Impact of 6PPD-q on Coho Salmon Populations and Possible Solutions

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Salmon are ingrained in the culture, environment, and economy of the Pacific Northwest. For the Indigenous peoples of the Salish Sea, salmon play a significant spiritual, historical, and communal role as well as an important resource through subsistence fishing. Salmon also greatly impact the local ecology. As a keystone species, salmon migrating from saltwater to freshwater provide nutrients to every segment of their ecosystems, from endangered Southern Resident Killer Whales to the very forest floor through which their streams and rivers run. The production and harvest of Pacific salmon can also provide economic benefits to the Pacific Northwest. Historically, this species was once an abundant resource for the region. However, according to the California Department of Fish and Wildlife, salmon populations, including the coho variety, have been rapidly declining since the mid 1900s. While various environmental and economic factors are contributing to the decline in coho salmon populations, one of the most notable and concerning factors is the infiltration of 6PPD-q into salmon habitats and migratory water bodies. More research into alternatives and regulated stormwater management is necessary to prevent further coho salmon population decline from 6PPD-q.

Factors in Coho Salmon Population Decline

According to the Endangered Species Act, four types of salmon are currently considered endangered or threatened: chinook, chum, coho, and sockeye (NOAA Fisheries). Coho salmon, in particular, are quite vulnerable due to their sensitivity to 6PPD-q and proximity to urban waterways. While 6PPD-q has become an emerging concern, since the topic of endangered coho salmon populations is a multifaceted issue, it is important to note the other and/or historical contributing factors to their decline. This accelerated decline in salmon populations has been attributed to multiple causes, namely overfishing, habitat loss, and climate change.

Since the 1800s, treaties between the Indigenous peoples of the Pacific Northwest and the United States ceded land and waterways for fishing operations. While these operations helped economically expand the region, these monetarial gains were not without losses. Unregulated competition between fishing industries and increased colonial populations in this area strained the once plentiful salmon populations (Morishima & Henry, 2020). Coho salmon, especially, were affected by unsustainable fishing practices, and their numbers have failed to significantly recover ever since.

In addition to losing numbers, coho salmon have also lost precious habitats. The same developments that advanced and expanded the colonial populations of the Pacific Northwest also decimated the lives of native salmon. Dams created barriers for salmon during their migration, logging practices destroyed old growth forests that provided shade and erosion protection to waterways, and the “resource extraction…and land conversion to agriculture have eliminated, severely degraded, and alienated much of the freshwater stream systems” (Finn et al., 2021). The more water and land utilized for urbanization resulted in less available native habitat for coho salmon. These remaining salmon habitats experience additional environmental strain due to climate change.

Climate change has exacerbated the population decline of what coho salmon remain from overfishing and habitat loss. More frequent extreme weather events, in particular droughts and warmer temperatures, negatively impact the migratory waters home to the coho salmon. According to the National Oceanic and Atmospheric Administration (NOAA), coho salmon thrive in water temperatures ranging from 14℃ to 17℃. Rising global temperatures attributed to climate change pose a critical risk to healthy and supportive habitats. In creek habitats, a common area for coho salmon, higher temperatures lead to increased algae, which in turn lowers oxygen levels and increases water temperatures (Baker, 2023). As a result of climate change, streams are becoming shallower, hotter, and thus less oxygen rich and more acidic (Siegel & Crozier, 2018). These consequences pose a danger to coho in particular since according to the Washington Department of Fish and Wildlife, they often live in small and sensitive urban streams. In addition to the previously mentioned contributors to decreasing coho salmon populations, another is becoming a rising concern in the fight to preserve and restore this important species: 6PPD-q.

6PPD-q: History and Impact

A recently discovered yet potent cause of the coho salmon population decline is the transformation product and aquatic toxicant 6PPD-q, which has been linked to juvenile and pre-spawn salmon deaths in urban water bodies. In fact, 6PPD-q is considered the second most toxic substance to aquatic life (Tian et al., 2022). Of all fish species, coho salmon are especially sensitive to 6PPD-q (Lo et al., 2023). Up to 90% of female coho salmon die before they reach their spawning grounds in urban streams, which include toxicants from stormwater runoff. Compared to non-urban streams, this mortality rate is less than 1% (Greer et al., 2023b). This high pre-spawn mortality significantly reduces the coho salmon's ability to repopulate. Even with sustainable fishing, habitat restoration, and climate change mitigation, these salmon cannot sustain let alone improve their population if almost 90% are dying due to 6PPD-q. So, what is 6PPD-q and why/how does it exist?

6PPD, the chemical N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine, is used commercially to prevent tires from degrading. However, according to the Washington State Department of Ecology (DOE), when this chemical is "exposed to air[,] it reacts with ozone to create 6PPD-quinone," also known as 6PPD-q. Additional preliminary studies also point to the photodegradation of 6PPD (exposure to sunlight) as another transformation pathway to 6PPD-q (Bălan et al., 2022). As tires roll along the road, the friction and exposure from this interaction releases dust, debris, and other byproducts known as tire wear particles onto roadways, and these particles contain 6PPD-q. During rain events, these byproducts wash away in the stormwater and make their way into receiving waters where coho salmon live and spawn. The introduction of 6PPD, and subsequently 6PPD-q, has led to drastic declines in salmon populations (Ryan, 2020). Even at extremely low concentrations of less than 1 part per billion, 6PPD-q is considered dangerous to coho salmon (DOE, 2021). This toxicant can be especially dangerous to juvenile salmon (Greer et al., 2023a). Due to the high death rates of these immature salmon, less and less mature salmon are returning home to repopulate.

Potential Solutions

While 6PPD-q seems like an insurmountable issue, there are potential solutions. In an ideal world, 6PPD, and consequently 6PPD-q, would be eradicated completely. However, removing every single tire in the world from the roadways all at once is not feasible. 6PPD plays a crucial role in preserving tires by preventing cracks and blowouts from general use (Binaeu, 2023). No tires means no cars, no buses, and no transportation, all which are essential parts of modern society. One proposed solution is replacement. Chemists from the DOE Hazardous Waste and Toxics Reduction Program are actively researching the effects of alternative chemicals to 6PPD. To date, however, even the best known potential alternatives to 6PPD are still considered mildly to moderately toxic (DOE, 2021). Another proposed solution is stormwater management.

The DOE is currently investigating the effects of three different best management practices (BMPs) on reducing 6PPD-q in stormwater runoff. The first of these three, stormwater source control BMPs, aim to prevent stormwater contamination from the source. By sweeping roads, these BMPs attempt to catch the tire particles before they have the chance to integrate into stormwater. The second, flow control BMPs, aim to introduce ponds, infiltration basins, and bioretention areas to reduce potential stormwater runoff into local water bodies. Whatever particles are not caught in the initial street sweep are caught by these flow control BMPs. Bioretention systems are typically a basin filled with a mixture of sand, soil, and/or compost that help absorb and infiltrate stormwater runoff. The ecological blend helps filter pollutants before they can intercept and contaminate water bodies. In fact, one study found that bioretention systems mitigated over 90% of 6PPD-q from entering streams during typical rain events (Rodgers et al., 2023). The last, runoff treatment BMPs, aims to physically filter or chemically treat the stormwater runoff in order to decrease potential pollutants. While these recent and ongoing studies show promising results, only time will tell if and how these BMPs impact the presence of 6PPD-q in water bodies, especially ones in high trafficked areas. Ultimately, a combination of multiple different policies and procedures will likely be needed to help prevent 6PPD-q from entering coho salmon habitats.

Conclusion

Coho salmon play a significant role in this region’s culture, environment, and economy. Due to historical and current factors, salmon populations are rapidly declining and as a result, the Pacific Northwest is quickly losing a vital part of its ecosystem. To combat the emerging concern of the 6PPD-q toxicant entering salmon habitats, researchers are working on developing alternatives and preventative measures. While preliminary findings suggest that bioretention may significantly reduce the presence of 6PPD-q in local water bodies, more research on potential alternatives to 6PPD and implementation of well developed stormwater management practices are necessary to preserve this important species from further decline. While 6PPD helps increase the lifespan of tires, when rubber meets the road, it drastically decimates the lifespan of coho salmon.

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