crude oil, which began leaking into Prince William Sound.

Three days passed before Exxon, the owner of the vessel, began cleaning up the oil. Meanwhile, at least 42 million litres (11 million US gallons)[81] of leaked oil had drifted more than 25 kilometres from the punctured supertanker. Within a week, crude oil stretched more than 140 kilometres, contaminating shorelines and killing wildlife across much of Prince William Sound, and out into the Gulf of Alaska. The oil slick eventually expanded 750 kilometres, covered 3400 square kilometres, and contaminated 1,990 kilometres of shoreline.[82] Based on the recovery of carcasses, immediate mortalities[83] included: 1,000-2,800 sea otters, 250,000 seabirds, 302 harbour seals, and countless intertidal invertebrates, such as clams and mussels, as well as beds of seaweed.[84]

Oil: A killer for whales

Prince William Sound is home to two types of killer whales: fish eating resident and mammal-eating transient whales. Killer whales are long-lived and slow to reproduce. Females give birth about every five years and typically produce only four to six calves throughout their lifetimes. Each whale is unique in its markings and fin shape, so it is possible to census the population with great accuracy.

Death by oil. Between 1000-2800 sea otters (above) and 250,000 seabirds (below) died immediately following the *Exxon Valdez* oil spill. Oil on the fur of otters or on the feathers of seabirds causes loss of insulation and often leads to death from hypothermia, smothering, drowning, and ingestion of toxic hydrocarbons. Harbour seals and killer whales were thought to have died from inhaling the toxic fumes of the oil. PHOTO, ABOVE: NOAA, BELOW: EVOS TRUSTEE COUNCIL

The AT1 transient killer whales[85] (mammal-eaters)

Before the *Exxon Valdez* oil spill, the AT1 transient population was stable at 22 whales. Although nine whales disappeared immediately after the spill, it took years to confirm these missing whales had died. This is because transient social structure is somewhat fluid. Individuals will sometimes leave their groups for varying lengths of time. However, in the 15 years following the spill, these individuals were not seen with any other groups and did not reappear in Prince William Sound, leading to the conclusion they had died.

Since the spill, 15 transient whales have gone missing from the AT1 group, a number of which were females. Although only five carcasses were ever found, these whales are almost certainly dead. Moreover, over the last 20 years no recruitment of calves into this population has been recorded. All evidence shows that this unique population of killer whales is going extinct. The timing and magnitude of missing individuals directly following the spill plus the known exposure of the AT1 pod to the oil (they are a year-round resident of Prince William Sound) suggests that oil was the cause. Scientists have hypothesized that these whales died from inhaling toxic oil vapors or from eating oiled harbour seals.[86]

The AB resident killer whales (fish-eaters)

Similar to the story of the transient killer whales, the link between the decline of the resident population and the oil spill was not immediately obvious. No carcasses of any resident whales were ever discovered. As with the transients, the resident whales were observed surfacing in oil slicks immediately following the spill and nearly all of the deaths occurred between then and over the following winter. The mortality rate was 19% in 1989 and 21% in 1990, roughly 10 times the natural rate.

Fourteen of 36 whales died in the AB pod, many of which were young and reproductive females. Although calves have been born into this population, unexpected mortalities and the loss of these important females has meant an uphill battle for recovery. Mortality and impacts are likely due to petroleum or petroleum vapors inhaled by whales.[87]

Alaskan resident killer whales (AB Pod). Although no oiled carcasses were recovered, two different populations of killer whales, both in Prince William Sound at the time of the spill, experienced dramatic declines. The whales shown here are members of the fish-eating AB resident pod. This group of killer whales lost 14 of its 36 members following the spill. A second population, the AT1 mammal-eating transients, which were seen surfacing in the oil near the *Exxon Valdez*. Since then, the group has not successfully reproduced. Most likely, this unique killer whale population will go extinct.[88] PHOTO: K. HEISE/ L. BARRETT-LENNARD

Exxon oil lingers on

"Twenty years later, the lingering ecosystem effects of the *Exxon Valdez* oil spill continue to affect the social fabric of native villages and communities. In some areas, subsistence gathering of intertidal resources has never resumed and commercial herring fisheries, worth millions of dollars remain closed".[91] EVOS TRUSTEE COUNCIL 20 YEAR REPORT

The effects of the spill on wildlife populations in Prince William Sound have been long-lasting. Scientific studies have shown that Pacific herring, an important commercial species, and pigeon guillemot (a seabird in the alcid family) populations have failed to recover after more than 20 years. Still recovering are sea otters, killer whales, and other marine birds such as Barrow's goldeneyes and harlequin ducks. Sediments and intertidal communities are also contaminated and slowly recovering, including the clams and mussels that provide nourishment to so many maritime animals.[89]

For many marine and terrestrial species, the baseline information on species numbers and distribution that are necessary to measure recovery were never collected, a fact often overlooked in the reports and studies of recovery following the *Exxon Valdez* oil spill. For example, we have no idea how the spill affected harbour porpoise and Dall's porpoise populations in Prince William Sound. Over 90 different species of oiled birds were recovered from the spill, but it has only been possible to track 10 bird species for signs of population level recovery.[90]

The toxicity of oil

When encountering an oil spill, one of the first things you notice is the smell. Impossible to capture in a photograph, it leaves a lasting impression. The strong-smelling vapours from crude oil contain toxic carcinogens, such as polycyclic aromatic hydrocarbons (PAHs). Consequently, spilled oil needs to be treated as hazardous waste. Oil spill clean up workers have shown evidence of long-term respiratory illness and even death as a result of exposure to oil.[92]

The *Exxon Valdez* oil spill has caused a shift in the way we now think about the persistence of oil in the environment. Previously, the assumption was that mortality in wildlife was almost exclusively from acute exposure. However, this spill has taught us that oil persists and retains its toxicity for a much longer time than originally thought. The persistence of toxic, sub-surface oil and chronic exposures, even at low levels,

Toxic Oil: Acute and chronic effects

Crude oil is a complex mixture of hydrocarbons and other compounds. Oil's toxicity is based on its ability to cause harm through acute (immediate) and chronic (repeated) exposure. Crude oil and other petroleum products also contain polycyclic aromatic hydrocarbons (PAHs), many of which are carcinogenic. Animals can be exposed to the toxicity of oil by swimming through it, breathing the vapours, consuming it on their food, or ingesting it when trying to clean their feathers or fur.

Cosco Busan Oil spill. In November 2007, the 277 metre container ship *Cosco Busan* collided with the San Francisco Bay Bridge, spilling an estimated 220,000 litres (58,000 US gallons) of heavy fuel oil into the Bay. Although the spill occurred within the harbour, clean up efforts were not mobilized in a timely way and the oil spread. Volunteers could not be used because of the oil's toxicity. The estimated costs of clean up were more than 70 million $US, excluding long-term restoration or socio-economic expenses. PHOTO: GCAPTAIN.COM

continues to affect wildlife in Alaska.[93] After twenty years, five to seven centimetres (two to three inches) beneath the surface, more than 80,000 litres (21,100 US gallons) of oil remain nearly as toxic as during the first few weeks after the spill.[94]

Mussels and clams in the lower intertidal continue to be exposed to this toxicity and the harlequin ducks, sea otters, and other species that feed on them are thus exposed to PAHs.[95] This is why in oiled areas, recovery for many species has been slow.

Can we realistically estimate the costs of spill cleanup?

To help industry and governments better budget for such occurrences, economists have tried to predict the costs of oil spill clean up. Globally, the cost to industry for spill cleanup *averages* 16,000 US dollars per tonne (1110 litres).[96] However, this estimate does not account for the costs of restoring habitat or the social fabric of the communities impacted by the spill.

In 2003, the cost of cleaning up a 378,000 litres (100,000 US gallons) heavy fuel oil spill in San Francisco Bay was an *estimated* 93 million US$.[97] Forty to sixty percent of the estimated cost was attributed to restoring habitat and compensating for socio-economic losses. However, in 2007 when the *Cosco Busan* spilled a little over half that amount into the Bay, the cost for the clean up alone was 70 million US$ (see sidebar).[98] In other words, true costs dramatically exceeded the estimates.

Did Exxon pay the full cost of the *Exxon Valdez* oil spill?

Although Exxon spent more than 3.4 billion US$ and the spill was the most expensive in history, the true costs were estimated to be 9.5 billion.[99] Ultimately, US citizens ended up paying the additional costs.

7. A Crude Proposal for Oil Tankers on the BC Coast

The 183 metre long tanker *Risanger* brings condensate into Kitimat, BC to be shipped by rail to the Alberta tar sands. The ship is almost half as long as the supertankers that would be used to transport tar sands crude oil from Kitimat to offshore markets. They would travel at 12-15 km/hr (8 to 12 knots) through narrow mainland inlets. PHOTO: C. FOX

Supertanker oil spills. Globally, an average of 3.5 major tanker spills occurs each year.[104] The average amount of oil spilled is about 100,000 tonnes (700,000 barrels) annually.[105] PHOTO: L. RYDBERG

In 1972, the Canadian federal government banned tankers from transporting crude oil through BC's inside passage. More than 70% of the BC population supports this ban.[100]

Despite this, Enbridge's Northern Gateway Project proposes to construct a 1,170 kilometre (727 miles) twinned pipeline from the oil sands in Alberta, to Kitimat, on BC's central coast. The development of the Alberta Tar Sands is rapidly becoming the largest industrialized project in human history. The proposed pipelines would cross salmon bearing rivers in the Skeena, Kitimat, and Upper Fraser River watersheds, as well as habitat for critically endangered mountain caribou.

One pipeline would carry 83 million litres (525,000 barrels) per day of tar sands oil to Kitimat, to be stored in a "tank farm"[101] until ready for transport to tankers. Notably, most petroleum spills occur at the facilities where oil is stored or processed.[102]

If the Northern Gateway project were built, two to three times per week, supertankers would enter Kitimat to load approximately 318 million litres (2 million barrels) of oil for shipment to California and overseas markets. Loaded tankers would pass directly through Wright Sound, a body of water with more than 5,000 vessels moving through it annually.[103]

Smaller tankers would bring condensate into Kitimat. Condensate is a petroleum based product used to dilute the thick bitumen-like crude so that it flows through the pipeline more readily. A second pipeline would carry over 30 million litres (193,000 barrels) of condensate from the central coast to the tar sands in Alberta.

The marine approaches to the coast of northern BC and the port of Kitimat are a dangerous coastline for ships. The region experienced a prolonged storm in 1977 that recorded the second highest wave heights ever measured. Also a storm wave

A storm brews over Hecate Strait on BC's north coast. PHOTO: C. FOX

of 30 metres (98 feet) was observed on October 23, 1968.[106] This area is at least as dangerous as Prince William Sound, where the *Exxon Valdez* hit Bligh Reef in Valdez Arm, in a navigable channel almost 10 kilometres (6.2 miles) wide. To enter Kitimat, supertankers will need to transit Douglas Channel, which is only 1.35 kilometres (0.84 miles) wide at the narrowest point. Severe weather heightens the risk of shipping accidents.

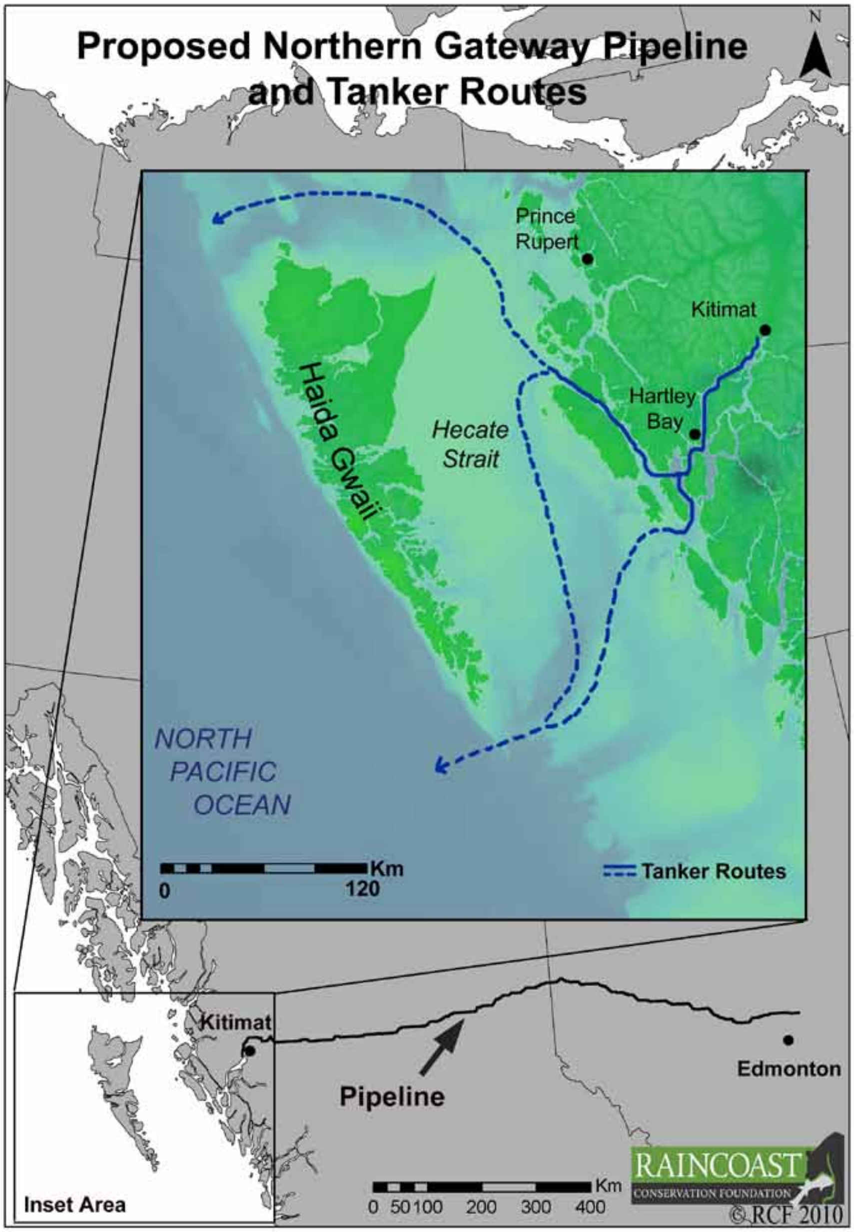


Figure 9. A proposal to ship oil through the BC coast. Enbridge's Northern Gateway project proposes a twinned pipeline to ship crude oil west from Bruderheim, Alberta and condensate east from Kitimat, BC.[107] The solid line on the tanker route is based on Enbridge's confined channel assessment[108] done for inside waters between Kitimat and Hecate Strait. The dotted line is based on early (2004) Enbridge documents[109] that identify potential routes from the inside waters through Dixon Entrance and Queen Charlotte Sound.

An *Exxon Valdez* size spill in BC

Figure 10. Potential area affected by an *Exxon Valdez* size spill. This scenario assumes an *Exxon Valdez* size oil spill from a supertanker running aground on a January night at "Cort Rock" in Caamaño Sound before the mainland inlet approaches to Kitimat. The area in black represents the path of oil spilled under winter conditions where moderate winds push the oil north only. Oil movement is based partly on spill behaviour modeling work carried out by the Living Oceans Society. However, winds in this region shift continually in their direction and magnitude and could blow oil northwest to Haida Gwaii (note red lines), and southwest to the Scott Islands and Vancouver Island.

The estimated spill distance is based on the spread of oil in Alaska after the *Exxon Valdez* ran aground. Fifteen days after the spill, oil had already spread 320 kilometres (198 miles), by day 30, oil had travelled as far as 450 kilometres (280 miles) away. Ultimately, the oil travelled up to 750 kilometres (466 miles) from Bligh Reef. Oil travelling a similar distance from Caamaño Sound could conceivably reach as far as Juneau in southeast Alaska.

Figure 11. Area affected by the Exxon Valdez oil spill. The black boundary delineates the 3400 sq km area of Prince William Sound affected by the *Exxon Valdez* Oil Spill.[110]

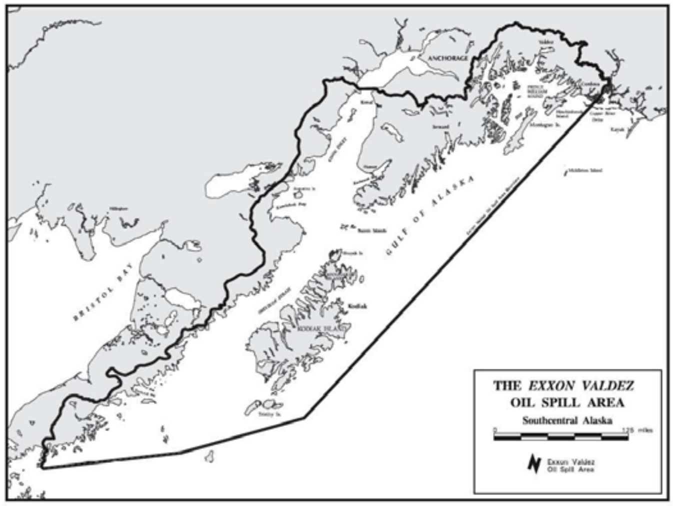


Figure 12. Area affected by the *Exxon Valdez* oil spill overlaid on the BC coast. The oil travelled 750 km and fouled 1990 km of shoreline.

Sea otters are particularly vulnerable to oil because it destroys the insulating value of their fur. An oil spill in Caamaño Sound would threaten a small recovering population of sea otters that is concentrated just 55 kilometres (34 miles) south of the area but which ranges at least as far north as the southern border of Caamaño Sound.[111] PHOTOS: (TOP) DAVID MENKE, (BOTTOM) MILA ZINCOVA

Humpbacks and fin whales are slowly returning to BC's coastal waters. This recovery could be hindered by supertankers. PHOTO: P.C. PAQUET

What does this mean for BC's whales?

Both the historical record and our current research suggest that supertankers could put large whales such as blue, sperm, fin and humpbacks at risk (Figures 13 and 14).

As whale populations recover from previous exploitation (chapter 5) and move back into their historic feeding grounds, they face new threats from supertankers travelling through areas where whales are known to concentrate. Indeed, the proposed tanker route goes directly through an area that has been proposed as critical habitat for northern resident killer whales.[112] The risks of ship strikes, chronic oiling or a catastrophic oil spill need to be considered when evaluating whether or not we allow the oil and gas industry to expand into the central and north coast of British Columbia.

Figure 13. The 3,400 sq km area affected by the Exxon Valdez oil spill overlaid on the locations of historical whale kills (1905–1967) in British Columbia.

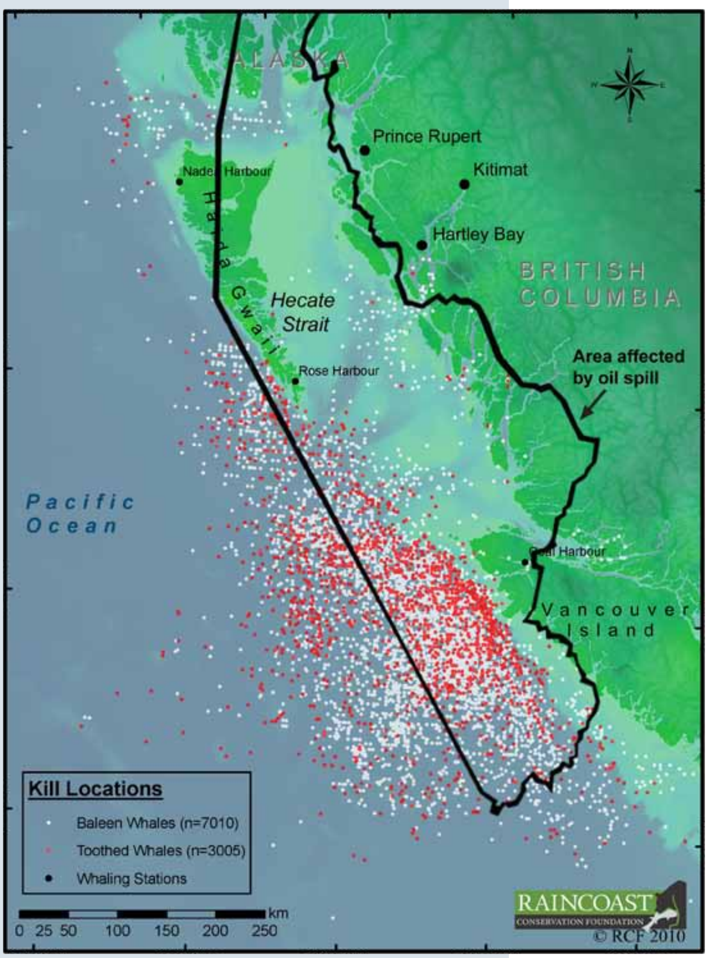
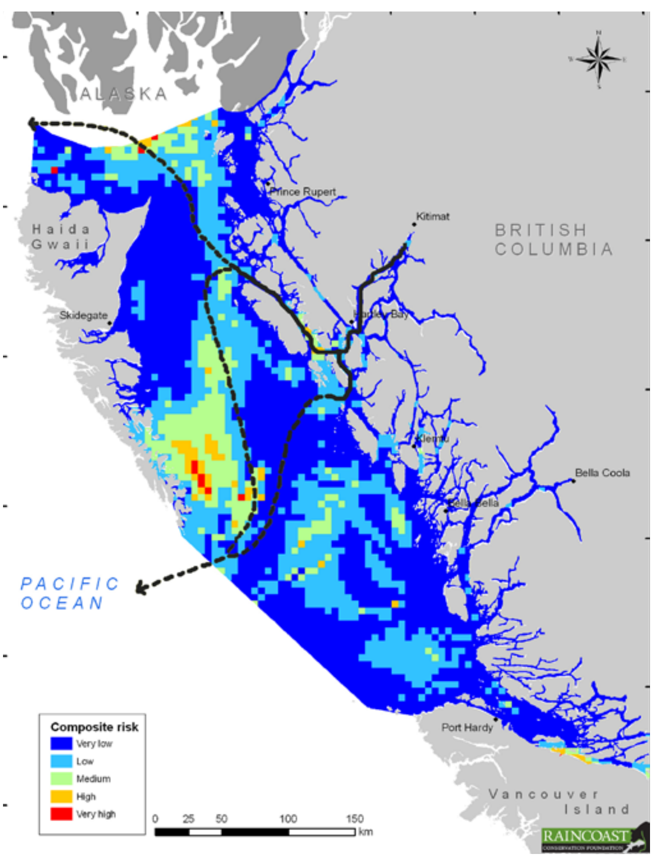


Figure 14. The proposed supertanker route overlaid on the locations of whale concentrations based on the results of Raincoast's at-sea surveys 2004-2008.



Vessel accidents in BC

More than 400,000 vessel movements occur annually on the BC coast[113], so it is not surprising that accidents are common, including collisions, groundings, fires etc. on board. Even vessels with state-of-the-art navigational equipment are vulnerable. The US National Science Foundation's 73 metre (240 feet) ship, the *Maurice Ewing* that has undertaken surveys in BC, ran aground while doing seismic surveys off Mexico's Yucatan Peninsula.[114]

Should an accident occur off the BC coast involving a large ship, serious inadequacies in response capabilities would hinder rescue and containment operations. For example the south

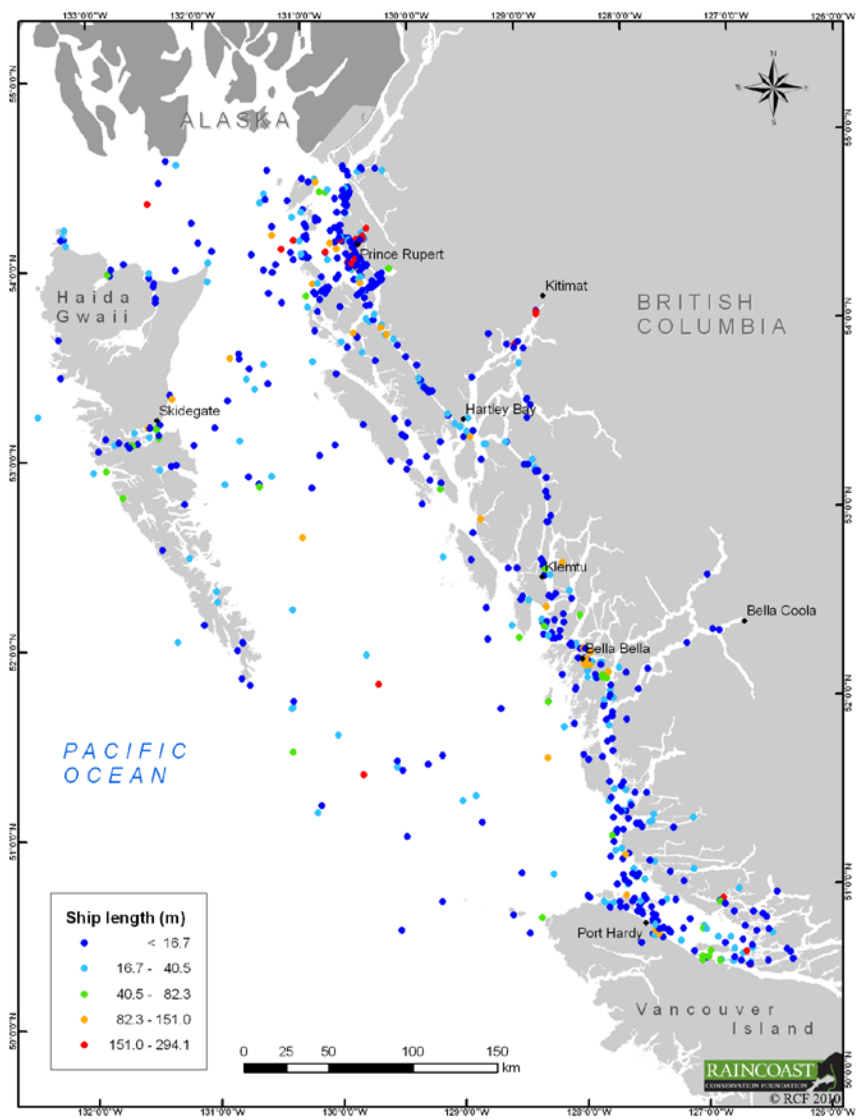


Figure 15. Vessel Incidents in BC as reported to Transport Canada. Vessel incidents as reported to Transport Canada (Jan 1, 1999-Dec 31, 2008). Included is the fatal sinking of the BC ferry the *Queen of the North* after striking Gil Island. Most of the 812 incidents shown were groundings.

coast relies heavily on the availability of rescue tugs based out of Washington State to respond to incidents. Moreover, procedures between the BC Provincial government and the Canadian federal government to coordinate responses to large vessel incidents at sea are not well harmonized.[115] In the past, this has resulted in considerable delays, as evidenced in the Leroy Trucking barge incident, or no response at all, as in the sinking of the *Queen of the North*.

Timely response capabilities?

Case scenario 1: LeRoy Trucking Barge spill in the Mike Bigg/Robson Bight Ecological Reserve, in the middle of critical habitat for the threatened northern resident killer whale population

August 20, 2007 – A barge belonging to Leroy Trucking flipped in Robson Bight, carrying logging equipment, including a fuel truck with 10,000 litres of diesel fuel

April 18, 2008 – Federal and BC provincial government announced a joint cost sharing agreement to remove the logging equipment

May 19, 2009 – Fuel truck successfully removed from the Bight

Even though the spill occurred in critical habitat for killer whales and near a well-known killer whale rubbing beach,[116] the federal and provincial governments needed 8 months to reach an agreement to remove the equipment. Inexcusably, an additional 13 months passed before it was actually removed. Listen to Orca Lab's recording of the barge sinking in Robson Bight.

Case Scenario 2: *Queen of the North*, a 125 metre (410 feet) long passenger and vehicle ferry, runs aground on Gil Island and sinks in 430 metres (1411 feet) of water.[117]

March 21, 2006 – *The Queen of the North* struck the northeast side of Gil Island. In less than 1½ hours, the vessel sank in Wright Sound.

The *Queen of the North* was loaded with 225,000 litres of diesel fuel, 15,000 litres of light oil and 3,200 litres of hydraulic fluid, and 3,200 litres of stern tube oil. Containment booms were set up to control and restrict spread of the spill.

March 12, 2008 – The federal Transportation Safety Board released the final report into the sinking of the *Queen of the North*, without mention of any concerns regarding fuel leakage.

March 24, 2010 – The *Queen of the North* continues to rest on the bottom and continues to discharge oil into the marine ecosystem.[118]

How well does Enbridge maintain its pipelines?

- In 2007, Enbridge reported 65 "reportable spills"[119] that leaked more than 2 million litres from their pipelines.[120]
- In 2008, the State of Wisconsin sued Enbridge for more than 500 land disturbance and wetland violations during the construction phase of a pipeline. Enbridge quickly settled the lawsuit for 1.1 million dollars.[121]
- In 2008, Enbridge[122] reported 93 spills, which leaked more than 900,000 litres (198,000 imperial gallons) of oil.
- In the first two months of 2009, Enbridge reported two spills that leaked more than one million litres (222,000 imperial gallons) of oil.[123]

Spill monitoring and chronic oiling

While accidental oil spills conjure up depressing images of oiled wildlife, it should be noted that each year five times as much oil enters the world's oceans through petroleum extraction and consumer use as it does through tanker spills.[124] This generally happens from slow, chronic releases largely into rivers and runoff, rather than catastrophic spills.[125] This is particularly significant in Canada and the United States where fossil fuel consumption is high.

BC does not publicly report the volume of oil spilled into the environment each year,[126] despite being a member of the Pacific States/ British Columbia Oil Spill Task Force since 1989. In contrast, the four Pacific states of California, Oregon, Washington, and Alaska voluntarily report spill volumes each year. The federal government, however, does undertake aerial monitoring of marine spills in BC.

Indeed, the problem extends to the east coast of Canada where there is an active offshore oil industry. The industry self-monitors within government guidelines, although requests for public access to information on spills have been denied.[127] We do know, however, that off the coast of Newfoundland and Labrador, up to 300,000 seabirds per year are killed due to chronic oil pollution.[128] This is similar to the number of birds that were estimated to have died following the *Exxon Valdez* oil spill in Alaska in 1989.[129]

Off the west coast of Vancouver Island, high proportions (56%) of seabird carcasses are oiled. This is similar to the rates seen on the east coast.[130] Oil kills seabirds by reducing their buoyancy and increasing their risk of hypothermia. Ingesting even small amounts may cause debilitating physiological changes or death.

Five times as much oil enters the ocean each year through consumer use and petroleum extraction than occurs through tanker spills.

8. Petroleum and Shipping Threats to Marine and Terrestrial Animals on the BC Coast

Fin whale wedged on bow of cruise ship. Fisheries and Oceans Canada examine the carcass of a fin whale struck by a cruise ship and carried into the Port of Vancouver in the summer of 2009. Ship strikes are a growing concern for whales in BC coastal waters, as shipping traffic is expected to increase by 300% from 2007 levels. PHOTO: AP

A black bear crosses a channel on the BC coast. Increased shipping traffic can affect terrestrial wildlife. Even though these animals spend less time in the water, they cannot dive or swim quickly to avoid danger. As such, they may be more vulnerable to ship strikes than marine mammals. PHOTO: C.T. DARIMONT

Ship strikes

Growing shipping traffic is escalating the risk of vessel strikes on whales and other marine mammals. The recent expansion of the Port of Prince Rupert, the potential for supertanker traffic in and out of Kitimat for oil and gas transport, plus high levels of cruise ship traffic, increase the potential for ship strikes. By 2020, container traffic travelling to Asia from British Columbia is expected to increase by 300 percent from 2007 levels,[131] further increasing the possibility of injury or mortality. Ship strikes are a growing concern for killer whales, fin whales, and humpback whales in particular.[132]

The BC coast is a naturally fragmented archipelago, and home to maritime animals that rely on healthy and abundant food supplies for survival. Often in search of food and other resources, terrestrial mammals swim among islands and insular mainland areas that are not large enough to support populations, or individuals, over time.

Although terrestrial animals are proficient swimmers, they do not have the burst acceleration or diving ability to avoid ship strikes compared with their marine cetacean cousins, which themselves occasionally fall victim. Accordingly, while these terrestrial animals do not spend as much time in the water as marine mammals, they are likely much more at risk when they are. These vulnerabilities, combined with significant increases predicted in vessel traffic on the BC coast,[133] suggest that terrestrial animals are at risk from ship strikes.

Toxicity exposure

In Chapter six we touched on the toxicity of oil to marine mammals. However, a suite of terrestrial animals, less studied in this context, is also at risk from toxicity. The first route is the external exposure to oil on shorelines and/or from the water surface. For example, both bear species, wolves, weasels (e.g. mink), rodents, and birds regularly come in direct and prolonged contact with shoreline environments, overturning seashore rocks, excavating intertidal sediments or swimming, as they search for prey.[134] Consumption of food provides the second route for exposure to toxic oil residues.

Common fare consumed by terrestrial wildlife includes suspension-feeding clams and mussels, and ground fishes. Shellfish and ground fish slowly metabolize hydrocarbons and have shown chronically high levels from oil exposure.[135] Consequently, when ingested, they can cause acute and long-term adverse effects in the health and diet of the animal. For example, detailed studies showed that for four years after the *Exxon Valdez* oil spill (1989-92), river otters living in oiled areas had lower body mass and elevated hydrocarbon biomarkers in their blood compared with otters inhabiting "non-oiled" areas. Similarly, otters from oiled areas had higher levels of fecal porphyrins (proteins that bind metals) and consumed a less diverse diet before 1992, after which these conditions started to improve.[136]

Food supply concerns from oil spills. Whether swimming or not, many terrestrial animals can still be at risk from oil spills through consumption of oiled marine resources or through declines in food supply. Declines in intertidal invertebrates, herring, and salmon all occurred post *Exxon Valdez* oil spill.[137]
PHOTOS: (TOP) N. DEBRUYN, (BOTTOM) D. BROWN

Concerns for food supply

Because coastal grizzlies, black bears, and wolves rely on salmon to maintain individual and population health, declines in coastal salmon runs are of considerable concern. Compared with historic abundance, most salmon runs are already depressed. Some are very depressed.[138]

More recently, wild runs of chum, sockeye, and pink salmon that are particularly important to bears have experienced substantial declines in catch and escapement. Consequently, many commercial fisheries are being closed.[139] These declines in salmon abundance are attributable to specific or cumulative impacts in marine survival, mixed-stock and over fishing, and habitat loss.[140] Impacts to salmon survival from oil spills would add to these existing problems.

More than 100 terrestrial species rely on salmon at some stage in their life and often have aspects of their life cycle linked to salmon presence.[146] Oil spills have the potential to adversely affect salmon, jeopardizing salmon stocks that are already in decline. The loss of salmon has substantial negative implications for coastal bears and other wildlife.
PHOTOS: N. DEBRUYN

Declines in salmon abundance occurred after the *Exxon Valdez* oil spill, and have been attributed to elevated mortality through several life stages and repeated exposure of eggs to oil on spawning grounds through multiple generations. Pink and chum salmon would be most vulnerable to these conditions because of their fidelity to spawning in the lower reaches of streams and rivers.

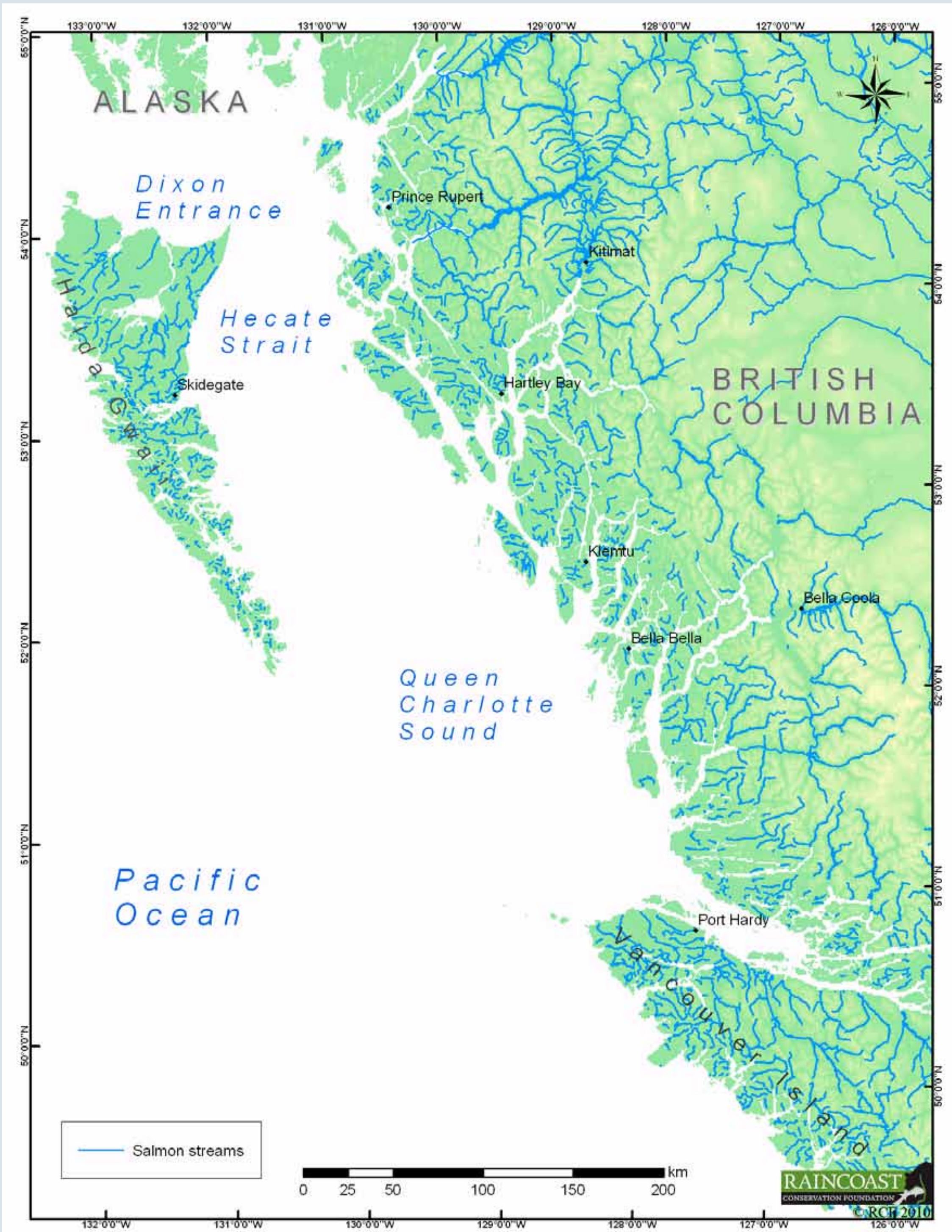
Laboratory studies have shown that poly aromatic hydrocarbons (PAHs) in crude oil are toxic to salmon eggs at concentrations as low as 1 ppb[141]; hence many eggs exposed to oiled spawning grounds would have been affected. Weathered oil with this level of toxicity can persist for years after a spill.[142] Mortality would also have occurred at the juvenile stage from impaired growth rates,[143] which would have reduced survival, in some cases up to 50%.[144] Reduced embryo survival in the second generation was also likely.[145]

Exposure and uptake of oil pollutants at early development stages in fish can increase mortality and reproductive impairment through endocrine disruption and developmental abnormalities.[147] Such impaired development in both salmon and herring was observed after the *Exxon Valdez* spill. The Alaskan demonstrations of compromised survival and reproduction from sub lethal doses of hydrocarbons have increased scientific understanding and public concern over the impacts of oil on salmon. Concomitantly, we are concerned that further declines in salmon from a catastrophic oil spill could exert strongly negative effects on bears and a wide diversity of terrestrial wildlife.

Why large populations of animals are important

Globally, marine mammals have been under threat from a variety of pressures including hunting, pollution, and competition for habitat and prey. Consequently, many of these mammals, including sei whales, right whales, and sea otters have been reduced to small and remnant populations. Small

Figure 16. Salmon streams of the BC coast. Federally catalogued salmon rivers and streams on British Columbia's north and central coast and in Haida Gwaii. Over 2,500 salmon runs spawn and rear in these freshwater habitats that drain to the coast. This is a minimum number of salmon streams as field work by Raincoast with the Heiltsuk and Gitga'at First Nations shows that many more small salmon streams exist, and could be at risk in the event of an oil spill.[148]



populations behave differently from larger populations which makes them more vulnerable to extinction.[149] There are three main reasons for this:[150]

First is the role of "chance variability." This occurs when there is a random drop in birth rate, an increase in death rate, or repeated offspring of the same sex in a generation all these can lead to extinction.

Secondly, when these small populations experience random events such as food shortages, disease, pollutants, or toxic spills, the loss of individuals, (especially breeding females), can have dire consequences. This is an important concept that underscores the importance of numbers to maintain the resilience and adaptive abilities of populations that are faced with disturbances.

Extinction scenario: the AT1 Alaskan transient killer whales. Small populations are more vulnerable to extinction through several mechanisms, one of which is the impact of random events like oil spills. The breeding females of the AT1 transient killer whale pod died following the Exxon Valdez oil spill. Now, with only males left (shown here), the extinction of this unique group of whales appears inevitable, as the males will not leave to find mates within other populations.
PHOTO: K. HEISE/L. BARRETT-LENNARD

A prime example of this is the loss of all the breeding females from the AT1 transient killer whale population in Prince William Sound after the *Exxon Valdez* oil spill. Killer whale culture is such that even though reproductive females are gone, males will not leave the population to find mates within other populations, hence their extinction is highly likely.[151]

Thirdly, small populations are vulnerable due to reduced genetic variation. By their very nature, small populations are a narrow subset of individuals from what was once a much larger population. As small populations breed, the role of chance error in genetic make up becomes much higher. For populations to adapt and evolve with changing conditions genetic variability must be present. Hence reducing genetic variation results in decreased survival (i.e. increased mortality). Like a negative feedback loop, increased mortality leads to further reduction in genetic variation resulting in what scientists call an "extinction vortex." Loss of genetic diversity through random genetic drift is the most commonly invoked evolutionary concern in conservation biology.

9. Conclusion

Priceless and irreplaceable

Canada's Pacific coast is a fragile archipelago with a boundary between land and ocean that changes by the hour, by the season, and over the millennia. The fragmented island and inlet nature of this ecosystem, nourished by the waters of the North Pacific, has fostered more diversity of plants and animals than occurs anywhere else in North America. The assembly of iconic animals such as whales, dolphins, wolves, and bears make the BC coast qualitatively different from most other exceptional places in the world. Distinctively, all these mammals, together with another 120 species of birds, are tied to the sea.

However, the very thing that has fostered this rich diversity also makes it fragile. BC's coastal ecosystem is an ecological treasure of species that can, evolutionarily speaking, be lost in the blink of an eye. Twenty-seven thousand kilometres of labyrinth seaboard place this web of diversity much more at risk than its 900 kilometre distance would suggest.

In the course of our work, we have been struck by the daunting reality that questions about BC's coastal environment far outweigh the answers. As part of an international desire to increase our understanding of this distinctive region, Raincoast committed to documenting the numbers and distribution of marine mammals and birds. The fact that five years of seasonal surveys provide only a snapshot into one aspect of this relentlessly mutable ecosystem emphasizes the complex nature of the BC coast. However, this data provides a foundation to build from and a place marker of where we stood at the beginning of the 21st century. Importantly, we have now identified where current or proposed high-risk activities might conflict with ocean habitats important for marine mammals and birds.

As we learn and understand more about the relationships of species with their environment, British Columbians are increasingly coming to cherish this maritime commons of animals, waters, islands, and forests. BC's coastal archipelago is a marvel of features and processes that support a remarkable diversity of life, including our own. *Priceless and irreplaceable:* its worth is immeasurable in monetary terms.

This is the very soul of British Columbia. The prospect of losing it compels us to think big and think long term. Accordingly, Raincoast's planning horizon is time without end. We want this ecosystem to thrive generations from now into perpetuity. Given that current political and economic thinking reflects the past and present, and not the future, we are embracing this conservation effort so the prospect for marine and coastal species is secured while the opportunity still exists.

At what price profit?

Attaching a dollar value to the damage that spilled oil does to marine ecosystems is impossible. The cost of the *Exxon Valdez* spill has been estimated at $9.5 billion, of which Exxon paid $3.5 billion, with taxpayers footing the rest. But does that even begin to cover the price of a pod of killer whales driven to extinction, or the demise of a coastal fishing community's way of life?

From Raincoast's perspective, species and wild ecosystems warrant protection for their intrinsic and aesthetic worth, regardless of the added utilitarian value that healthy environments provide for people. Clearly, the monumental global task of preserving biodiversity is fundamentally one of ethics. Nonetheless, a focus on protecting the services that marine ecosystems provide is realistic and relevant to framing the threats posed by shipping oil. Together, values and pragmatism compel us to safeguard all animals, including humans, which depend upon a healthy and ecologically rich coastal environment to maintain their cultures and communities.[152]

Governments may eventually conclude that revenues from an oil corridor on the BC coast are more important than the health of our environment, or the wellbeing of the flora and fauna. The public, however, should be properly and clearly informed as to the risks and potential losses. If we get this wrong, these losses will be incalculable.

Coastal First Nations executive director Art Sterritt summed up the threat posed by oil tankers: "*The minute there is tanker traffic, there is damage to a way of life*." If the Enbridge Northern Gateway pipeline is constructed, oil tankers at least as big as the *Exxon Valdez* would ply BC's rocky coastline almost daily. Twice a week, over 500,000 barrels of the world's dirtiest oil would be shipped out and condensate shipped in. Is the benefit to Alberta and the shareholders of Enbridge Inc. from supplying Asian and American markets with oil worth the risk, if it means subjecting the BC coast to the threat of a catastrophic spill?

Failure to reconcile ecology and commerce has been a hallmark of international marine policy for decades. Whereas conservation and restoration efforts are directed at improving current and future conditions, market interests usually discount future benefits and costs in favour of present consumption. Because information about the future is limited, a premium is placed on the present. Therefore, short-term profits are usually favoured over the uncertain profits of the future. This attitude continues to prevail because only monetary benefits and costs associated with resource products are recognized in conventional marketplace transactions. Accordingly, unchecked exploitation of the ocean environment has mortgaged the future while accruing a massive ecological debt.

Acute and chronic condition

As dreary as it is to contemplate, we need to be honest about the extent of this ecological debt. There is now unequivocal evidence of significant decadal-scale biological changes, which have had adverse consequences for the abundance and occurrence of marine species. Not surprisingly, BC's marine waters, sea bottom, and coastline have been degraded by human activities. Many (if not most) marine mammals, land mammals, and seabirds that rely on the marine food web for their livelihood are already burdened by petroleum-based pollutants. This contamination is widespread, inescapable, and persistent. As evidence of immune and reproductive deficiencies mount, scientists are becoming increasingly concerned that marine dependent species are physiologically stressed.[153] To complicate matters, some of these stressed species are genetically compromised, the result of being driven to near extinction by a century of commercial exploitation. With lowered genetic diversity (from reduced genetic variability), the ability of species to respond or adapt to additional disturbance is reduced.

Add to this the implications of a rapidly changing food base (trophic collapse), the result of overfishing, habitat destruction, and a warming planet. By themselves these cumulative trends have serious consequences, but continuing climate change may compound them, creating further unpredictable disturbances. Alarmingly, these changes are often occurring faster than we can understand them. Although the exact course of climate change is unknown, we should be preparing for the effects. We should be acting with far greater prudence (the precautionary principle), if for no other reason than to avoid the perils of hidden consequences. Climate change could be the catalyst that tips this already fragile system. Paradoxically, the choice to lift the oil tanker moratorium and approve the Enbridge pipeline would only intensify the disruption.

Our concerns are not new, nor are the problems that precipitated them. They are, however, a powerful argument in favour of urgent action to counter these perils; a reminder for all of us to set a better example by restraining our own biodiversity-threatening activities while adopting more sustainable behaviours. Clearly, there has already been a substantial price to pay for human progress. Moreover, if we fail to halt and reverse the juggernaut of our unsustainable lifestyles, our coastal ecosystem may pay the price. Although easy to confuse value with price, the unspoken question remains: is society willing to sacrifice the integrity of the coastal environment for the pursuit of monetary profit?

Given the condition of our coastal environment, we need to begin treating the ocean as an unhealthy patient in desperate need of care. We know that the primary problem is chronic unsustainable use and abuse, so our focus now must be to halt, slow, and reverse destructive activities, while eliminating the possibility of new threats. The bottom line is that the 35-year-old "now-you-see-it-now-you-don't" moratorium on oil tanker traffic must be legislated and codified into law. From here, other protective and restorative actions can be taken, so the priceless and irreplaceable BC coast can continue its unparalleled evolutionary journey.

A future of past abundance

One hundred years ago, humpback and fin whales were hunted from the waters of Whale Channel around Gil Island. In the course of our surveys, we had several sightings of large baleen whales (including one sighting of 26 fin whales) in this general region. Queen Charlotte Sound and Dixon Entrance are likewise the historic habitats for blue, sperm and sei whales. Again, the slow return of these animals is occurring. Yet the proposed routes for Enbridge's oil tankers traverse directly through these feedings grounds. Additionally, the proposed route transects potential critical habitat for northern resident killer whales. The projected level of shipping increases will occur synonymously in the habitat of these recovering whales and oil tankers place them at high-risk in the event of a spill.

Conversely, we could embrace the fact that whales are re-establishing their historic presence in BC's coastal waters and take action to protect their feeding grounds and other important habitats.

Similarly, changes to fisheries management and securing protection of habitat might rebuild the region's 2,500 plus salmon runs. Using an ecosystem perspective, these salmon runs could then be managed to sustain terrestrial species that earn part of their living from the sea. Likewise, the management of herring could also reflect the critical role they play in the maritime food web. Changing the way we manage humans and their activities might be enough to give our tired maritime environment the reprieve needed to recover and become healthy once again. We are poised at a crossroads. Polling on which direction to follow shows that for most British Columbians, the preferred path is an oil-free coast. The question remains, however, whether those within government who will determine the fate of BC's coast, *recognize exactly what's at stake.* Maybe more importantly, do they care?

Appendix 1: Endnotes

1 Czech and Daly 2004, Czech 2009.
2 Kaiser 2002
3 Meyer et al. 2004.
4 Royal Society of Canada, 2004.
5 Thomas et al. 2007
6 Czech et al. 2009.
7 Czech and Daly 2004, Czech 2009, Jackson et al. 2001.
8 Vitousek et al. 1997.
9 Pauley 1995.
10 Odum 1987.
11 Pauley 1995.
12 Myers and Worm 2003, Pauly et al. 1998.
13 Worm et al. 2009.
14 Jackson et al. 2001
15 Jackson et al. 2001
16 Worm et al. 2006
17 Wade et al. 2007
18 Eggers et al. 2005, Schweigert et al. 2009.
19 DFO 2006
20 Alverson et al. 1994.
21 Kelleher 2005.
22 Jackson et al. 2001.
23 Jackson et al. 2001
24 Vitousek et al. 1997.
25 http://www.sciencedaily.com/releases/2008/02/080215121207.htm
26 Vitousek et al. 1997.
27 http://www.pmel.noaa.gov/co2/OA/A_Sea_Change_Excerpt.mov
28 Fabry et al. 2008
29 Hester et al. 2008.
30 Orr et al. 2005.
31 Orr et al.2005
32 NOAA http://marinedebris.noaa.gov/info/patch.html#1
33 NOAA http://marinedebris.noaa.gov/info/patch.html#1
34 Gulland and Greig
35 From Algalita Marine Research Foundations 1999 survey of plastic
36 As described in Thomas et al. 2007
37 Buckland et al. 2004
38 Best and Halpin 2009
39 Schipper et al. 2008
40 Williams and Thomas 2007
41 Taylor et al. 2007
42 Heise et al. 1996
43 Pike and MacAskie 1969
44 Gregr et al. 2006, Reilly et al. 2008
45 Hipfner 2005.
46 Burger 2002.
47 Rodway 1991
48 Piatt et al. 1990
49 EVOS Trustee Council 2009
50 Burger 2002
51 National Research Council, 1995.
52 National Research Council, 1995.
53 "Because most of this information was obtained through studies of dead animals that had stranded, the actual cause of death is uncertain. In Texas, however, a stranded pygmy sperm whale, which was taken into captivity, died later from the effects of plastic garbage bags, a bread wrapper, and a corn chip bag ingested while in the wild (O'Hara et al., 1987). Analyses of the stomach contents of sperm whales at an Icelandic whaling station from 1977 to 1981 revealed plastic drinking cups and children's toys as well as large pieces of fishing nets. Because sperm whales readily ingest and subsequently regurgitate the hard parts of prey, principally fish bones and cephalopod beaks, small pieces of plastic are thought to pose no significant problem. But in one case, an ingested fishing net weighing 139 pounds was considered to be large enough to cause eventual starvation of the sperm whale. Other marine mammals that have died as a result of ingestion of debris include a northern elephant seal and a Steller sea lion (Mate, 1985)." Pg 332 National Research Council, 1995.
54 Mate 1985
55 Baker and Bamford 2009
56 Darimont et al. 2004.
57 Hobson and Sealy 1991; Verbeek 1998.
58 Darimont et al. 2003; 2004; 2009.
59 Darimont et al. 2008.
60 Hildebrand et al. 1999.
61 Darimont and Paquet 2000; Paquet et al. 2006; McAllister and Darimont 2007.
62 Darimont and Paquet 2000.
63 Christenson et al. 2005.
64 Reimchen et al. 2003, Helfield and Naiman 2001, Wilkinson et al. 2005.
65 Cederholm et al. 1999.
66 Raincoast (unpublished data).
67 e.g. Bergman 1936 [Grizzly Bears]; Payne 1975 [Black Bears]; Hahn 2001 [cougars]; Nelson and Mech 1984 [wolves and deer].
68 Webb 1988.
69 Nichol et al. 2002
70 Trites and Larkin 1996, NMFS 2007
71 Rosen 2009
72 Olesiuk 2008
73 Olesiuk 2008.
74 Bigg 1985, Bigg 1988
75 Olesiuk 2008.
76 Andrew Trites (Marine Mammal Research Unit) and Peter Olesiuk (Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo) unpublished data cited in Heise et al. 2003
77 Olesiuk and Bigg 1988
78 Ford et al. 2007
79 Heise et al. 2003
80 Olesiuk 1999.
81 Exxon's estimate. Other estimates are as high as 144 million litres (38 million US gallons).
82 Peterson et al. 2003
83 Should be considered minimum estimates.
84 Peterson et al. 2003
85 Matkin et al. 2008.
86 EVOS Trustee Council http://www.evostc.state.ak.us/Recovery/status.cfm
87 Matkin et al. 2008
88 Matkin et al. 2008
89 EVOS Trustee Council 2009
90 EVOS Trustee Council 2006
91 EVOS Trustee council 2009
92 Zock et al. 2007
93 Peterson et al. 2003
94 EVOSTC 2009
95 Peterson et al. 2003
96 Vanem et al. 2007
97 Etkin et al. 2003
98 Transportation Safety Board Report on the *Cosco Busan*

99 Vanem et al. 2007
100 Synovate polling July 2008. Commissioned by Dogwood Initiative with funding assistance from Raincoast and other ENGOs.
101 According to the Enbridge 2008 brochure, 11 crude and 3 condensate tanks
102 Enbridge 2009
103 LOS shipping report
104 Gerald Graham presentation to the Priddle Panel in 2004. Anderson and LaBelle (2000) cite that between 1974 and 1999 there were 278 crude oil spills of 1,000 or more barrels around the world
105 OSB 2003 Fate of oil in the sea III
106 Report and Recommendations of the West Coast Offshore Exploration Environmental Assessment Panel (April 1986) Chapter 3: Regional Settings.pdf http://www.empr.gov.bc.ca/OG/offshoreoilandgas/ReportsPresentationsandEducationalMaterial/Reports/Pages/WCOffshoreExplorationEnviroAssessmentPanel.aspx Accessed March 18, 2010
107 Pipeline route map on Enbridge's website at http://www.northern-gateway.ca/project-info/route-map accessed March 15, 2010
108 Enbridge 2010 Email correspondence
109 Van Hinte, 2005
110 Map drawn by Alaska Department of Natural Resources and published in the Exxon Valdez Oil Spill Restoration Plan: Update on Injured Resources and Services 2006.
111 Nichol et al. 2009
112 Based on Ford 2006
113 Living Oceans Society (LOS) 2008
114 http://www.cbc.ca/cp/world/050217/w021772.html Accessed February 2005
115 LOS 2008
116 Identified in Fisheries and Oceans Canada Resident Killer Whale Recovery Strategy 2008
117 Transportation Safety Board report on the Q of the N http://www.tsb.gc.ca/eng/medias-media/majeures-major/marine/m06w0052/mi-m06w0052.asp
118 BC Provincial web site http://www.env.gov.bc.%ca/eemp/incidents/queen_north_06.htm 121 in pdf
119 The volume of a "reportable" spill varies from state to state and province
120 Page 32 Enbridge 2008 Corporate Social Responsibility report by Enbridge 2,190,543 litres (13,777 barrels)
121 http://www.doj.state.wi.us/absolutenm/templates/template_share.asp?articleid=24&zoneid=3
122 Enbridge 2009
123 Enbridge 2009
124 BC OSB 2003
125 BC OSB 2003
126 Cameron 2009 (Pacific States/British Columbia Oil Spill Task Force 2009 Annual Report)
127 Fraser and Ellis 2009
128 Wiese and Robertson 2004
129 Piatt and Ford 1996
130 O'Hara and Morgan 2006
131 BC Crown speech 2007-
132 Williams and O'Hara 2010
133 Williams and O'Hara 2010.
134 e.g. Darimont and Paquet 2000; Smith and Partridge 2004; Ben-David et al. 1995; Verbeek 1998.
135 Jewett et al. 2002; Peterson et al. 2003.
136 Bowyer et al. 2003.
137 Peterson et al 2003.
138 Price et al 2008
139 Commercial fishery closures for wild salmon on the Central and North coast and Haida Gwaii (Areas 3-10) in 2008 and 2009 include: Area 9 and 10 sockeye (2008, 2009), Area 7 sockeye (2008, 2009) Area 1-5 chum (2008, 2009), Area 6-10 chum (2008) Area 6-10 pink (2008), Area 9, 10 pink and chum (2008, 2009). Some directed fisheries on enhanced (hatchery runs ex. Pallant, Kitimat, Kitisoo, McLaughlin) have occurred.
140 Price et al. 2008.
141 Marty et al. 1997.
142 Peterson et al 2003.
143 Marty et al.1997.
144 Heinz et al. 2000
145 Peterson et al. 2003
146 Willson et al. 1998.
147 Peterson et al. 2003.
148 Raincoast reports: Small Streams Survey Final Report 2003-2006 and Raincoast – Gitga'at Coastal Monitoring Preliminary Report, 2008 Field Season This should be properly quoted and the references included in the list
149 Trail et al. 2007
150 Paquet et. Al. 2006
151 Matkin et al. 2008
152 Bearzi 2009
153 Arthur et al. 2009

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