Impacts of LNG Development to Salmon Habitat on Lelu Island and Flora Bank

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1 Executive Summary

The Skeena estuary mudflats and other intertidal areas have been identified as critical habitats for Skeena River juvenile salmon. Flora Bank supports 50-60% of the eelgrass in the Skeena estuary, and was ranked second only to Inverness Passage as habitat of critical importance for the rearing of juvenile salmon. Of the 376 million juvenile salmon entering the Skeena estuary from the Skeena River watershed, approximately 88% turn north into Inverness Passage, and ultimately pass over Flora Bank. Both location and habitat quality make Flora Bank an extremely important juvenile salmon rearing area. Petronas is now proposing a 1.6 km long suspension bridge over Flora Bank. While this proposed "mitigation" does appear to address some issues with respect to impacts from dredging, many other issues still remain unaddressed:

1. The proposed bridge concept is a significant change from Petronas' EIS/Application and should be sent back to the beginning of the CEAA process for proper design scrutiny and public input.
2. The bridge requires more engineering, geological, meteorological, and oceanographic studies to determine if it is actually a viable proposal.
3. Petronas is currently basing its assessment of impact to Flora Bank on a survey which underestimates the size of the eelgrass bed on Flora Bank, particularly underneath the newly proposed bridge concept. The eelgrass on Flora Bank needs to be resurveyed, preferably in late July or August.
4. It is likely that Flora Bank is in a delicate balance between forces of erosion, such as storm waves and currents, and forces of deposition, such as sediment supply from the Skeena River. Any proposed structure which interferes with the natural movement of sediments in the marine environment must undergo detailed oceanographic modeling to determine if there will be adverse impacts from the changes in sediment supply. Petronas has yet to make public any studies on the effects of their proposed design on sediment transport.
5. Petronas intends to dredge 200,000 m^3 of sediment from their MOF (materials off-loading facility) and dispose of this material at Brown Passage. Subtidal sediments from the MOF have concentrations of dioxins and furans which range from 0.059 to 2.64 pg/g, with values higher than the ISQG (0.85 pg/g) in 5 of 24 samples. According to Environment Canada's new draft guidelines, Petronas cannot use a dispersive site for the disposal of its contaminated dredgeate. To date, Petronas' dispersion models have been inconclusive with respect to determining whether or not Brown Passage is non-dispersive.
6. Dioxins and furans bioaccumulate (become concentrated inside the bodies of living things), and can be a risk to both humans and the ecosystem. A full ecological risk assessment should be required to predict the probability of adverse effects on the ecosystem as a result of dioxin and furan bioaccumulation, and a full human health risk assessment should also be required because a significant percentage of the local population are either First Nations, or practice subsistence living, and thus eat large amounts of country foods. Contaminated sediments can also impact juvenile salmon - juvenile Chinook traveling through contaminated estuaries have an overall rate of survival that is 45% lower than for Chinook moving through uncontaminated estuaries.
7. The Prince Rupert Gas Transmission (PRGT) project will dredge ~300,000 m^3 of sediment for their landfall at Lelu Island. The last 45 m of this landfall trench is through rocky substrates that may require drilling and blasting, potentially causing "serious harm to fish". PRGT states that it intends to return excavated sediments to the trench after lowering the pipe in, and that no trenching activities would yield sediments requiring disposal.
8. Petronas' proposed MOF will destroy 19,833 m^2 of marine riparian habitat, 43 m^2 of intertidal habitat, and 904 m^2 of eelgrass on the NW side of Lelu Island in Porpoise Channel. Additionally, the MOF construction will "alter" 35,905 m^2 of intertidal habitat. The entire MOF shoreline will be hardened and straightened. The location of the MOF is in a region of critical habitat used by juvenile salmon outmigrating from the Skeena River. Fish moving along the shore use the eddies created by shoreline complexity as resting places when they are travelling against the tide. This is particularly important for juvenile salmon, whose swimming speed is frequently less than the velocity of the region's tides. Maintaining shoreline complexity is essential to their survival, and ultimately, return as adults.

9. To date, Petronas' habitat offsetting plans have had inadequate scientific studies and oceanographic current and sediment modelling, little or no consultation with the public, and were potentially likely to cause more habitat destruction than habitat creation.
10. While increased atmospheric CO_2 has generally been considered the culprit behind the current increase in ocean acidification, acid deposition also has the capacity to affect the ocean. This effect is most pronounced near the coasts, which are already some of the most heavily affected and vulnerable parts of the ocean due to pollution, over-fishing, and climate change. Emissions of air pollutants from Petronas' facility are estimated to be as high as 0.62 tpd of SO_2, 14.64 tpd of NO_2, and 14,019 tpd of CO_2 (tpd = metric tons per day). Given the serious concerns that the BC shellfish industry has regarding ocean acidification and its relationship to the recent die-offs of oysters and scallops, coastal areas in BC may already be at risk for ocean acidification. Increased ocean acidification can impact juvenile salmon by causing declines in the organisms on which they feed.
11. Based on the known range of salmonid hearing, sounds generated during pile driving activities are likely to influence both fish behavior and distribution of schooling salmonids within a radius of 600 m from the source.
12. Petronas' proposed facility will have a large number of overwater structures, which include the pioneer dock, the MOF, the bridge/jetty, and the marine terminal. Overwater structures can increase the mortality of juvenile fish using shallow estuarine and nearshore marine environments by creating "behavioral barriers" that can deflect or delay migration (including juvenile salmonids avoidance of swimming beneath overwater structures as a result of shading effects), reducing the availability of prey, and altering predator-prey relationships associated with high intensity night lighting.

2 Introduction - Role of Lelu Island and Flora Bank as Salmon Habitat

The Skeena is the second largest river in the province, and one of the longest un-dammed rivers in the world. The Skeena River estuary is a unique system in that it does not have a single distinct intertidal delta typical of most estuary systems. Instead, suspended sediments are deposited in shoals along the lower river and the channels which connect the estuary to the open ocean, creating a region of extensive mudflats and shallow, intertidal passages. These estuary mudflats and other intertidal areas have been identified as critical habitats for Skeena River juvenile salmon (Higgins and Schouwenburg 1973).

Eelgrass is high value nursery habitat for juvenile salmon. Flora Bank supports 50-60% of the eelgrass in the Skeena Estuary (Fisheries Services 1972 cited by Hoos 1975), and was ranked second only to Inverness Passage as habitat of critical importance for the rearing of juvenile salmon (Higgins and Schouwenburg 1973). Of the 377 million juvenile salmon entering the Skeena estuary region each year, 376 million come from the Skeena River watershed. Based on surveys of juvenile salmon done in 2007 (Gottesfeld *et al.* 2008) and 2013 (Carr-Harris & Moore 2013), it was estimated that the vast majority of these Skeena watershed juveniles (88% or 331 million) turn north into Inverness Passage, and ultimately pass over Flora Bank (Faggetter 2014b). Studies during the 2014 outmigration of juvenile salmon from the Skeena River (Eriksson *et al*. 2014) supported this estimate, showing that 91% of the juvenile salmon traveled north through Inverness Passage, and only 9% entered Telegraph Passage before turning north. Eriksson *et al*. (2014) reported:

> *… the vast majority of migrating young salmon we observed turned off the main-stem of the Skeena and traveled northwest through Inverness Passage. On glassy calm days this could be observed as thousands of little dimples from one end of the channel to the other. On the flood tide these fish would move into the back eddies along the shore line and in particular work their way to the large back eddy formed by Lelu Island at the entrance to Stapleton Passage. Fish that did not turn at Inverness, but instead kept going down the main-stem, were observed dispersed and only in small numbers despite a good deal of effort spent looking in this part of the estuary. No significant concentration of smolts either in the main-stem or out front in the main plume and shore lines of De Horsey, Kennedy or Smith Island were observed.*

Many of these juvenile salmon traveling north along Inverness Passage (over 80%) are epibenthic, or bottom, feeders that depend heavily on shallow, nearshore nursery habitats (Faggetter 2014b). Flora Bank is one of the best quality habitats for epibenthic juvenile salmon, providing both food and shelter from predators (Faggetter 2014b). Therefore, both location and habitat quality make Flora Bank an extremely important juvenile salmon rearing area. However, industrial developments around Flora Bank, Lelu Island, Inverness Passage, and Porpoise Channel have a significant likelihood of causing serious impacts to juvenile salmon outmigrating from the Skeena River. Direct impacts to juvenile salmon, as well as loss of high value juvenile salmon habitat, especially eelgrass, can occur as a result of pile driving, shading, dredging, shoreline infilling, and ongoing sedimentation from activities occurring at the site (Faggetter 2014b).

3 Issues Associated with the Newly Proposed Bridge Concept

Petronas is now proposing a 2.7 km jetty/bridge deck consisting of an approximately 1.6 km suspended span suspension bridge over Flora Bank from Lelu Island to Agnew Bank, and an approximately 1.1 km conventional pipe pile trestle from the suspension bridge to the marine terminal berth in Chatham Sound (Pacific NorthWest LNG Limited Partnership & Stantec Consulting Ltd. 2014). This is a significant change from their EIS/Application. While this proposed mitigation does appear to address some issues with respect to impacts from dredging, many other issues still remain unaddressed:

- The bridge concept represent a large deviation from Petronas' EIS/Application, with many technical details that need to be evaluated in order to determine the overall impact of the proposal. Should Petronas be directed by the government to go back to the beginning of the CEAA process for proper design scrutiny and public input? Large changes to a project should not be pushed through the system without the proper counterchecks and balances. Currently, the public seems to be unable to provide input to the CEAA process on this new mitigation proposal.

- The bridge is both long (1.6 km) and wide (24 m), and is oriented perpendicular to the prevailing winds, which have reached maximum gust speeds of 137 km/h and maximum sustained speeds of 93 km/h. Has the bridge been properly designed to withstand the force of this wind? Remember the "Gallopin' Gertie" (Tacoma Narrows Bridge Collapse – see http://www.youtube.com/watch?v=j-zczJXSxnw).
- Petronas still refuses to admit that there is eelgrass underneath their trestle/bridge. Petronas is currently basing its assessment of impact to Flora Bank on a survey which underestimates the size of the eelgrass bed on Flora Bank, particularly underneath the newly proposed bridge concept. Petronas is also basing their habitat offsetting plans on this underestimated extent, thus reducing the required compensation amount (Faggetter 2014a). The eelgrass on Flora Bank needs to be resurveyed, preferably in late July or August. Furthermore, recent studies in the area have indicated that there may be subtidal eelgrass present on the NW side of Flora Bank. Petronas' estimated impacts of the shading effects on eelgrass by the new bridge concept will be incorrect, as will their estimated requirements for mitigation, until better data on the eelgrass distribution and abundance have been obtained
- There needs to be sediment transport modelling for scouring around the towers and the trestles.
- The bedrock in the region is mainly metamorphic rock, which can break apart quite easily under load. Has a geological/engineering analysis been carried out with respect to the bedrock's capability to safely support the proposed bridge? Has an earthquake analysis been done for the bridge design? In particular, will the towers withstand a significant sized earthquake given the nature of the bedrock?
- Originally, the newly proposed location for the berth was analyzed and rejected because meteorological studies showed that the wind and waves were too strong at this location to allow the required number of ships to berth each year. What has changed to make this site viable now?
- What is Petronas' "fallback" position should the bridge concept fail during actualization? If the project is approved under CEAA, the approval should be very specific as to what is approved (e.g., the bridge concept), and what will not be approved (e.g., the original proposal involving ~7 million m^3 of dredging).

4 Sediment Transport and Ocean Circulation Modelling

Flora Bank, and the eelgrass that is supported by it, are amazingly stable marine features in a high-energy oceanic environment. The bank and its eelgrass coverage have changed little since the first surveys done in 1972 (Fisheries Services 1972 cited by Hoos 1975). Surveys carried out by Borstad Associates Ltd. in August, 1997 (Forsyth *et al.* 1998) and Ocean Ecology in May, 2009 (Faggetter 2009) and again in June, 2013 (Faggetter 2014a) showed similar patterns of sand deposition and eelgrass coverage as the original 1972 survey. This is quite unusual, since sand banks and their associated eelgrass beds are subject to large tidal ranges, strong currents, and heavy winter storm activity in northern B.C. Studies at other sites in the region have shown that strong currents and storm waves produce seasonal sand migration, with the sand moving offshore to sand bars in the winter and back to the intertidal beach area in the summer (Faggetter 2011). Eelgrass beds subject to sediment migration tend to show changes in their distribution patterns both seasonally and annually. However, the surprising constancy of the Flora Bank eelgrass bed suggests that Flora Bank is in a delicate balance between forces of erosion, such as storm waves and currents, and forces of deposition, such as sediment supply from the Skeena River.

Any proposed structure which interferes with the natural movement of sediments in the marine environment must undergo detailed oceanographic modelling to determine if there will be adverse impacts from the changes in sediment supply. In spite of comments in their EIS/Application which seem to recognize this need for sediment transport/oceanographic modelling, Petronas has yet to make public any studies on the effects of their proposed design on sediment transport. Recently, the following statement from Dr. Patrick McLaren, a geologist and a leader in the field of sediment transport and sedimentation dynamics, has been released (T. Buck Suzuki Foundation 2014):

> *Despite exposure to high energy waves and locally strong currents the bank has remained surprisingly stable over a very long period. Dr. McLaren cannot yet predict the impact the proposed large berth structure might have on the bank but hopes to do so following completion of his research on the local sediment dynamics which he expects to have finished by late December. Preliminary results, however, suggest some cause for concern.*
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> *Dr. McLaren believes it is possible that Flora Bank is held in place in part by high energy waves which restore any sand which migrates off the bank. If that dynamic is in fact taking place, the trellis docking structure of Petronas' new design could severely reduce the incoming wave energy enabling sand from the bank to migrate seawards resulting in the gradual deterioration of this important habitat. Furthermore, reduction of energy levels might favour the deposition of mud on the bank reducing the ability for eel grass to grow.*

5 Dredging

Petronas intends to dredge 200,000 m^3 of sediment from their MOF (materials off-loading facility) and dispose of this material at Brown Passage. Their original plans were to dredge ~690,000 m^3 of sediment at the MOF. Petronas states that the change in total dredgeate volume results from the assumption that ~490,000 m^3 of the original amount is now considered to be rock, and will be used for Project construction (Pacific NorthWest LNG Limited Partnership & Stantec Consulting Ltd. 2014). As yet, it is unknown what component of the Project will be constructed from this rock. Their EIS/Application proposed to use waste rock in habitat offsetting plans; however, these plans had inadequate scientific studies and oceanographic current and sediment modelling, little or no consultation with the public, and were potentially likely to cause more habitat destruction than habitat creation (Faggetter 2014a).

Petronas is now proposing a 2.7 km jetty/bridge deck consisting of an approximately 1.6 km suspended span suspension bridge over Flora Bank from Lelu Island to Agnew Bank, and an approximately 1.1 km conventional pipe pile trestle from the suspension bridge to the marine terminal berth in Chatham Sound. As a result of this new proposal, Petronas says that no removal, transportation, or disposal of the originally required ~7 million m^3 of sediment will be conducted at the marine terminal berth (Pacific NorthWest LNG Limited Partnership & Stantec Consulting Ltd. 2014).

The Prince Rupert Gas Transmission (PRGT) project, which will supply gas to Petronas, is proposing to excavate a trench approximately 2 km long, 10 m wide and 3 m deep in the nearshore marine environment at the SE end of Lelu Island. Offshore, this trench would widen to 25 m and continue for another 2.5 km. The trench will require armouring and potentially protection by sheet piles in the intertidal and shallow subtidal zones. The last 45 m of the trench is through rocky substrates that may require drilling and blasting, potentially causing "serious harm to fish" in a region 10 m wide x 45 m long. The total amount of dredgeate produced would be ~300,000 m^3. PRGT states that it intends to return excavated sediments to the trench after lowering the pipe in, and that no trenching activities would yield sediments requiring disposal (Stantec Consulting Ltd. 2014a; Stantec Consulting Ltd. 2014b).

Dredging activities can impact the marine environment by removing the subtidal benthic species and communities that are present, by causing short-term increases in the level of suspended sediment which can give rise to changes in water quality thus effecting marine flora and fauna, and by the settlement of these suspended sediments which can result in the smothering or blanketing of subtidal communities and/or adjacent intertidal communities. If the dredged sediments are contaminated, they may cause acute or chronic toxic responses in organisms, and may potentially result in serious ecological impacts as the toxins get transmitted through the food chain. Contaminated sediments can have significant impacts on juvenile salmon, particularly epibenthic species. Juvenile Chinook traveling through contaminated estuaries have an overall rate of survival that is 45% lower than for Chinook moving through uncontaminated estuaries (Meador 2014).

Petronas' proposed facility is within the effluent plume of the old Skeena Cellulose pulp and paper mill. Consequently, the sediments in and around their proposed facility are contaminated, particularly with dioxins and furans. In a detailed core analysis of subtidal sediments (now the standard protocol required by Environment Canada), the concentrations of dioxins and furans ranged from 0.059 to 2.64 pg/g, with values higher than the ISQG (0.85 pg/g) in 5 of 24 samples (Stantec Consulting Ltd 2014d). The maximum concentrations were reported for the top 0.5 m. Unlike Petronas' project, the PRGT pipeline lies outside of the Skeena Cellulose effluent plume. A detailed core analysis of sediments along their proposed pipeline route shows that concentrations of dioxins and furans were all below the ISQG (0.85 pg/g), with the maximum value being 0.234 pg/g (Stantec Consulting Ltd 2014c).

Dioxins and furans bioaccumulate (become concentrated inside the bodies of living things), and can be a risk to both humans and the ecosystem. At Petronas' proposed dredge site, these substances are found at concentrations which could cause adverse effects in both animals and people. As a result of this, a full ecological risk assessment should be required to predict the probability of adverse effects on the ecosystem as a result of dioxin and furan bioaccumulation, and a full human health risk assessment should also be required because a significant percentage of the local population are either First Nations, or practice subsistence living, and thus eat large amounts of country foods. However, to date, Petronas has only done limited studies on ecosystem and human health risks from dioxin and furan bioaccumulation (Faggetter 2014a).

Safe disposal of contaminated sediments must take into account the risk of bioaccumulation, dispersal of the sediment by currents and waves, and cumulative impacts based on repeated exposures to contaminated sediments. In May, 2014, Environment Canada put out a draft document called "*Interim Guidance for the Assessment of risks from Dioxins and Furans in sediments proposed for Disposal at Sea in Pacific and Yukon Region*". In this document, Environment Canada indicates that sediments which do not in any portion exceed a dioxin and furan concentration of 0.85 pg/g can be disposed of safely at dispersive sites (sites where the dredged material is expected to leave the disposal site due to environmental forces, such as ocean currents). However, sediments which in some portion exceed 0.85 pg/g, but do not in any portion exceed 9 pg/g, can only be disposed of safely at non-dispersive sites (sites where the dredged material remains within the disposal site boundaries), as long as the volume-weighted average concentration of dioxins and furans in the material from the entire dredging project does not exceed 0.85 pg/g. Thus, Petronas cannot use a dispersive site for the disposal of its contaminated dredgeate. At this point, it is unknown whether or not Brown Passage, the proposed disposal site, is dispersive or non-dispersive. In order to determine whether the disposal site is dispersive or not, it is necessary to model how the sediments will travel once they are deposited at the site. To do this, good quality current data is required, particularly data about currents within 1 meter of the sea floor (e.g., bottom currents). ASL did run some models on Brown Passage for Petronas, but none of the current data was close to the bottom, so the models were inconclusive with respect to determining whether or not Brown Passage was dispersive (Stantec Consulting Ltd 2014e).

6 Shoreline Infilling, Hardening, and Straightening

Shoreline infilling, hardening, and straightening result in adverse impacts to shoreline ecological functions and habitat degradation such as

- reduction of refugia for young salmonids.
- decreased habitat for estuarine fishes.
- restriction of native riparian vegetation to small pockets scattered along the shoreline, which results in the isolation of the intertidal flats from inputs of sediment, nutrients, and organic matter (i.e., woody debris) from upland riparian vegetation zones. This isolation degrades the habitat quality of these flats.
- starvation and/or impoundment of beach sediment which diminishes longshore sediment transport.
- exacerbation of erosion.

Shoreline complexity provides a diversity of habitats for marine organisms and promotes high marine biodiversity. Fish moving along the shore use the eddies created by shoreline complexity as resting places when they are travelling against the tide. This is particularly important for juvenile salmon, whose swimming speed is frequently less than the velocity of the region's tides. Maintaining shoreline complexity is essential to their survival, and ultimately, return as adults.

Petronas' proposed MOF will destroy 19,833 m^2 of marine riparian habitat, 43 m^2 of intertidal habitat, and 904 m^2 of eelgrass on the NW side of Lelu Island in Porpoise Channel. Additionally, the MOF construction will "alter" 35,905 m^2 of intertidal habitat. Petronas claims that the altered habitat will still be available for marine organisms. They do not describe the degree of alteration or the types of marine organisms which might still be able to use the habitat. The entire MOF shoreline will be hardened and straightened.

The location of the MOF is in a region of critical habitat used by juvenile salmon outmigrating from the Skeena River. The small bay where the MOF is proposed to be constructed provides an important resting and feeding habitat for juveniles on their outward migration to Flora Bank. Construction of the MOF will reduce the habitat quality of this site by up to 30% (Faggetter 2014b). In their studies during the 2014 outmigration of juvenile salmon from the Skeena River, Eriksson *et al*. (2014) report:

> *As out migrating smolts move farther from the river they concentrate in large numbers along the drop off line on the north west edge of Flora Bank through into Porpoise Channel and Port Edward. This area consistently had the highest abundance of all salmon species as well as large schools of herring and smelt of several different life stages. Several little points and bays on both sides of Porpoise Channel provided excellent back eddy habitats for feeding smolts, herring and smelt. The drop off line of Flora bank near the outlet of Porpoise Channel had the largest Coho and Chinook smolts within our sample area as well as the only place we caught very large old growth herring along with large smelt. Our experience would lead us to believe these Coho and Chinook are spending considerable time in this general area, probably months, feeding on young smelt, pink, and chum.*

Clearly this habitat is extremely important to juvenile salmon, not only because of habitat quality and type, but also as a result of location. Attempting to replace habitat destroyed in this area by creating habitat offsetting at other sites will not be successful, as it is unlikely that those offsetting locations will provide the same ecosystem services to the same fish species.

7 Marine Habitat Offsetting Plans

In their EIS/Application, Petronas' habitat offsetting plans had inadequate scientific studies and oceanographic current and sediment modelling, little or no consultation with the public, and were potentially likely to cause more habitat destruction than habitat creation. It is not justifiable to alter perfectly functional habitat simply because it allows the proponents to meet the amount of habitat offsetting required by their proposed project, or it reduces the amount of material that will need to be disposed on land or at sea. The "beneficial re-use" of dredgeate is not a justification for disposal of contaminated sediments in an a location where they will be dispersed by wave and tidal action. Additionally, any proposed structure which interferes with the natural movement of sediments in the marine environment must undergo detailed oceanographic modeling to determine if there will be adverse impacts from the changes in sediment supply (Faggetter 2014a).

Petronas states that while their new bridge concept will still require habitat offsetting as a result of potential effects on habitat at the MOF, they claim that the offsetting project will be at a much smaller scale as compared to the original EIS/Application (Pacific NorthWest LNG Limited Partnership & Stantec Consulting Ltd. 2014). The plans for this offsetting have not yet been publicly released, and will need to be evaluated from both an ecological and an oceanographic perspective to determine if they will actually be effective.

8 Acid Deposition

Ocean “acidification” occurs when chemical compounds such as carbon dioxide, sulfur, or nitrogen mix with seawater, a process which lowers the pH and reduces the storage of carbon. Ocean acidification decreases the ability of marine organisms - such as sea urchins, starfish, brittle stars, shellfish, corals, fish, and certain types of plankton - to use calcium carbonate for making hard outer shells or “exoskeletons”, or for maintaining their internal body chemistry. These organisms provide essential food and habitat to other species, so decreases in their populations could affect entire ocean ecosystems (WHOI 2014).

While increased atmospheric CO_2 has generally been considered the culprit behind the current increase in ocean acidification, acid deposition also has the capacity to affect the ocean. This effect is most pronounced near the coasts, which are already some of the most heavily affected and vulnerable parts of the ocean due to pollution, over-fishing, and climate change. In addition to acidification, excess nitrogen inputs from the atmosphere promote increased growth of phytoplankton and other marine plants which, in turn, may cause more frequent harmful algal blooms and eutrophication (excess algal growth which can create oxygen-depleted “dead zones”) in some parts of the ocean (Doney et al. 2007, WHOI 2014).

Emissions of air pollutants from Petronas' facility are estimated to as high as 0.62 tpd of SO_2, 14.64 tpd of NO_2, and 14,019 tpd of CO_2 (tpd = metric tons per day) (Stantec Consulting Ltd. 2014f). Unfortunately, studies on the impact of a coastal LNG facility on ocean acidification have not yet been done, thus the magnitude of the impact that acid deposition from Petronas' facility could have on the marine environment is not known. However, given the serious concerns that the BC shellfish industry has regarding ocean acidification and its relationship to the recent die-offs of oysters and scallops, coastal areas in BC may already be at risk. Increased ocean acidification can impact juvenile salmon by causing declines in the organisms on which they feed. For example small ocean snails called pteropods, which may make up more than 50% of the juvenile pink salmon diet, are already being affected by the acidification of the ocean.

9 Sound

Since Flora Bank is a highly productive nursery area for juvenile fish, and since both the construction and terminal operation activities are in very close proximity to Flora Bank, there is significant concern regarding the impacts of sound on juvenile fish utilizing this nursery habitat. Impacts which would cause juvenile fish to leave the nursery habitat prematurely, thus resulting in lost feeding opportunities and potential starvation, or which caused juvenile fish to develop behavioral responses (e.g., sound acclimatization) which could make them more susceptible to predation would be especially concerning.

Based on the known range of salmonid hearing, sounds generated during pile driving activities are likely to influence both fish behavior and distribution of schooling salmonids within a radius of 600 m from the source. The number of schooling salmonids has been shown to drastically decrease on pile driving days as compared to non-pile driving days (Feist 1991). Juvenile Chinook salmon and chum salmon become disoriented after exposure to sounds ranging between 40 and 50 kPa, and mortality occurs with sounds in the range of 150 kPa (Vagle 2003). Juvenile Chinook salmon display both flight and avoidance responses to sounds in the 10 Hz range (Knudsen *et al*. 1997).

10 Overwater Structures

Petronas' proposed facility will have a large number of overwater structures, which include the pioneer dock, the MOF, the bridge/jetty, and the marine terminal. Overwater structures can increase the mortality of juvenile fish using shallow estuarine and nearshore marine environments by (Nightingale & Simenstad 2001; Toft et al. 2007):

- creating "behavioral barriers" that can deflect or delay migration (including juvenile salmonids avoidance of swimming beneath overwater structures as a result of shading effects).
- reducing the availability of prey.
- altering predator-prey relationships associated with high intensity night lighting.

Piers reduce the presence and feeding of juvenile salmon, indicating that areas under piers provide less-valuable habitat to salmon species (Munsch *et al*. 2014). When shoreline-oriented juvenile salmonids encounter an overwater structure or deep riprap, they either swim under the structure or move into deeper water. If juvenile salmon schools are forced into deeper water by overwater structures, they change their behavior. This may have implications for within-species competition, feeding behavior, and susceptibility to predation (Toft et al. 2007; Munsch *et al*. 2014).

Night time artificial lighting on dock structures can change fish species assemblages and pose increased risk of predation by subsequent changes in night time migration, activity, and location of predators (Nightingale & Simenstad 2001). For example, pink and chum salmon tend to congregate below security lights, and at high light intensities, chum salmon may be attracted and their out-migration delayed (Prinslow *et al.* 1979).

Petronas states that on their newly proposed bridge concept, deck lighting will be shielded and pointed downward at the jetty surface to reduce light spill into the water (Pacific NorthWest LNG Limited Partnership & Stantec Consulting Ltd. 2014). However, they do not suggest that night time lighting will be altered at any of their other overwater structures. It is also not clear at this time how significant the reduction in night time lighting will be from this mitigation, since some light will still spill into the water.

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