(excerpts from JRP submission and Salmon and Oil report)

Cumulative impacts to salmon

The degree to which small, seemingly independent actions compile into large consequences over the long term is the essence of cumulative effects. As salmon abundance declines, diversity and resilience are reduced and risk of extinction is increased. A population with lower diversity is less resilient to stresses such as disease, pollution or changing climate.

When one considers the multiple lines of threats to salmon it's no wonder so many populations are struggling. The extraction of marine species (other food web species and salmon themselves), changes to freshwater hydrology and habitat, destruction of shorelines, decline in estuary function, aquatic pollution, introduced species and diseases, and increasing CO_2 inputs are all acting synergistically to compromise survival through all life histories and food web interactions.[1]

Cumulative impacts emerge when single events compound; the combined effects on species and/or ecological processes are often greater than the sum of their parts.[2] Changes are now occurring in marine ecosystems that will further affect the diversity and abundance of wild Pacific salmon. A broader issue is the implications for salmon ecosystems and dependant species in the face of large shifts in marine and freshwater productivity.[3]

In addition to changing productivity, factors such as disease, parasites and viruses, fishing pressure, habitat loss in marine and freshwater, acoustic disturbance, sea level change and declining marine biomass (effecting food supply and habitat needs)– and their potential interaction – all conspire against salmon.

Habitat loss

In BC's rivers, streams, lakes, watersheds and marine waters , the incremental and combined effects of human activities are compiling on salmon. These are not only occurring across broad categories but within them. For example, the urbanization of coastal watersheds and freshwater habitat loss combined with declining pH/rising acidity in marine waters produce cumulative impacts to coastal waters.[4]

Fishing pressure

Many salmon runs have been reduced in abundance by excessive fishing pressure that existed over the past century. Populations of Chinook and chum for example were orders of magnitude more abundant in the Queen Charlotte Basin in the early part of the 20th century.[5]

Salmon Aquaculture

There have been well-documented impacts to wild salmon associated with salmon farming in BC - namely, the transfer of disease, pathogens and sealice from farmed to wild fish.[6] This is because open net-pens used to raise dense concentrations of salmon cannot contain pathogens and often, the fish themselves. These problems remain unaddressed as long as aquaculture net pens share the same fluid environment as wild salmon.

Salmon Enhancement and Hatcheries

Research suggests that overreliance on salmon enhancement jeopardizes the diversity and resilience of wild salmon. Negative impacts from hatchery and enhancement facilities include replacement of wild salmon, with enhanced fish but with no net increase in production, competition, disease, higher ocean mortality and lower return rates in enhanced fish, and lowered genetic integrity; diversity, and fitness of wild salmon populations.

Run-of-the-River Power Projects

Independent Private Power (IPP) projects proposed for watersheds throughout BC present another threat to freshwater salmon habitat in a similar way that dams have so negatively impacted salmon populations in the U.S. Pacific Northwest.[7] IPP water diversions will affect flow timing in the diversion reach, sediment transport, ramping rates and water temperature, all critical components of freshwater habitat quality for salmon.

Ocean carrying capacity

Recent studies suggest the North Pacific Ocean may be nearing the limit of its salmon rearing capacity.[8] The large and increasing releases of hatchery-reared fry (five billion primarily pink and chum salmon by 2008)[9] may be contributing to competitive interactions between hatchery and wild populations that is limiting recovery of wild salmon.

Climate change

Temperature and moisture determine the distribution of species on earth. Climate change influences temperature and moisture. While natural at some level, it is the pace at which shifts in these conditions are occurring that is causing such concern. A change in one aspect of these conditions can cause a cascade of responses that can counteract or magnify the initial change.

Stream temperatures

Water temperature changes of just one or two degrees can be significant for salmon. In freshwater, the optimal temperature range for the growth and reproductive success in the five species of commercial salmon are generally below 15^{oC} (table 8.1).[10] Streams that experience a weekly water temperature greater than the upper thermal tolerance limit for a species are considered lost habitat.[11]

Stream and snow pack changes

Warming temperatures pose a serious threat to salmon streams. Changes in temperature, and the accompanying changes in precipitation, will alter the snow pack, snow melt timing, and the volume, timing and quality of water flows. Much of this is already begun as the snowpack across the mountain ranges of the west coast has been changing for five decades,[12] and BC glaciers are now retreating at rates unprecedented in the last 8,000 years.[13]

Other temperature impacts to salmon survival

Increased water temperature can also increase predation on juvenile fish, inhibit migration, extend periods of thermal stress, and increase pre-spawning mortality.[14] Warmer water also makes salmon vulnerable to the negative effects of invasion by non-native fish, invertebrates, and plants.[15] Warmer temperatures also impacts thyroid function which can increase the mobilization of stored pollutants.

Declining summer flows from changing snowmelt and glacial runoff patterns can also effect stream chemical signatures.[16] This has important implications for the freshwater homing migration of salmon to a given stream, or spawning ground, which is thought to be governed by their olfactory ability to detect natal streams, a trait that may be genetically inherited.[17] The critical process of imprinting may depend on chemical characteristics of a particular stream remaining stable over

Stratification and acidification of marine waters

Future climate change scenarios, especially at higher latitudes, include increased temperature and reduced salinity in the upper ocean. This can reduce density, reduce nutrients and lower oxygen concentrations at deeper depths, creating regions of low productivity. These conditions are already being observed in the North Pacific Ocean. [18]

Increased uptake of CO_2 by the ocean also leads to acidification. By the mid 1990s, the pH of the ocean's surface had dropped from 8.2 to 8.1 (a 30% increase in acidity) from C02 emissions emitted over the previous two centuries.[19] By the end of this century, forecasts suggest pH will drop another 0.3-0.4 units lower, which translates to a 100–150% increase in acidity. [20]

Increased acidity also reduces the availability of calcium carbonates that marine organisms use to build hard shells and carbonate skeletons. This can impact salmon by increasing predation on juvenile from carnivorous fish that switch prey, or as by reducing salmon food supply.[21]

Unknowns: Sound and impacts from low frequency shipping noise

Water is an excellent medium for sound transmission because of its high molecular density. As such, sound travels about five times faster in water than in air, with wavelengths that are about five times longer.[22] Sound also attenuates less over the same distance. As a consequence, sound travels much greater distances at higher amplitudes in water. Sound will likely be affected by climate change as well, travelling further with less absorption (louder) with increased $C0_2$ uptake.[23]

Generally, little is known about the effects of human generated sounds on fish. Even less is known about the impacts to developing eggs and embryos.[24] It is becoming clear however that artificial underwater noise may not be benign.[25] Sub lethal effects from underwater noise generated by shipping include increased heart rate, increased metabolism and motility, and the secretion of stress hormones.[26] While the harm caused by short-term intense sounds like sonar, pile driving and explosions have attracted the most attention, research suggest that the greater impact on fish will be from less intense sounds that are of longer duration with the potential to affect much larger areas.[27]

Most fish are able to detect sound with a hearing range between 100 and 500 Hz.[28] Sound produced by vessel traffic is more intense at low frequencies.[29] Enbridge's tankers will be emitting low frequency (100-200Hz) at levels in the range of 175-180 dB.[30] According to Enbridge, this sound will be detectable by salmon and other hearing generalist marine fish up to 7-8 km from the marine terminal and 4-6 km from the tanker route.[31]

Specific concerns in Kitimat Arm

Construction of an oil storage tank and marine shipping terminal in Kitimat Arm will likely have a significant impact on local salmon populations and their habitat in both the short and long term. These impacts represent steady cumulative stressors to the Kitimat River's salmon populations already degraded by extensive logging, urbanization, chemical contamination, structural and physical changes in the estuary, hatchery enhancement activities and fishing pressure.[32] Habitat conditions in the estuary will very likely be further eroded by the construction and operation of the one approved and numerous other LNG terminals. At minimum, chronic oiling, remobilization of contaminated sediments and increased suspended solids will accompany the proposed petrochemical activities adding more stress to the processes and structures that support rearing habitat for salmon, eulachon and other forage fish.

Unfortunately, most of the Kitimat River salmon populations (chinook, chum, Coho, steelhead and cutthroat) are now enhanced by the hatchery. Given the projected cutbacks within DFO, it is possible the Kitimat Hatchery will no longer receive federal funding. Indeed, funding has been provisional in recent years. If funding is cut, wild salmon populations in the Kitimat River will need to recover from extremely low levels of abundance. Because the Kitimat estuary is critical for the recovery of these populations and species, further declines in its health and ability to support rearing juveniles might conspire to facilitate the complete loss of wild salmon from this area. Given the impaired quality of the estuary, activities that accompany construction and operation of an oil-shipping terminal impose additional stress on all these fish populations and their associated ecosystem beneficiaries. These considerations should weigh very heavily on the decision to construct such a terminal.

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[1] Lackey 2008, Wood 2001, NRC 1996, Slaney et al. 1996.

[2] Spaling and Smit 1993

[3] An ongoing problem is the fact that these issues are not been accounted for in past or present management. See Bottom et al. 2009. http://www. ecologyandsociety.org/vol14/iss1/art5/

[4] Often the effects of perturbations that are close in time and space are not dissipated before the next one occurs. Ultimately declines in environmental quality resulting from combined disturbances are gradual and usually go unnoticed. This can lead to 'shifting baselines' and long-term loss of ecosystem functioning.

[5] Argue and Sheppard 2006

[6] Krkosek et al. Science, Also see Cohen Discussion and Technical papers

[7] Gower et al. 2012.

[8] Ruggerone et al. 2010

[9] Ruggerone et al. 2010

[10] Shuter 1999.

[11] Mantua et al. 201009.

[12] US GCRP 2009

[13] Walker and Sydneysmith 2008.

[14] ISAB 2007, Vigg and Burley 1991, Hinch and Martins 2011, Kocan et al. 2003.

[15] Sanderson et al. 2009.

[16] Stahl et al. 2008.

[17] Dittman and Quinn 1996, Quinn et al. 2000.

[18] Hutchings et al. 2012, Irvine and Crawford 2011

[19] Friedlingstein et al. 2010

[20] Orr et al. 2005

[21] Fabry et al. 2008.

[22] traveling about 1500 vs. 300 m/s, e.g. for a 100 Hz signal: 3 m in air, 15 m in water

[23] Hester et al. 2008.

[24] Popper 2009

[25] Slabbekoorn et al. 2010

[26] Graham and Cooke 2008, Buscaino et al. 2010, Smith et al. 2004, Wysocki et al. 2006, Slabbekoorn et al. 2010.

[27] Popper 2009, Slabbekoorn et al. 2010.

[28] Buscaino et al. 2010.

[29] Ross 2005.

[30] Enbridge 2010. Marine Acoustics TDR, pg. 2-2.

[31] Enbridge 2010. Volume 8B. pg. 9-25.

[32] see RCF's full salmon and oil report or RCF submission to National Energy Board's Joint Review Panel for detail.