Current knowledge and need for further research regarding environmental impact of the proposed Gateway Pacific Terminal

25 August 2013

1. Introduction

Research Can was established in June 2013 in direct response to the realization that the scoping process for the Environmental Impact Statement (EIS) for the Gateway Pacific Terminal (GPT) at Cherry Point, WA identified critical areas for which targeted research is needed. The GPT is designed to export 50 million tons annually of Powder River Basin coal to Asia, and most of the research necessary to fully understand its potential impact is not `fundamental' in nature. Rather, there is a time-sensitive, specific need to answer a set of environmental, health, and economic research questions. These questions are motivated by the issues specified by Whatcom County, the Washington Department of Ecology, and the U.S. Army Corps of Engineers in their bid to produce a joint EIS for the proposed GPT and Burlington Northern Santa Fe (BNSF) Railway Custer Spur track expansion.

The purpose of this document is to outline the need for the targeted, site-specific research projects that are important for building a comprehensive EIS for GPT. It is intended to provide an understanding of the nature of the work that Research Can supports, and to convince potential supporters that such work comprises a set of time-sensitive projects whose results are needed to guide important public policy decisions.

We first provide a brief background on the importance of using the best available science to inform key public policy decisions. We then introduce the areas of research prompted by the GPT EIS. The rest of the paper provides a detailed explanation of each area of research, what has already been accomplished in each and where further work is required, and a proposal for projects.

While Research Can was created as a response to near-term research needs to inform GPT decision-making, the scoping and EIS process plays out year in

and year out on a variety of environmental, health, and economic issues in communities across the nation. We view our reactions to the GPT proposal as a pilot project to test a model by which to fund targeted research for policymaking. With the assistance of Research Cans Science Advisory Board of recognized scientific leaders, it will identify key research that needs to be done. This paper identifies those needs.

1.1 Best available science

In the United States, many of the laws governing environmental conservation and management stipulate that the best available science be used as the basis for policy and decision making [75]. The Washington Administrative Code (WAC 365-195-905) provides assessment criteria to assist in determining whether information constitutes the best available science, i.e., by having been developed through a valid scientific process. A valid scientific process is one that produces reliable information that is useful in understanding the consequences of regulatory decisions and in developing policies and regulations. Best available science comprises the following elements [75]:

· A clear statement of objectives;
· A conceptual model, which is a framework for characterizing systems, making predictions, and testing hypotheses;
· A sound experimental design and a standardized method for collecting data;
· Statistical rigor and sound logic for analysis and interpretation;
· Clear documentation of methods, results, and conclusions; and
· Peer review.

Science provides a basis for measuring changes in the environment, understanding how ecosystems operate, and predicting how a change in environmental conditions might affect ecosystem operation. While science alone cannot provide a basis for choosing human goals with respect to the management of these systems, it can inform society about the consequences of its management goals and actions. Detailed and objective science must exist in order to provide this basis, however, and for GPT, many objective questions remain unanswered and major uncertainties remain.

The scope of the EIS proposed by Washington State agency leaders suggests they are sympathetic to the importance of, and committed to adhering to, the

best available science criteria as a means for providing information to policymakers. Research Can is committed to identifying and supporting research that contributes to these goals.

1.2 Research areas

On 31 July 2013, Whatcom County, the Washington State Department of Ecology, and the US Army Corps independently determined the preliminary scope, or subject matter, they will require in the EIS.

Subject matter mandated by the Corps under the National Environmental Policy Act (NEPA) includes an extensive analysis of GPT's onsite and nearby impacts, including environmental effects on wetlands, shoreline and intertidal areas, water and air quality, cultural and archeological resources, fish and wildlife, and noise and vibration. Whatcom County and the Washington State Department of Ecology, acting under the State Environmental Policy Act (SEPA), require detailed assessment of rail transportation impacts near the project site and in affected out-of-state areas; an assessment of how the project would affect human health; an evaluation of greenhouse gas emissions from terminal operations, rail and vessel traffic, and end-use coal combustion; and a general assessment of cargo ship impacts beyond Washington waters. Although not specified in the EIS mandate, assessment of vessel traffic impact within Washington waters is also important to include in the analysis.

In this document, we identify specific areas for which targeted research is needed. These include air quality and its impact on human health; water quality and its impact on ecosystem health; increased risks of rail and vessel accidents and coal spills; and land-use effects on culture.

Within each area, we explain the potential for adverse impacts due to GPT; current information that addresses certain aspects and the need for further study; and a proposal for further research that will help inform the EIS.

2. Human health and air quality impacts[1]

The Washington Department of Ecology and Whatcom County mandated that the EIS for the proposed GPT include an assessment of how the project would affect human health, including impacts from related rail and vessel transportation. In this section, we address the deleterious effects of diesel exhaust and coal dust from trains carrying coal from Wyoming and Montana to GPT on air quality and human health. Should GPT receive a permit, an additional 18 trains per day, 9 filled with coal on the way to Cherry Point and 9 returning empty, would traverse the greater Seattle metropolitan region and other major urban areas in Washington.

2.1 Health impacts related to diesel exhaust and fugitive coal dust

In 2012, diesel exhaust particulate was established by the World Health Organization as a carcinogen responsible for lung cancer [44]. A large body of peer-reviewed literature indicates that exposure to mobile source emissions causes a wide range of health impacts: asthma, respiratory illness, reduced lung function, and low birth weight and premature birth in newborns; as well as increased mortality, especially in vulnerable populations such as infants, children, the elderly, and pregnant women [8, 13, 29, 38, 39, 48, 56, 78, 79, 82, 83]. Increased train traffic with existing locomotives would exacerbate these effects.

In addition, transporting coal by train and creating stockpiles for shipping sends fugitive coal dust into the air, which further diminishes air quality and subjects nearby populations to dust inhalation [1, 23, 73]. Health effects from exposure to coal dust include increased asthma, wheezing, and cough, especially in children and the elderly. While dust can be reduced by spraying carloads with surfactants, this procedure is not completely effective as PRB coal dries out and cracks in transit, becoming increasingly dusty as trains approach Seattle [40].

Heavy metal toxins present in coal dust include lead, mercury, nickel,

[1] The human health and air quality section is based largely on scoping comments submitted by Dr Arthur Winer, Distinguished Professor Emeritus at UCLA School of Public Health, and Michael Riordan, PhD.

cadmium, selenium, manganese, antimony, and arsenic. Coal dust may also be carcinogenic due to the presence of polycyclic aromatic hydrocarbons (PAH), a recognized carcinogen. Exposure to any of these can lead to serious health problems. As one example, the human kidney accumulates cadmium which leads to renal toxicity and, if not controlled, kidney failure. Cadmium burdens have also been linked to osteoporosis and breast cancer [12, 22, 49, 50, 58].

The air pollution resulting from diesel trains transporting coal presents major health problems and must be addressed.

2.2 Current knowledge and need for further research

Over the past decade, the focus of regulators and researchers has shifted from regional air pollution problems to more localized, direct exposures of populations to emissions from mobile sources such as motor vehicles and diesel locomotives. This change is the result of several factors. First, in most U.S. airsheds, the National Ambient Air Quality Standards (NAAQS) for the six criteria pollutants are either already met or are close to being met.

Second, air pollutant exposure assessments now focus specifically on determining what people are breathing where they spend their time, rather than using air quality measurements at a few widely spaced outdoor air monitoring stations to infer exposure of people many kilometers away.

Reliance upon data from, or models related to, the standard fixed site monitoring network of local or regional air quality agencies in western Washington will fail to capture the true air pollutant exposures caused by rail traffic associated with the proposed GPT project. The few widely scattered air-monitoring stations are of little value in characterizing the highly localized exposures of populations to the pollutants they are actually breathing in proximity to mobile source emissions. Federal agencies U.S. Environmental Protection Agency (EPA) and the National Highway Transportation Agency, as well as state air agencies such as California's Air Resources Board, now require localized air monitoring adjacent to, and downwind of, transportation-related 'line sources.' These measurements are intended to characterize more accurately the exposures and health impacts of air pollution from these major sources.

It is important to emphasize that focusing only on the criteria pollutants

regulated under the NAAQS fails to address the potential health effects of other critical, but presently unregulated, combustion-related species. Some of the most important pollutants include diesel exhaust particulate (DEP), ultrafine particles from locomotives (those less than 100nm diameter), and heavy metals and polycyclic aromatic hydrocarbons (PAHs) found in both exhaust and coal dust.

DEP has been declared a toxic air contaminant by the World Health Organization, EPA and the California Air Resources Board. Ultrafine particles emitted from combustion are able to penetrate cell walls and cross the blood-brain barrier [44]. They are thought to be a 'causative agent' in fresh combustion emissions responsible for degrading health, and exposure to them has been linked to cardiovascular and respiratory hospital admissions [38, 59].

The California Air Resources Board conducted a risk assessment in 2000 for a large railyard at Roseville, CA, which has no nearby truck traffic, thereby allowing assessment of health impacts only from diesel locomotives. In this study, Hand et al. identified cancer risk levels of 500 per million in the neighborhood immediately downwind of the railyard, and 100 per million further downwind in the Roseville community [37, 38]. Aerosols downwind were shown to contain toxic heavy metals whose concentrations increased with decreasing particle size, suggesting that concentrations could be even higher in the ultrafine particle size range that corresponds to very high lung capture efficiencies and are linked to ischemic heart disease [14, 15]. Fifteen different carcinogenic or mutagenic PAHs were found in diesel samples downwind of Roseville [14, 15].

Additionally, it is well recognized that mobile source emissions in urban areas often have disproportionate health impacts on minority and low income populations due to the higher concentrations of low socioeconomic status and minority neighborhoods in the vicinity of roadways and railways [41, 42, 43, 46]. A previous study of disadvantaged populations' exposure adjacent to freeways traversing Seattle and Portland clearly indicates the potential for coal-related rail traffic through minority and high poverty neighborhoods in Seattle and other major urban centers in Washington State [5]. This would render such populations subject to disproportionate diesel locomotive exposure, health and noise impacts compared with more affluent areas of the region.

It is worth noting that communities have often been built around existing railroads, which has led to the low-income concentration issue. In response to the increase in railway traffic which is likely to further impact low socioeconomic status neighborhoods, a possible mitigation effort would be to push for railroads to improve their infrastructure to prevent auto traffic congestion by building flyovers, underpasses, etc. in urban corridors where the impact of increase rail traffic will become a problem.

2.3 Proposal for further study

A thorough understanding of health effects of all the pollutants, including gasses and particles, released from diesel trains and coal dust, the size ranges and concentrations of the particles, and the potential for human exposure due to meteorological conditions is critical for evaluating the health impacts should GPT receive a permit. Research Can advocates projects to:

· Model the downwind concentrations of air pollutants and resulting human population exposures within 3 km of the rail lines that would be used by diesel locomotives, along the entire length of those rail lines. Include impact zones in each major city, plume rise and spread of locomotive emissions, and coal dust coming off railcars. This would be accomplished by acquiring detailed wind speed and direction data as well as information regarding source quantities and concentrations. It would be a simple modeling study that uses existing data to demonstrate the potential extent of exposure, and would assess present day emissions as well as modeling future emissions due to additional trains.

· Parameterize the above concentration model to consider the exposure to unregulated pollutants including diesel exhaust particulate, ultrafine particles from locomotives, and heavy metals and PAHs from both coal dust and locomotives. This would be done by considering the composition of both coal and locomotive exhaust, and evaluating the transport properties of each size particle. The study would assess the potential health impacts that could result from chronic exposure over periods as long as decades for populations living or working within the downwind plumes of GPT-related diesel locomotives. It should combine existing epidemiology data and emissions data to build links between concentrations and illness/mortality.

· Determine the extent and combined impacts of regulated and

unregulated emissions at, adjacent to, and downwind of the GPT facility itself. This work would include models of fugitive coal dust released from storage piles and during transfers to and from these piles, and dust losses from rail cars waiting unloading. In addition, the carbon monoxide pollution due to smoldering coal in storage piles should be evaluated, as the Intalco aluminum smelting plant next door is the worst carbon monoxide emitter in Whatcom County, and their combined emissions may exceed EPA limits [61]. Again, this would assess present day emissions as well as modeling future emissions due to additional trains.

· Model the potential for environmental justice-related disparities in exposure, health, noise and other impacts resulting from GPT-related rail transport of coal, as well as from the associated diesel locomotive emissions, through minority and low-income neighborhoods in major urban centers of southern and western Washington. Data collection and assessment, as well as estimates of exposures and health impacts in minority and low-income populations, should be guided by Presidential Executive Order 12898 of February 11, 1994, entitled Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations [68].

· The results from these modeling studies, and other existing data, could be combined to conduct a benefit-cost analysis that leads to an economic measure of health impacts.

3. Ecosystem health and water quality[2]

The EIS requires an extensive analysis of the proposed GPT project's onsite and nearby impacts, including adverse environmental impacts on wetland, shoreline and inter-tidal areas; water and air quality; and fish and wildlife, among other possible effects. In this section, we address the extent of fugitive coal dust from GPT and the potential for large coal losses into the waters around Cherry Point, as well as contamination by leaking bunker fuel, and its effects on water quality and ecosystem health in the Salish Sea.

[2] The ecosystem health and water quality section is based largely on scoping comments submitted by Michael Riordan, PhD; H. Gary Greene, Professor Emeritus, Moss Landing Marine Labs/Tombolo; Joseph Gaydos, VMD, PhD, Chief Scientist and Wildlife Veterinarian, UC Davis Wildlife Health Center; San Olson, DVM, US Navy veteran, and first responder for Island Oil Spill Association; Richard Steinhardt, PhD; and Robert Johnson, PhD.

3.1 Spreading coal in a marine ecosystem

As proposed, GPT could have significant impact on the fragile marine community in the Salish Sea. A principal concern is the possibility that coal, with its known carcinogens and neurotoxins, could escape from the terminal and find its way into Georgia Strait waters and beyond.

Fine particles of coal dust can easily be wafted by winds far away from intended destinations in storage piles and ships, and the process of loading over 50 million tons of coal each year presents dangers to the Cherry Point Aquatic Reserve because of the high chance of coal escaping into the water. Even if loading could be made 99.999% efficient, over 50 tons would be deposited there annually. That corresponds to a loss of one ton per shipload, which would accumulate to hundreds of tons over the decades of operation. It is important to determine the maximum losses that can occur while still avoiding damage.

A 2006 publication in the International Journal of Coal Geology, which examined coal accumulations on the sea floor around the Westshore Terminals, showed that extensive deposits had accumulated during a 22-year period [51]. Coal concentrations of over 10% were observed at 350 meters from the terminal, and 2% concentrations occurred as far as 1,750 meters away. Some of this may be due to fugitive coal dust from the storage piles and other operations at the terminal, which loses an average 715 tons of coal per year via this process [18]. But according to the 2006 article, the dominant fraction is due to losses during ship loading.

Losses of coal into the waters of the Cherry Point Aquatic Reserve would inevitably occur during the normal loading process at the proposed GPT. The principal questions remaining include how large these losses might be, given the gale-force winds often experienced at Cherry Point, and how significant the adverse impacts could be on the marine environment especially in the Cherry Point Aquatic Reserve surrounding the proposed piers. The process by which loading occurs also affects potential for loss: at Westshore, coal is transferred via conveyor belt to holds, and multiple holds are filled with coal simultaneously. This means that carrier hatches remain open during the entire loading process. Winds can easily loft coal dust during this process, with an upward force that increases as the square of the windspeed, thus there is potential for large losses during transfer and loading.

From the storage piles and coal carriers, the dust can travel northwest or southeast along the Whatcom County coast and toward the San Juan Islands both via the strong currents and winds that characterize the area. They can smother local eelgrass beds or be taken into the marine food chain.

3.2 Ecosystem health and water quality

The Salish Sea comprises approximately 17,000 square kilometers of marine water that is habitat to 37 species of mammals, 172 bird species, nearly 300 species of marine and anadramous fishes and over 3000 macroinvertebrates [27, 28, 66]. As of January 2011, jurisdictions within the region had listed 113 of these species as threatened, endangered, of concern, or candidates for the listing, which suggests an ecosystem that is not in a good position to survive incremental stressors.

If toxic materials derived from coal dust, diesel emissions, and vessel fuel are ingested by marine organisms low in the food chain, they become concentrated in tissues of wildlife that feed upon them. Such toxins include copper from rail traffic that would be released at GPT railway terminals upland from the Cherry Point herring spawning grounds. The adverse impact on this genetically unique strain of herring could be significant and should be studied. Direct impacts on bottom feeders such as crabs are also a concern. And while the dangers from some heavy metals in coal dust such as lead, mercury, and arsenic are widely known, lesser-known cadmium is found in smaller quantities but its toxicity is such that it may pose an even greater danger. Contamination from all such toxins would be cumulative over the lifetime of the terminal.

In addition to toxic coal dust particles, increased acidification of the ocean due to carbon dioxide absorption threatens the marine food chain. This would be exacerbated by burning the additional 50 million tons of coal per year that are shipped from GPT, and other emissions associated with the terminal. Acidification causes pteropod, which are small snail-like sea creatures important to many fish including pink salmon, and other foraminifera including clams and mussels, to experience thinning and dissolution of their calcium-carbonate exoskeletons. This has led to increased morbidity and mortality at current oceanic pH levels that were not predicted to be reached until 2038 [69]. Additionally, potential local impacts to investigate include

whether coal dust in water leads to acidification, and whether it affects the ability of eelgrass and other vegetation to take up carbon dioxide [3].

Acidification threatens any organism dependent on calcium carbonate for a shell or body parts, and fish eggs and other larvae at the base of the marine food web are similarly threatened. In past epochs, mass extinctions occurred when oceans became similarly acidic. However, because the chemical changes occurred over many centuries, the ancestors of today's sea creatures were able to adapt to that slowly souring environment. The speed and scale of today's chemical changes may not allow marine organisms to evolve species-preserving strategies.

Vessel transport introduces further threats to water quality. Should one of the massive, single-hulled coal carriers run aground, there is a good chance that up to 2-million gallons of bunker C fuel could be spilled, which is equivalent to about 20% of the Exxon-Valdez spill in Prince William Sound, Alaska. However, bunker C fuel is much more toxic than the crude oil spilled in Alaska. A spill of 1 million gallons of bunker C fuel in 1993 in Tampa, FL, affected the benthic community for at least the next 8 years [60]. In a cold-water environment like the Salish Sea, the microbial breakdown of this contaminant will be even slower.

The increased vessel traffic also increases the likelihood of introducing new invasive species into the Salish Sea. With 400-500 ships arriving at the terminal per year, each carrying up to 17-million gallons of Asian ballast water, the region's waters could become further contaminated with invasive species that displace endemic species if proper ballast water handling plans are not strictly followed.

The marine waters of the Salish Sea are important culturally and economically to the First Nations of Washington and British Columbia (see Section 5). In addition to supporting recreational and commercial fisheries, the watchable wildlife of the region support $2 billion/year industry [62]. Impact to water quality and the marine ecosystem thus extends to the businesses and livelihoods they support.

3.3 Current knowledge and need for further research

The extreme winds occurring periodically at Cherry Point exacerbate

conditions for spreading coal dust into the waters. According to University of Washington meteorologists, gale-force NE winds can be expected annually at Cherry Point and this is reflected in recent NOAA records. Hurricane-force winds occur in the vicinity every 5-10 years [55], and in 1990 northeast winds exceeding 90 mph caused extensive damage in Whatcom and San Juan Counties. Cherry Point sits within the area that experienced winds gusting over 30 meters per second (68 mph), close to hurricane-force. Such conditions can thus be expected to occur several times during operations of the proposed GPT. The entire facility should therefore be designed to prevent or at least limit release of coal into Cherry Point waters in these extreme events.

The potential for coal dust loss at both low and extreme wind speeds must be determined. Extreme winds will severely impact the coal storage piles. A 100 mph wind exerts over ten times the forces as does 30 mph wind, so the effects will be correspondingly greater and turbulent effects may come into play. If covered storage facilities are employed instead, they should be designed to survive hurricane-force winds. Whatever kind of storage is used in the proposed project, extensive computer simulations will be needed to understand these forces and the likely coal losses due to typical and extreme wind patterns into the Georgia Strait. Similar simulations of the air flow around carriers docked at the piers would be helpful in determining coal losses in loading and the maximum allowable windspeeds for such activities to occur. NOAA anemometer data since 2007 from Cherry Point document wind conditions to 6-minute resolution and would help make such simulations possible.

Toxins released from the coal affect certain organisms in devastating ways. Shellfish actively sequester cadmium in their bodies due to the presence of a metal-binding protein. This bioaccumulation can greatly magnify the concentrations of cadmium in the environment by factors as high as 40,000-fold. As a result, any organism that consumes these shellfish will obtain a dose of cadmium that is much greater than ambient environment levels [3, 7, 9, 21, 24, 54, 64]. Crabs are particularly sensitive to this toxin [3]. Organisms at higher trophic levels that consume shellfish can suffer adverse consequences from consumption of cadmium-containing tissues. This has been well documented for avian species [10, 20]. Further study is needed to address increased shellfish mortality and decreased population levels, increased cadmium burdens in shellfish tissue with resultant accumulation in wildlife, and potential shutdown of recreational and commercial harvests and/or

increased human body burdens.

Copper pollution from rail traffic will also impact the unique Cherry Point herring population. One study suggests that 9.4 kg of copper per kilometer of railway track would be released each year [45]. Larger amounts of copper would be released at GPT railway terminals and in maneuvering areas upland from the Cherry Point Herring spawning grounds [45]. Further study of the cumulative release of rail traffic generated copper into marine and wetland environments and the potential effects of pollution on the local marine and wetland ecosystems is needed.

Once the pollutants reach the water, they infiltrate all trophic levels. A critical forage fish found at Cherry Point Aquatic Reserve, the Pacific sand lance (PSL), serves as the primary link between zooplankton and higher order predators, and is a vital food source for 29 species of birds, 10 species of marine mammals, and 30 species of commercial and sport fishes [4, 30, 32, 57, 70, 71, 76]. The region's ecosystem depends on the large biomass of such forage fish that transfer phytoplankton production to higher trophic levels [25, 19, 26, 52, 85, 86]. The PSL is known to deposit its spawn on sandy upper intertidal beaches throughout the Puget Sound Basin, and roughly 10% of the shoreline of the Puget Sound basin comprised of fine-grained beaches has been found being used by spawning sand lance. Based on the known habitat types of PSL and the tendency of the fish to occupy clean, well-aerated substrates, the possibility that coal particles could be swept onto beaches and into the subtidal habitats is of paramount concern.

Although PSL is a key component in the Northwest Straits regional food web, little is known of this species' burrowing behavior, relative abundance and distribution, local spawning habits, and spawning and burial substrates [70, 71, 76]. PSL are dependent upon benthic sediment habitats to burrow into and, therefore, are most often associated with fine- to coarse-grain sand- or gravel-oxygenated sediments [4, 57] in nearshore inter-tidal and shallow (to 100 m) habitats [4, 63, 65, 67, 71, 84]. Sand-wave fields consisting of ripples, waves and dunes are common in such areas, and several fields have been mapped near the San Juan Islands [6, 11, 33]. Although such fields may be present in and around GPT, no clear bathymetric images exists to confirm this.

Other adverse effects on spawning grounds would be brought about by unburnt coal damage to the surrounding marine vegetation. When present in

marine environments in sufficient quantities, coal will have physical effects on organisms including abrasion, smothering, alteration of sediment texture and stability, reduced availability of light, and clogging of respiratory and feeding organs [2]. Forage fish and salmonoids depend on eelgrass beds for spawning grounds. Coal in the water can damage these beds by blocking sunlight due to suspended particles and smothering them due to accumulation. There is a lack of studies that focus on toxic effects of contaminants of coal at the organism, population or assemblage levels, in a marine environment, but the limited evidence indicating bioavailability under certain circumstances suggests that more detailed studies would be justified [2].

Finally, forcing native species to compete with invasive ones has already been shown to be detrimental in Puget Sound. Asian invasive oysters have already decimated the region's endemic oyster species, and several examples show other invasive species impacting commercially important fish and shellfish populations in the region. Potential stressors should be evaluated for every species of concern.

3.4 Proposal for research

A detailed EIS requires thorough understanding of how toxins and pollutants can spread to the water from diesel trains and coal storage, the specific effects of different toxins, and the higher level ecosystem effects caused by damage to different organisms. Research Can advocates projects to:

· Model the likely impacts of gale- and hurricane-force winds (at, say, 30, 60, and 90 mph) upon the coal-delivery system and storage facilities, and how many tons of coal would be released into Cherry Point waters in such an event. NOAA data regarding Cherry Point wind speeds and directions will be crucially important for implementing this model. Questions to address include the impacts of turbulent air flows around storage piles and coal carriers, how far into Georgia Strait coal dust will travel during such extreme winds, what measures or procedures can be used to lessen the chances of such releases, and what procedures can be established for bulk carriers docked at the wharf to follow during extreme wind events.
· Investigate, based on experience at other coal terminals, the coal loading efficiencies that could be achieved in actual practice under normal operating conditions, and the quantity of coal that would

consequently escape into the waters of the Cherry Point Aquatic Reserve and settle at the sea floor or drift further. The experience at Westshore Terminals near Vancouver, BC, would be particularly relevant in this regard, as conditions are similar and detailed studies of coal issues have already been done. This would also address measures that could be taken by terminal managers to reduce coal lost; for example, by mandating stricter operating procedures or specifying wind speeds at which loading should be halted and the ship hatches closed [51].

· Study the impacts of coal on Cherry Point herring, Dungeness crab that feed on the sea floor, indicator species such as PSL, and eelgrass beds which provide vital habitat and help filter carbon dioxide out of the seawater. This should include attention to how fugitive coal particles will be incorporated into natural sediments, how concentrated the particles will become, and how far the particles will be distributed from their point of entry into the water. Thus impact on marine life a few miles distant from Cherry Point must be included, for example by locating and mapping all subtidal PSL habitats within close proximity to GPT and along the bulk carrier routes.

· Determine the long-range economic costs to the shellfish industry in Washington state due to ocean acidification from burning the coal shipped from GPT; and the economic losses in terms of jobs and capital infrastructure as a result of losing important marine species. The recreational fishing and tourism industries should also be considered.

· Determine the existing background levels of cadmium and other heavy metals in areas that will be subject to coal dust accumulation and direct absorption, both in the vicinity of Cherry Point and in waters along the rail routes from the Powder River Basin. Estimates should be made of future accumulations of toxins that can be expected from current, planned, and proposed future activities, and of bioaccumulation rates of cadmium in all species that will consume and be consumed by other organisms as part of the food chain, including humans. This work will include calculations of the quantity and range of coal dust dispersal due to prevailing winds and be completed for nearshore and sediments.

· Propose a process by which the coal transfer from storage to vessel could be made to reduce the time during which coal remains exposed to the atmosphere. This would require an understanding of how the conveyor belt/loading process is planned to occur, calculation of how much loss would occur via the standard method, and calculation of how

much this loss could be reduced by changing the transfer and loading process.

· Analyze the GPT-specific and cumulative effects of carbon dioxide emissions on ocean acidity due to burning of exported coal and fine particles in coal smoke that are transported back to the US from end use sites. This would require an understanding of gas phase pollution from Asia, and the survival time in air of fine particles relative to the circulation time at this latitude.

4. Rail and vessel accidents[3]

The EIS is supposed to include a general assessment of cargo ship impacts beyond Washington waters, and a detailed assessment of rail transportation impact on communities in Washington and out of state. Although not specified, assessment of impact caused by vessel traffic in Washington waters themselves is also important to include in the analysis. The most catastrophic of such impacts would be the case of a large-scale collision or derailment.

The GPT would require an increase in not only the number of large vessels traversing the waterways in Puget Sound (Georgia Strait, Haro Strait, Rosario Strait, and Strait of Juan de Fuca), but also the frequency of rail traffic impinging on communities from Montana and Wyoming through the Seattle-Tacoma metropolitan area and north to Bellingham in Washington. Based on numbers alone, the increased traffic increases the likelihood of a sea or rail accident. Many examples from the past decade show the disastrous impact on human and ecosystem health when such an event occurs.

4.1 More accidents at sea

Projections of almost one thousand additional bulk carrier transits of the Haro or Rosario straights each year mean that even a 0.1% chance of a major accident would correspond to one occurrence every year. As an illustration of what constitutes a 'major accident,' we take the 2012 collision of the bulk carrier Cape Apricot attempting to dock at Westshore Terminals berth no. 2 off the coast of Vancouver, British Columbia.

[3] The rail and vessel accidents section is based partly on scoping comments submitted by Michael Riordan, PhD.

The carrier drifted wide of its mark and plowed through the causeway and conveyor belt linking Westshore's coal storage facilities to its berth at wharf no. 1. About 300-400 feet of the coal-conveyor system were destroyed, spilling 30 to 120 tons of coal into the Georgia Strait and proving disastrous for local ecology [34]. The cause of the incident was attributed to a combination of the human error, equipment malfunction, and severe weather conditions.

During the Westshore incident, southerly winds gusted to 20 mph between 1 and 2 am that morning, sufficient to drive the large carrier off course and into the trestle [17, 80]. Moving the ship in high winds could be considered a misjudgement in itself. Much stronger south and SSE winds will be encountered at Cherry Point. Not only could bulk carriers unaided by tugs be similarly blown into a wharf or coal conveyor system, but in a worst-case scenario, a large bulk carrier could be driven into adjacent tidelands, spilling coal or leaking fuel into Cherry Point Aquatic Reserve waters.

Other spills illustrate the non-uniqueness of a similar scale event. In November 2007, the container ship Cosco Busan spilled over 53,000 gallons of bunker fuel into the San Francisco Bay after it struck the Delta Tower of the San Francisco/Oakland Bay Bridge in thick fog. The National Transportation Safety Board blamed pilot and crew negligence, lack of communication between Pilot and Master as well as between ship and Vessel Traffic Safety, failure to maintain foghorns on the bridge, and malfunctioning radar to be among the causes of the accident [72]. Tidal flows in the Bay caused the spill to spread rapidly, impacting public beaches as far south as Pacifica and killing thousands of birds and herring eggs [36]. Bay Area fisheries suffered and fishing seasons were postponed, with total monetary damages estimated at $2.1M for the ship, $1.5M for the bridge, and more than $70M for the oil spill cleanup [72]. Thick fog and herring spawning grounds are intrinsic parts of the GPT environment, and human negligence cannot be avoided.

Another disaster in 1993 saw a freighter and two tug-assisted barges collide near the entrance of Tampa Bay, FL, resulting in a fire on one of the barges and causing a spill of 32,000 gallons of jet fuel, diesel, and gasoline plus 33,000 gallons of heavy oil fuel into the bay. Thirteen miles of beaches were impacted and birds, sea turtles, mangrove habitat, salt marshes, shellfish beds, and other marine resources suffered injuries. Restoration projects are still underway twenty years later [60].

A near miss occurred in November 2012, when a 279-meter container ship loaded with freight ran aground in Prince Rupert Harbor, northern British Columbia, while trying to avoid a fishing vessel. In this incident no harm was done as the ship hit soft sand, but the potential for disaster was imminent should the vessel have hit rocky ground.

4.2 More accidents on land

Rail accidents will also increase should the predicted 18 additional transits of coal trains occur each day for bringing coal to Washington (9 filled with coal, 9 returning empty). Multiple derailments occurred over the summer in 2012: seven cars derailed from a Union Pacific train in Kansas, and a Norfolk Southern train jumped off the track and back on again, spilling enough coal to cause three railroad crossings to be shut down. Both were carrying Powder River Basin coal, and the derailments led to dispersals of toxic coal dust. Another derailment near Chicago involved a bridge collapse that killed two motorists driving underneath. Further, tracks warp due to heat, worsening the chance of derailment, and the coal dust itself poses a serious threat to the stability of the track structure [68, 16].

One only needs to look as far as the news to read about freight rail accidents in 2013. In rural Pennsylvania, a freight train struck a bus carrying impaired seniors and younger adults. Two freight trains in Missouri collided at a rail intersection and caused an overpass to collapse, injuring 7 people. As this paper is being written, a new report has been issued about a sodium hydroxide leak after a Louisiana train derailed. More trains means a higher probability of such accidents occurring per year.

4.3 Proposal for further study

Research Can advocates investigations that will help quantify damage likely to occur due to increased rail and vessel traffic, and should:

· Survey rail accidents that have occurred in the past decade, particularly those involving freight, as well as the frequency and speed of trains that would be involved in transporting coal to and from Cherry Point. A statistical comparison and parametric study would consider the effects of vessel speed, wind conditions, volume of freight, fuel losses,

dollars spent on legal/cleanup/health issues, and human injury. This study should also include models to identify ways in which infrastructure improvements could make crossings safer on flyovers, underpasses, etc.

· Survey sea accidents that have occurred in the past decade, particularly those involving freight, as well as the frequency and speed of vessels that would be involved in transporting coal to and from Cherry Point. A statistical comparison and parametric study would consider the effects of vessel speed, wind conditions, volume of freight, fuel losses, dollars spent on legal/clean-up/health issues, and human injury.

· Extend the recent Vessel Traffic Risk Assessment (VTRA) report to evaluate added risks of oil and bunker fuel spills due to the additional carrier traffic that will result from GPT activities [77].

· Analyze the force of wind and waves upon a large Capesize coal carrier in gale-force winds impinging on the vessel from various directions, plus measures to counter these forces at dockside or in swift tidal currents.

· Analyze the chances that a bulk carrier will collide with the GPT wharf, the coal delivery system, or another vessel during a typical year of operations; how many tons of coal and gallons of bunker fuel would likely enter Cherry Point waters in such accidents; and what mitigations and procedures can be adopted to lower the chances of such collisions and the ensuing associated releases of coal.

5. Beyond air and water quality[4]

The EIS requires extensive analysis of the GPT project's impacts on cultural and archaeological resources, and of noise and vibration from rail and vessel transportation on surrounding communities. In this section, we address effects of the proposed GPT on the local people and land, including Lummi Nation treaty rights, increased traffic congestion due to railroad crossings,

[4] The rail and vessel accidents section is based partly on scoping comments submitted by Michael Riordan, PhD; Dr Charles Greene, Director of Ocean Resources and Ecosystems Program at Cornell University Department of Earth and Atmospheric Sciences; San Olsen, DVM, US Navy veteran, and first responder for Island Oil Spill Association; Richard Steinhardt, PhD; Joseph Gaydos, VMD, PhD, Chief Scientist and Wildlife Veterinarian at UC Davis Wildlife Health Center; and Tim Ballew II, Chair, Lummi Indian Business Council.

vessel-related noise, and the potential for geological hazards to wreak havoc on terminal structures.

5.1 Interacting with the people and the land

If the GPT were built and operated, it would significantly impair the Lummi Nation treaty right to harvest crab and fish at Cherry Point, and thus the Lummi way of life. The potential for impact to the fishing industry as described in Section 3 would extend far beyond an economic problem: rather, it would violate the treaty rights of a sovereign nation.

Non-native peoples stand to suffer major disturbances due to increased rail traffic and noise as well. Families living near the BNSF rail line between Tacoma and Bellingham have already experienced coupling noise, engine noise, and structural damage from rail vibrations due to normal traffic on the lines next to their homes. These factors have led in the last five years to a negotiated noise reduction and speed agreement with BNSF in lieu of a class action lawsuit. Adding 18 more mile-long trains per day would lead to stand-stills at railway crossings and enormous disruption of traffic patterns, with the associated rise in exhaust emissions from idling vehicles, within the densely populated Seattle-Tacoma metropolitan area.

It is not only rail traffic and noise that will cause disturbances for the denizens of the Puget Sound area. Underwater vessel noise from the increased traffic to and from the coal terminal would interfere with marine mammals that use sound to communicate, to detect prey and predators, and to navigate and forage. Underwater noise levels in parts of the Salish Sea have been monitored, but there is a knowledge gap in understanding the influence that increased noise will have on marine populations.

Seismic activity in the region is also cause for concern. The Pacific Northwest is one of the most seismically active regions in the contiguous United States, according to geologists and seismologists at the US Geological Survey. Especially worrisome is the potential of a magnitude 8 to 9 earthquake occurring along the Cascadia fault off the Oregon and Washington coastlines [31]. A series of smaller faults from Seattle north to Vancouver can also lead to damaging earthquakes of magnitude 6 to 7. Based on experiences from the 1989 Loma Prieta and the 1994 Northridge earthquakes in California, major damage can occur many miles from the quake epicenter in areas characterized

by minor faults or loosely compacted soils, which can liquefy due to the intense shaking. Thus the possible adverse impacts of such earthquakes - and a subsequent tsunami - must be addressed in the design and operating procedures of the proposed GPT, especially given the potential for large coal releases into Cherry Point waters that can occur in such events.

Storing coal at the GPT site creates challenges. While PRB coal contains 20% moisture when mined, it dries out in transit, so the storage piles at GPT will be dusty. Millions of gallons of water per day would be required as a coal dust suppression measure, and would likely come from the Nooksack River east of Cherry Point, thus affecting salmon runs and farming communities along it. Further, dousing PRB coal with water leads to an exothermic reaction that will cause the storage piles to smoulder, releasing noxious gases like carbon monoxide.

5.2 Current knowledge and need for further research

5.2.1 Native tribes

The tribal treaty rights have a long and troubled history in Native American struggles for cultural survival. The Lummi were the first reefnet fishermen in the Pacific Northwest, and their 'First Salmon Ceremony' offered respect to the salmon as a gift for all the people. Ancestral reef-net fishermen were buried at Cherry Point, and possession of the area has never been returned to the Lummi people after the Bureau of Indian Affairs allegedly sold the land in violation of treaties [47]. Further, Washington state enacted laws to restrict Indian fishing to within reservation boundaries. However, in 1974, Federal District Judge H. Boldt mandated that it was the tribes who had been forced to cede their right to fish to non-Indian settlers, not the other way around.

In 1979, a Supreme Court ruling on the Boldt decision reaffirmed that 50% of the salmon resource of Washington State be allocated to Indian treaty tribes, in part as compensation for the ceding of lands by the Northwest tribes to the state. The decision also affirmed the fishing tribes' right to have the salmon habitat protected, in the form of veto power over future industrial development that might impact critical habitat for salmon stock. Indeed, the Lummi tribe sought closure for conservation purposes of the herring fishery that extended along Cherry Point and was worth about $3 million per year to the treaty fishermen, thus sacrificing fishing income for the sake of restoration

of future herring population [47]. Their 'sacred obligation' to the Cherry Point area, reflected in the Boldt decision and its implications, must be maintained. To demonstrate the extent to which Lummi cultural and economic livelihood would be affected by the ecosystem damage from GPT effects discussed in Sections 3 and 4, a detailed analysis is needed to determine impact on specific fisheries, taking into account how similar impacts have affected other Northwest tribes and been handled by legal bodies.

5.2.2 Noise and congestion

The well being of non-native communities also requires further study, particularly regarding how the coal-related rail traffic will be managed to reduce congestion. Increased traffic congestion and slow speeds across hundreds of railway crossings would be particularly problematic for at-grade crossings. This could also decrease economic productivity due to delaying people's commutes to work.

The Washington State 2010-2030 Freight Rail Plan provides guidance for rail initiatives and investments that will preserve the ability of the rail system to efficiently serve its customers, while facilitating freight system capacity to improve mobility and reduce congestion [35]. It also reflects strategies to implement rail benefit/cost analysis required by legislature, broaden understanding of rail issues for all stakeholders, and increase the effectiveness and energy efficiency of the rail system. The plan includes an assessment of freight rail needs in Washington based on data provided directly by the state's freight railroads, ports, public agencies, and other key stakeholders; however, this assessment was conducted in 2009. A new assessment needs to be done in light of new data from the past several years including impacts of all the proposed new terminals on the railway system.

Increased noise and congestion is not just an issue for people. Physicist Val Viers' hydrophone monitoring at Lime Kiln off the west side of San Juan Island has provided 16 months of underwater noise data in 2011 and 2012, showing noise levels in the Haro Strait to range from background levels of 100 dB to 125 dB when a large ship passes by (www.orcasound.net). Speedboats create local high levels of sound, and ships' noises fill underwater canyons and can be heard for miles. Commercial shipping dominates the noise spectrum at both low and high frequencies. The effects of anthropogenic noise on marine mammals are a function of sound intensity, frequency, duration, acuteness,

and repetitiveness [74]. The 125 dB noise levels during typical large ship passages limit orca communication near the shore to less than 100 m, and it would be even worse for orcas closer to the passing ship. Further analysis is needed to distinguish sound levels of various kinds of ships, and show how noise levels affect orcas' feeding and other behavioral patterns.

5.2.3 Key geological hazards

Finally, subsurface effects must be considered when assessing any site for a large construction project. This is particularly important in a region such as the Cascadia subduction zone, which is a very long sloping fault that extends from northern Vancouver Island to northern California. Here, the oceanic crust of the Juan de Fuca plate sinks beneath the North American continental plate offshore of Washington and Oregon. The vast area of this fault makes it capable of producing very large earthquakes. Historically, the Cascadia fault has been the site of magnitude 8+ earthquakes, and geological evidence suggests that these have occurred every 300 to 600 years and been accompanied by tsunamis. Strain associated with plate boundary deformation leads to further crustal faults and folds.

The Cherry Point region, along with the land traversed by the rail lines in Washington, lies in this seismically active area and an earthquake has the potential to lead to large coal releases into the air or water. A recent article identified two nearby active faults: the Sandy Point fault a few miles offshore of the proposed site, and the Birch Bay fault inland of it. According to the authors, these faults are capable of producing earthquakes in the 6.0 to 6.5 moment magnitude range and may pose a seismic hazard to the lowland urban corridor between Vancouver, Canada, and Bellingham [53]. The likelihood of such an event is as yet undetermined, and impacts of ground motions due to these local geological features upon terminal structures should therefore be included in computer simulations that guide terminal design.

A large earthquake on the Cascadia fault would likely be followed by a tsunami. A tsunami would reach Cherry Point about two hours after a major quake and would last for several hours, as predicted in recent computer simulations by state and national agencies [81]. Not only is a teleseismically generated tsunami a concern, but locally generated tsunamis, particularly those not associated with seismic events, may also occur. Unless measures are taken to counteract earthquake and tsunami forces, a bulk carrier could be

torn from its moorings at the stationary wharf by ground motions and surging waters. Large coal releases from the vessel and delivery system would be likely to occur. The probability of a magnitude 8 to 9 Cascadia earthquake and its resulting tsunami occurring in the possible terminal lifetime exceeds 10% according to recent analyses [31]. Demonstrably effective measures and procedures to deal with this eventuality must be designed and required for implementation before GPT can receive a permit.

5.3 Proposal for research

Research Can advocates investigations that will provide a thorough understanding of how ecosystem damage would affect tribal cultures and treaty rights, especially of the Lummi Nation; the extent to which noise, vibrations, and congestion can wreak havoc on local communities; and the potential for large-scale geological events. Investigations will:

· Analyze the adverse cultural and socioeconomic impacts upon Native American tribes of the Salish Sea that would be caused by declines in crab, salmon and herring populations due to ocean acidification, coal spills, toxic contamination, and noise pollution due to GPT. This study would be undertaken in context of treaty rights violations that have occurred historically.
· Assess freight rail needs in Washington based on newer data than the 2009 report and including additional rail traffic due to all the proposed Northwest coal terminals. It should include a public health study regarding how chronic noise will affect the health and quality of life of people, and how noise, pollution, and inconvenience due to congestion would impact property values.
· Determine the number of graded crossings and train speeds that should be expected from the increased GPT rail traffic, and model the increased road traffic idling times that would result. This should include a site study for Marysville, WA, which has 16 at-grade railway crossings, in order to provide data from which to develop a model of how such an increase in rail traffic would affect small communities. Additionally, a model could be developed to show the economic loss of productivity due to railway crossings causing delayed commutes.
· Determine underwater noise levels due to various kinds of ships, especially Capesize and Panamax coal carriers. These levels would have to be evaluated for ships passing crucial areas of marine mammal

activity such as the west shore of San Juan Island and the Strait of Juan de Fuca. It should also assess how these noise levels might affect marine mammals' feeding, communication, and migration patterns.

· Investigate the chance that a magnitude 6 or greater earthquake will occur on nearby faults during the lifetime of the terminal, and the probable impacts of the corresponding ground shaking on parts of the coal-delivery system located over the water. This study would also evaluate relative motions of the piers and coal carriers tied up to them at the moment a quake strikes.

· A parallel study should evaluate the likely scenarios for tsunami actions at Cherry Point in the event of earthquakes, both regional (Pacific-wide) and local. Both studies should include suggested measures and procedures that can be adapted to reduce coal losses and mitigate the likelihood of major releases into Cherry Point waters.

6. Summary

Environmental impacts of the proposed GPT are likely to affect air and water quality, human and ecosystem health, and have the potential to affect the people and land ranging from the immediate vicinity of the terminal, through the metropolitan areas of Washington state, and along the rail lines to the Powder River Basin.

The Washington State Department of Ecology and Whatcom County have mandated an EIS which requires, among other things, a detailed assessment of transportation impacts near to and far from the project site and how the project would affect human health; an evaluation of greenhouse gas emissions from terminal operations, rail, and vessel traffic; and a general assessment of coal carrier impacts beyond Washington waters. It is also important to assess coal carrier impacts within Washington waters themselves.

Analyses of these impacts are critical for providing information to policymakers as they evaluate decisions regarding permitting and management of GPT. These analyses must adhere to the criteria of best available science. It is the goal of Research Can to ensure that the best available science does exist and is specific to the impacts and sites in question. In support of this goal, Research Can advocates and will seek support for research projects that can be broadly grouped into the following areas:

· Air quality impacts on human health. Such projects include modeling studies to determine downwind concentrations of air pollutants from diesel exhaust and fugitive coal dust and the resulting human population exposures along the entire lengths of rail lines and near the GPT facility itself. Modeling studies also need to include environmental justice-related disparities in exposure, health, and noise.
· Water quality impacts on ecosystem health. Such projects include analysis of wind speed and direction data at Cherry Point, coal-loading efficiencies at the terminal, and how such factors translate into amounts of coal that would be released into the Salish Sea, along with how far currents would transport the particulate matter. Studies must include how coal will impact forage fish such as Pacific sand lance as well as herring, salmon, Dungeness crab, and eelgrass, and the resulting economic cost to the fishing industry. Specific toxins must be considered when evaluating impacts.
· Increased incidence of rail and sea accidents. Such projects include a survey of rail and sea accidents that have occurred in the past decade, along with the precise number, frequency, and speed of trains and ships that would be involved in transporting coal to and from GPT, to assess the likelihood of a catastrophic event due to increased rail and vessel traffic.
· Interactions with people and the land. Such projects include analysis of the cultural and socioeconomic losses to Native American Tribes of the Salish Sea from further decline in salmon and herring populations; public health studies regarding how chronic noise will affect the health and quality of life of people; studies of the extent to which vessel noise would adversely affect marine life; and an investigation of the chances that a earthquakes, tsunamis, and other natural hazards will occur during the lifetime of the terminal.

The goal of Research Can is to provide the site-specific scientific support necessary to evaluate the impact of any project which will be intricately tied to the natural environment.

Objective scientific analysis of how a project like GPT affects these resources is critical for producing the information that will be used as a basis for policy and decision making. Such informed decision making is, in turn, necessary for adherence with the principle of resource management that considers past, present, and future generations. Statements issued by Whatcom County, the

Washington Department of Ecology, and the U.S. Army Corps of Engineers document the scope of study for the EIS under the National Environmental Policy Act and State Environmental Policy Act. The projects proposed by Research Can support this scope and extend it to other areas that need to be considered.

References

[1] M Ahern and M Hendryx. Cancer mortality rates in Appalachian mountaintop coal mining areas. Journal of Environmental and Occupational Science, 1(2):63-70, 2012.
[2] MJ Ahrens and DJ Morrisey. Biological effects of unburnt coal in the marine environment. Oceanography and Marine Biology: An Annual Review, 43:69-122, 2005.
[3] M Ahsanullah and GH Arnott. Acute toxicity of copper, cadmium, and zinc to larvae of the crab Paragrapus quadridentatus (H. Milne Edwards), and implications for water quality criteria. Marine and Freshwater Research, 29(1):1-8, 1978.
[4] PJ Auster and LL Stewart. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic): Sand lance (Ammodytes spp). Technical Report. Connecticut Univ., Groton (USA), 1986.
[5] C Bae, G Sandlin, A Bassok, and S Kim. The exposure of disadvantaged populations in freeway air-pollution sheds: a case study of the Seattle and Portland regions. Environment and Planning B: Planning and Design, 34(1):154, 2007.
[6] JV Barrie, KW Conway, KP, and HG Greene. Large-scale sedimentary bedforms and sediment dynamics on a glaciated tectonic continental shelf: Examples from the Pacific Margin of Canada. Continental Shelf Research, 29(5):796-806, 2009.
[7] M Baudrimont, J Schafer, V Marie, R Maury-Brachet, C Bossy, A Boudou, and G Blanc. Geochemical survey and metal bioaccumulation of three bivalve species (Crassostrea gigas, Cerastoderma edule and Ruditapes philippinarum) in the Nord Medoc salt marshes (Gironde estuary, France). Science of the Total Environment, 337(1):265-280, 2005.
[8] R Beelen, G Hoek, PA van den Brandt, RA Goldbohm, P Fischer, LJ Schouten, M Jerrett, E Hughes, B Armstrong, and B Brunekreef. Longterm effects of traffic-related air pollution on mortality in a dutch cohort (NLCS-AIR study). Environmental Health Perspectives, 116(2):196, 2008.
[9] LI Bendell. Cadmium in shellfish: The British Columbia, Canada experience mini-review. Toxicology letters, 198(1):7-12, 2010.
[10] LI Bendell. Sea ducks and aquaculture: the cadmium connection. Ecotoxicology, 20(2):474-478, 2011.
[11] J Blain. Pacific sand lance (Ammodytes hexapterus) present in the sand

wave field of central San Juan Channel, WA: Abundance, density, maturity, and sediment association. PhD thesis, Class Paper, Fish 492 Research Apprentice, Friday Harbor Labs, Friday Harbor, WA, 2006.
[12] JJ Brown. Treaty rights: twenty years after the Boldt decision. Wicazo Sa Review, 10(2):1-16, 1994.
[13] B Brunekreef, NAH Janssen, J de Hartog, H Harssema, M Knape, and P van Vliet. Air pollution from truck traffic and lung function in children living near motorways. Epidemiology, 8(3):298-303, 1997.
[14] TA Cahill, DE Barnes, NJ Spada, JA Lawton, and TM Cahill. Very fine and ultrafine metals and ischemic heart disease in the California central valley 1: 2003{2007. Aerosol Science and Technology, 45(9):1123-1134, 2011.
[15] TA Cahill, TM Cahill, DE Barnes, NJ Spada, and R Miller. Inorganic and organic aerosols downwind of California's Roseville Railyard. Aerosol Science and Technology, 45(9):1049-1059, 2011.
[16] BNSF Railway Company. Weekly performance report. Technical report, August 2013.
[17] Weather Station CYVR. Sand heads buoy data. Technical report, Weather Station CYVR, 2012.
[18] E de Place. Are coal export terminals good neighbors? Sightline Daily, March 2011.
[19] EJ Duffy. Early marine distribution and trophic interactions of juvenile salmon in Puget Sound. PhD thesis, University of Washington, 2003.
[20] R Eisler. Cadmium hazards to fish, wildlife, and invertebrates: a synoptic review. Number 2. Fish and Wildlife Service, US Department of the Interior, 1985.
[21] CX Feng, J Cao, and L Bendell. Exploring spatial and temporal variations of cadmium concentrations in Pacific Oysters from British Columbia. Biometrics, 67(3):1142-1152, 2011.
[22] E Figueira, A Lima, D Branco, V Quintino, AM Rodrigues, and R Freitas. Health concerns of consuming cockles (Cerastoderma edule L.) from a low contaminated coastal system. Environment International, 37(5):965-972, 2011.
[23] RB Finkelman, W Orem, V Castranova, CA Tatu, HE Belkin, B Zheng, HE Lerch, SV Maharaj, and AL Bates. Health impacts of coal and coal use: possible solutions. International Journal of Coal Geology, 50(1):425-443, 2002.
[24] JM Frazier. Bioaccumulation of cadmium in marine organisms. Environmental Health Perspectives, 28:75, 1979.
[25] KL Fresh. Distribution and abundance of fishes occurring in the nearshore surface waters of northern Puget Sound, Washington. M.S. Thesis,

University of Washington, 1979.
[26] KL Fresh, RD Cardwell, and RR Koons. Food habitats of Pacific salmon, baitfish, and their potential competitors and predators in the marine waters of Washington, August 1978 to September 1979. State of Washington, Department of Fisheries, Progress Report No. 145, 137, 1981.
[27] JK Gaydos, L Dierauf, G Kirby, D Brosnan, K Gilardi, and GE Davis. Top 10 principles for designing healthy coastal ecosystems like the Salish Sea. EcoHealth, 5(4):460-471, 2008.
[28] JK Gaydos and SF Pearson. Birds and mammals that depend on the Salish Sea: a compilation. Northwestern Naturalist, 92(2):79-94, 2011.
[29] U Gehring, AH Wijga, M Brauer, P Fischer, JC de Jongste, M Kerkhof, M Oldenwening, HA Smit, and B Brunekreef. Traffic-related air pollution and the development of asthma and allergies during the first 8 years of life. American Journal of Respiratory and Critical Care
Medicine, 181(6):596-603, 2010.
[30] AC Geiger. Trophic interactions and diurnal activity patterns of the Pacific sand lance, Ammodytes hexapterus, at San Juan Island, Washington. Marine Fish Biology Class Paper, University of Washington, 1987.
[31] C Goldfinger, CH Nelson, A Morey, JE Johnson, J Gutierrez-Pastor, AT Eriksson, E Karabanov, J Patton, E Gracia, R Enkin, et al. Turbidite event history: Methods and implications for Holocene paleoseismicity of the Cascadia subduction zone. US Department of the Interior, US Geological Survey, 2012.
[32] P Goldmark. Cherry Point Environmental Aquatic Reserve management plan. Washington State Department of Natural Resources, 2010.
[33] HG Greene, GD Wyllie-Echeverria, J Bizzarro, V Barry, K Fresh, C Robinson, D Cacchione, D Penttila, M Hampton, and A Summers. Deep-water Pacific sand lance (Ammodytes hexapterus) habitat evaluation and prediction in the Northwest Straits region. Final Report, May 1, 2010 June 30, 2011, to Northwest Straits Commission, Mt. Vernon, WA, 2011.
[34] G Hamilton. Ship crashes into dock at Westshore Terminals, spilling coal into water. Vancouver Sun, December 2012.
[35] PJ Hammond. Washington State 2010-2030 freight rail plan. Washington State Department of Transportation State Rail and Marine Office, December 2009.
[36] S Hampton, G Baker, and A Donner. Natural resource damage assessment for the Cosco Busan oil spill bird injury summary. California Office of Spill Prevention and Response, 2008.
[37] R Hand, P Di, A Servin, L Hunsaker, and C Suer. Roseville Railyard study.

State of California Air Resources Board, 2004.
[38] G Hoek, H Boogaard, Anne Knol, Jeroen De Hartog, Pauline Slottje, JG Ayres, P Borm, B Brunekreef, K Donaldson, F Forastiere, et al. Concentration response functions for ultrafine particles and all-cause mortality and hospital admissions: results of a European expert panel elicitation. Environmental Science & Technology, 44(1):476-482, 2009.
[39] G Hoek, B Brunekreef, S Goldbohm, P Fischer, and PA van den Brandt. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. The Lancet, 360(9341):1203-1209, 2002.
[40] RJ Hossfeld and R Hatt. PRB coal degradation: Causes and cures. PRB Coal Users Group, 2005.
[41] D Houston, M Krudysz, and A Winer. Diesel truck traffic in lowincome and minority communities adjacent to ports: environmental justice implications of near-roadway land use conflicts. Transportation Research Record: Journal of the Transportation Research Board, 2067(1):38-46, 2008.
[42] D Houston, P Ong, J Wu, and A Winer. Proximity of licensed child care facilities to near-roadway vehicle pollution. Journal Information, 96(9), 2006.
[43] D Houston, J Wu, P Ong, and A Winer. Structural disparities of urban traffic in southern California: Implications for vehicle related air pollution exposure in minority and high-poverty neighborhoods. Journal of Urban Affairs, 26(5):565-592, 2004.
[44] International Agency for Research on Cancer (IARC). Diesel engine exhaust carcinogenic, June 2012.
[45] International Solid Waste Association World Congress, Hamburg, Germany. Long-term Management of Track Ballast- A Case Study In Prevention and Recycling of Large Waste Flows, November 2010.
[46] JO Jacobson, NW Hengartner, and TA Louis. Inequity measures for evaluations of environmental justice: a case study of close proximity to highways in NYC. 2004.
[47] Jewell Praying Wolf James. The search for integrity in the conflict over Cherry Point as a coal export terminal. Whatcom Watch, August 2013.
[48] NAH Janssen, B Brunekreef, P van Vliet, F Aarts, K Meliefste, H Harssema, and P Fischer. The relationship between air pollution from heavy traffic and allergic sensitization, bronchial hyperresponsiveness, and respiratory symptoms in Dutch schoolchildren. Environmental Health Perspectives, 111(12):1512, 2003.
[49] L Jarup and A Akesson. Current status of cadmium as an environmental health problem. Toxicology and Applied Pharmacology, 238(3):201-208, 2009.

[50] L Jarup, M Berglund, CG Elinder, G Nordberg, and M Vanter. Health effects of cadmium exposure - a review of the literature and a risk estimate. Scandinavian Journal of Work,
Environment & Health, 24 Suppl 1:1-51, 1998.
[51] R Johnson and RM Bustin. Coal dust dispersal around a marine coal terminal (1977-1999), British Columbia: The fate of coal dust in the marine environment. International Journal of Coal Geology, 68(1):57-69, 2006.
[52] SW Johnson, JF Thedinga, and KM Munk. Distribution and use of shallow-water habitats by Pacific sand lances in southeastern Alaska. Transactions of the American Fisheries Society , 137(5):1455-1463, 2008.
[53] HM Kelsey, BL Sherrod, RJ Blakely, and RA Haugerud. Holocene faulting in the Bellingham forearc basin: Upperplate deformation at the northern end of the Cascadia subduction zone. Journal of Geophysical Research: Solid Earth (1978-2012), 117(B3), 2012.
[54] JR Larison, GE Likens, JW Fitzpatrick, and JG Crock. Cadmium toxicity among wildlife in the Colorado Rocky Mountains. Nature, 406(6792):181-183, 2000.
[55] CF Mass, S Businger, MD Albright, and ZA Tucker. A windstorm in the lee of a gap in a coastal mountain barrier. Monthly Weather Review, 123(2):315-331, 1995.
[56] R McConnell, K Berhane, L Yao, M Jerrett, F Lurmann, F Gilliland, N Kunzli, J Gauderman, et al. Traffic, susceptibility, and childhood asthma. Environmental Health Perspectives, 114(5):766, 2006.
[57] TL Meyer, RA Cooper, and RW Langton. Relative abundance, behavior, and food habits of the American sand lance, Ammodytes americanus, from the Gulf of Maine. Fish. Bull, 77(1):243-253, 1979.
[58] TS Nawrot, JA Staessen, HA Roels, E Munters, A Cuypers, T Richart, A Ruttens, K Smeets, H Clijsters, and J Vangronsveld. Cadmium exposure in the population: from health risks to strategies of prevention. Biometals, 23(5):769-782, 2010.
[59] A Nel, T Xia, L Madler, and N Li. Toxic potential of materials at the nanolevel. Science, 311(5761):622-627, 2006.
[60] NOAA. Damage assessment, remediation, and restoration program case: Tampa Bay oil spill, FL. Technical report, NOAA, 2013.
[61] WA Northwest Clean Air Agency, Mt Vernon. Personal communication with Michael Riordan, 2013.
[62] Washington Department of Fish, Wildlife, Trade Washington Department of Community, and Economic Development. Wildlife viewing activities in Washington: A strategic plan. Report to the Washington State Legislature,

1979.
[63] WD Ostrand, TA Gotthardt, S Howlin, MD Robards, and JW Orr. Habitat selection models for Pacific sand lance (Ammodytes hexapterus) in Prince William Sound, Alaska. Northwestern Naturalist, 86(3):131-143, 2005.
[64] GG Pesch and NE Stewart. Cadmium toxicity to three species of estuarine invertebrates. Marine Environmental Research, 3(2):145-156, 1980.
[65] JM Pinto. Laboratory spawning of Ammodytes hexapterus from the Pacific coast of North America with a description of its eggs and early larvae. Copeia, 1984(1):242-244, 1984.
[66] Proceedings of the Salish Sea Conference, Vancouver BC. Species of concern within the Salish Sea: changes from 2002 to 2011, November 2011.
[67] T Quinn. Habitat characteristics of an intertidal aggregation of Pacific sandlance (Ammodytes hexapterus) at a North Puget Sound beach in Washington. PhD thesis, University of Washington, 1999.
[68] Federal Register. Safety advisory 2012; buckle-prone conditions in continuous welded rail track. Federal Railroad Administration, (77 FR 41881; 2012-17343), 2012.
[69] JB Ries. Oceanography: A sea butterfly flaps its wings. Nature Geoscience, 5(12):845-846, 2012.
[70] MD Robards, MF Willson, RH Armstrong, and JF Piatt. Sand lance: a review of biology and predator relations and annotated bibliography. Notes, 2000.
[71] MD Robards, JF Piatt, and GA Rose. Maturation, fecundity, and intertidal spawning of Pacific sand lance in the northern Gulf of Alaska. Journal of Fish Biology, 54(5):1050-1068, 1999.
[72] M Rosenker, R Sumwalt, K Higgins, and D Hersman. Marine accident report: Allision of Hong Kong-registered containership m/v Cosco Busan with the Delta Tower of the San Francisco Oakland Bay Bridge, San Francisco, California, November 7, 2007. National Transportation Safety Board, (NTSB/MAR-09/01).
[73] KR Smith, H Frumkin, K Balakrishnan, CD Butler, ZA Chafe, I Fairlie, P Kinney, T Kjellstrom, DL Mauzerall, TE McKone, et al. Energy and human health. Annual Review of Public Health, 34:159-188, 2013.
[74] BL Southall, AE Bowles, W T Ellison, JJ Finneran, RL Gentry, CR Greene Jr, D Kastak, DR Ketten, JH Miller, PE Nachtigall, et al. Marine mammal noise-exposure criteria: initial scientific recommendations. Bioacoustics, 17(1-3):273-275, 2008.
[75] PJ Sullivan, James Acheson, PL Angermeier, T Faast, J Flemma, CM Jones, EE Knudsen, TJ Minello, DH Secor, R Wunderlich, et al. Defining and

implementing best available science for fisheries and environmental science, policy, and management. Fisheries, 31(9):460, 2006.
[76] SC Tribble. Sensory and feeding ecology of larval and juvenile Pacific sand lance, Ammodytes hexapterus. Master's Thesis, University of Washington, 2000.
[77] JR van Dorpe, JR Harrald, JR Merrick, and M Grabowski. Assessment of oil spill risk due to potential increased vessel traffic at Cherry Point. Vessel Traffic Risk Assessment, August 2008.
[78] P van Vliet, M Knape, J de Hartog, N Janssen, H Harssema, and B Brunekreef. Motor vehicle exhaust and chronic respiratory symptoms in children living near freeways. Environmental Research, 74(2):122-132, 1997.
[79] AJ Venn, SA Lewis, M Cooper, R Hubbard, and J Britton. Living near a main road and the risk of wheezing illness in children. American Journal of Respiratory and Critical Care Medicine, 164(12):2177-2180, 2001.
[80] J Wagler. Westshore terminals files lawsuit after ship collision. Business Vancouver, December 2012.
[81] TJ Walsh, VV Titov, A J Venturato, HO Mofjeld, and FI Gonzalez. Tsunami hazard map of the Bellingham area, Washington: Modeled tsunami inundation from a Cascadia subduction zone earthquake. Department of Natural Resources, Division of Geology and Earth Resources, 2004.
[82] GA Wellenius, MR Burger, BA Coull, J Schwartz, HH Suh, Petros Koutrakis, G Schlaug, DR Gold, and MA Mittleman. Ambient air pollution and the risk of acute ischemic stroke. Archives of Internal Medicine, 172(3):229, 2012.
[83] M Wilhelm and B Ritz. Residential proximity to traffic and adverse birth outcomes in Los Angeles County, California, 1994-1996. Environmental Health Perspectives, 111(2):207, 2003.
[84] PJ Wright, H Jensen, and I Tuck. The influence of sediment type on the distribution of the lesser sand eel, Ammodytes marinus. Journal of Sea Research, 44(3):243-256, 2000.
[85] JE Zamon. Seal predation on salmon and forage fish schools as a function of tidal currents in the San Juan Islands, Washington, USA. Fisheries Oceanography, 10(4):353-366, 2001.
[86] JE Zamon. Mixed species aggregations feeding upon herring and sandlance schools in a nearshore archipelago depend on flooding tidal currents. Marine Ecology Progress Series, 261(1):243-255, 2003.

