Juvenile Chinook salmon behavior in the Lake Washington nighttime urban lightscape

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We used a fine-scale acoustic tracking system to evaluate Chinook salmon smolt behavior within the nighttime urban lightscape at two study sites: 1) the west end of the SR 520 bridge in Lake Washington; and, 2) the I5 bridge and University Bridge in the Ship Canal. Each study site was unique, influenced by multiple artificial light sources and containing heterogeneous areas of varying light intensity. Most prominent light sources at both sites were sodium lamps, emitting characteristic orange-colored lighting. Some light sources on the University Bridge were fluorescent or other types emitting light that appeared whiter or more in the blue-green spectrum. Tagged fish behavior was evaluated during June and July in 2007 and 2008.

The nighttime lightscapes created by urban lighting presented novel habitats that substantially influenced fish behavior and spatial distribution at each site. Fish usage hot spots occurred in brightly lit areas (0.7-226 lux) and along shadow lines created by artificial lighting. Tagged Chinook salmon were generally attracted to artificially lit areas. However, there were exceptions to this generality, as well as a notable plasticity in the degree of attraction. Tagged fish were more strongly attracted to lit areas in 2008 than 2007, perhaps due to differences in ontogenetic stage, turbidity, or other environmental conditions between the two years. In 2008, some fish were observed spending entire nights in small areas beneath only one or two lights. In 2007, fish often moved between lit areas, spending relatively little time in each.

Tagged fish oriented along shadow lines at the I5 and SR 520 bridges. Fish were observed milling near shadow lines, swimming back and forth along shadow lines, and using shadow lines as pathways to move from one area of the site to another. Contrast between light and shadow sides of shadow lines was ≥ 2 lux, although contrast at outer shadow lines along the SR 520 bridge could not be accurately measured.

The moderately-lit area (0.5-2.5 lux) lit by fluorescent and cooler wavelength lights near the University Bridge was generally avoided. Other areas with similar light levels but lit by the orange-colored sodium lamps attracted fish. Though not conclusive, this suggests that the type of lighting may have influenced fish attraction, something that has been observed in other studies.

Variations between sites and years were also observed in the following: 1) light levels required to elicit positive selection; 2) response to increasing light intensity (increasing selection or plateaued); and, 3) selection of ambiently lit areas (negative or proportional). This study was not designed to identify causal factors underlying these variations. However, we believe that ontogenetic stage, environmental conditions (turbidity, ambient light conditions, temperature), and perceived predation risk may have contributed.

Fish first started showing attraction to lit areas 40-60 minutes after sunset. Attraction continued until 20-40 minutes before sunrise for some fish. Chinook salmon in Lake Washington and the Ship Canal migrate during the day, starting about 45 minutes before sunrise and continuing until about 20 minutes before sunset. Therefore, artificial lights may delay the onset of active migration in the morning by up to 25 minutes. Active migration appears to cease in the evening before artificial lights would have much effect.

Other studies have found that artificial lighting at night may attract juvenile salmonids and expose them to increased rates of predation from visual predators (Tabor et al. 2004). Visual predators in Lake

Washington and the LWSC include cutthroat trout, smallmouth bass, and northern pikeminnow. Avian predators are also present, and have been anecdotally observed foraging in artificially-lit areas.

Artificial nighttime lighting is a ubiquitous feature of urban settings and often necessary for human safety. However, effects from lighting may be minimized by thoughtful use and design, including ensuring that lights near water are necessary, and are shielded or otherwise designed to minimize the intensity of light reaching the water surface. Additional measures for reducing shadow lines may include adding lights beneath bridges and other large overwater structures. Further research on different types of lighting and their effects on fish attraction and predation may yield additional benefits. Other measures, such as cycling lights off and on, may also be investigated for potential benefits in reducing fish attraction to artificially lit areas.