Lake and Reservoir Management 22(3):245-249, 2006

Preliminary Results of Light Transmission under Residential Piers in Lake Washington, King County, Washington: A Comparison between Prisms and Grating

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Abstract

Gayaldo, P.F. and K. Nelson. 2006. Preliminary results of light transmission under residential piers in Lake Washington, King County, Washington: A comparison between prisms and grating. Lake and Reserv. Manage. 22(3):245-249.

During the summers of 2003 and 2004, 11 piers (two public and nine private) were evaluated for their ability to transmit light through the decking to the water surface below. Solid decking produces distinct shading that migrating juvenile Chinook salmon appear to avoid by swimming into deeper water where more potential predators live. Two new types of surface treatments (acrylic prisms and grating) were evaluated and compared to traditionally spaced decking as well as solid decking. Grating (with 37-58% open space) was found to transmit significantly more light to the water surface below (mean = 7.5% of full sunlight) than 23 x 5 cm acrylic prisms (mean = 0.7% of full sunlight). In other words, compared to full sunlight, grating transmits 10 times more light under the pier than acrylic prisms. In addition, light that passes through open grating penetrates the water evenly under the pier. Light transmitted through prisms concentrates beams of light that do not always reach the water surface.

Key Words: deck spacing, grating, light transmission, pier, prisms, salmon, shading

On March 24, 1999, Chinook salmon (*Oncorhynchus tshawytscha*) in the Puget Sound region were listed as threatened under the Endangered Species Act (ESA or the Act). Primary concerns for juvenile Chinook salmon regarding new and remodeled piers in Lake Washington include habitat changes in the nearshore from pier shade and structure, shoreline modifications to build and access the piers, and degradation of water quality from pier construction and use. Shade from piers is caused by the decking, pilings and support structures and attached floats and may provide predatory fish some advantage in capturing prey. Helfman (1981) found that fish hovering in shade could see approaching objects better and were themselves more difficult to see. Tabor *et al.* (2004) found that cottids preyed most effectively on sockeye salmon (*O. nerka*) in complete darkness, and that the lowest predation occurred at the brightest light intensity.

When juvenile Chinook salmon are very small, they use over-water cover (including piers and overhanging vegetation) during the day. As they grow larger, they seem to avoid over-water structure during both the day and night (Tabor and Piaskowski 2001). As juvenile Chinook salmon increase in size they appear to progressively reduce their use of overhead structure.

During the late spring or early summer, juvenile Chinook salmon form small schools of approximately 50-200 fish and begin migrating along the shoreline. Juvenile Chinook salmon have usually been observed in water 1.5-3 m deep and 10-20 m from shore. At Stan Sayres Park in Seattle, Washington, Tabor and Piaskowski (2001) observed schools of out-migrating juvenile Chinook salmon swimming around piers rather than under them, presumably because of the change in light condition. On several days in June 2003 and

2004, Tabor *et al.* (2006) observed numerous schools of migrating Chinook salmon move to slightly deeper water before swimming under piers or around the pier or turning around and swimming away from the pier.

Abrupt transitions from light to dark can cause juvenile Chinook salmon to alter their migration pathway from the nearshore to deeper water or avoid the pier altogether (Tabor *et al.* 2004). Migration through deeper water could expose juvenile Chinook salmon to more predation in addition to lengthening the migration period. Minimizing the effects of shading is expected to be beneficial to juvenile Chinook salmon. This report evaluates the amount of light transmitted through residential piers by comparing different pier surfaces, including solid decking, 50% open space grating and acrylic prisms. Observations of other design features that affect light transmission under piers are also discussed briefly.

As of 2000, approximately 2,737 residential piers have been built in Lake Washington, an average of one pier every 49 m of shoreline (Toft 2001). Because of continuing development pressure, the potential effects of additional over-water structures to juvenile Chinook salmon continue to increase. In addition, the aggregate effects of new and remodeled pier structures on Chinook salmon migration behavior are not known.

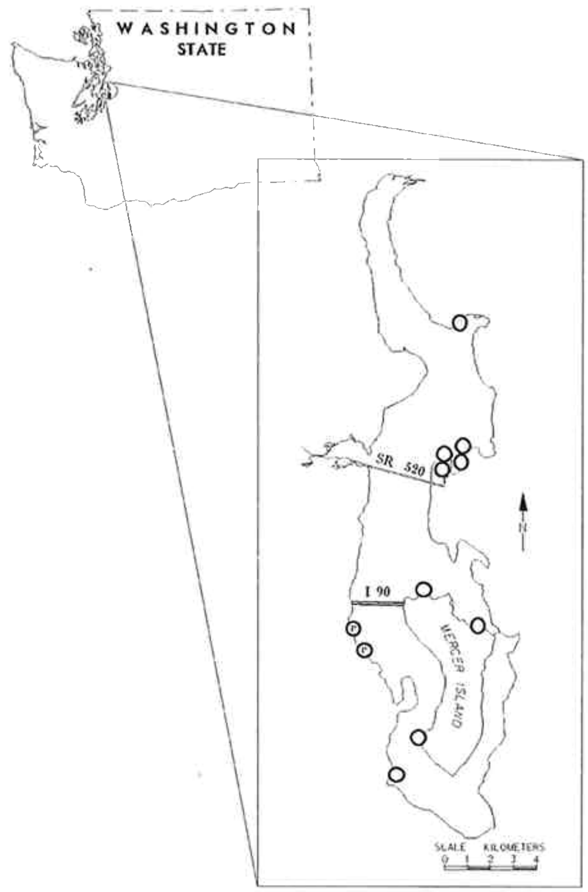

Figure 1.-Location (circles) of piers used to examine the effect of light transmittance, Lake Washington, 2003 and 2004. "P" indicates a public pier; others are private.

Materials and Methods

We surveyed nine private residential piers (Brooks/Hart, Captain, Flint, Galanti, Gasparina, Ling, Olsen, Peters, and Skuja) and two public piers (McClelland and Stan Sayres) located in Lake Washington (Figure 1; Table 1). In June 2003 and July 2004, we measured photosynthetically active radiation (PAR; 400-700 nm) beneath and adjacent to the selected piers (paired samples). The wavelengths of PAR adequately represent those viewed by juvenile salmon (Flamarique 2002 and W. Dickoff, personal communication). We measured light transmitted through four surface treatment types:

1. acrylic prisms – 23 x 5 cm acrylic, rectangular deck prisms at typical installation densities of 1-3 per 33 m^2 (Figure 2).
2. grating – classified into three types (percentage represents open space):
    a. 37.5% open – ThruFlow® high density polyethylene interlocking panels (Figure 3),
    b. 50% open – ironwood grating consisting of 1-in board width and 1-in wide open space (Figure 4), and
    c. 58% open – Chemgrate® molded fiberglass resin (Figure 5).
3. traditional decking – 14-25 cm wide wooden boards spaced 0.7-2 cm (Figure 6).
4. solid decking (control conditions) – each above treatment covered with a canvas tarp 1.2 m long and extending the entire width of the selected pier (Figure 7).

A LI-COR LI-190SA quantum sensor was held under each pier to measure the ambient light (PAR) in micromoles of quanta per second per square meter ($\mu mol\ s^{-1}m^{-2}$) at the water surface. We moved the sensor in a circular motion (approximately 0.5 m radius) at the water surface directly beneath prism, grating or decking for a period of 10 sec to obtain an averaged light measurement for each treatment. Immediately following each under-pier measurement, the technique was repeated in full sunlight adjacent to the pier to calculate the percentage of full sunlight available for each surface treatment. The circular motion and 10-sec averaging techniques

Table 1.-List of piers and their respective treatments. Paired readings included a light measurement beneath a treatment type followed immediately by a measurement in full daylight.

Site	# of Paired Readings	Measured Treatment
Brooks/Hart	6	- covered/solid decking (control)
	6	- prisms
Captain	18	- grated decking (50 percent)
Flint	9	- traditional decking
Galanti	9	- covered/solid decking (control)
	12	- traditional decking
	19	- grated decking (50 percent)
	33	- prisms
Gasparina	3	- traditional decking
	3	- prisms
Ling	3	- covered/solid decking (control)
	9	- grated decking (50 percent)
	6	- grated decking (50 percent) shaded by temporary items (*e.g.*, kayaks)
	3	- prisms
McClelland (*public*)	37	- traditional decking without pier skirting
Olsen	7	- grated decking (37.5 percent)
	4	- grated decking (50 percent) shaded by temporary items (*e.g.*, kayaks)
	3	- prisms
Peters	9	- traditional decking
	9	- grated decking (37.5 percent)
	9	- prisms
Skuja	13	- grated decking (58 percent)
Stan Sayres (*public*)	9	- traditional decking

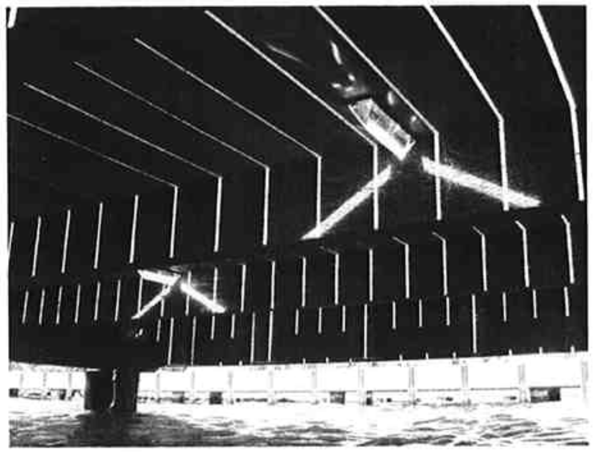

Figure 2.-Acrylic prisms.

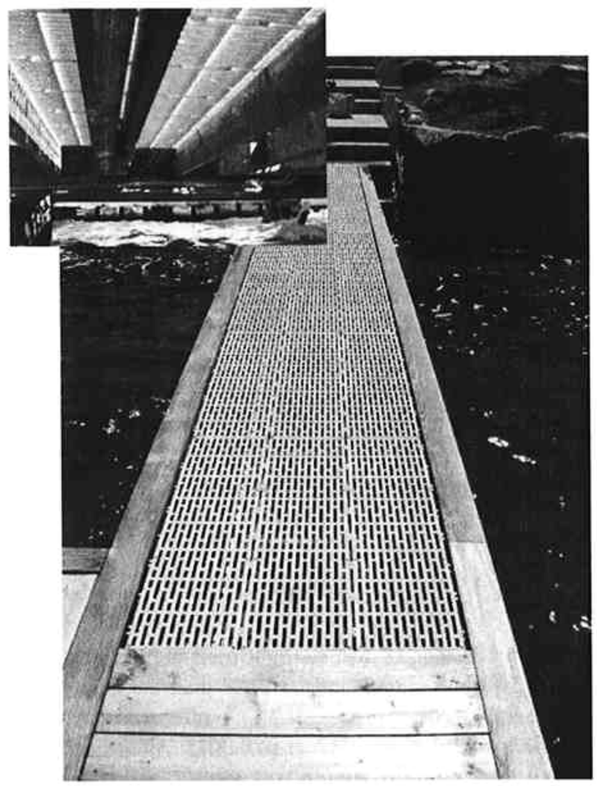

Figure 3.-37.5% open-spaced grating (ThruFlow®).

were used to minimize the sensor variation between direct and indirect sunlight beneath the pier.

A single factor analysis of variance (ANOVA) experimental design (effect of decking treatment on light transmission) was used, followed by the Tukey *a posteriori* test of multiple comparisons (modified for unequal samples sizes within treatments) to identify significant differences ($\alpha = 0.05$) of means between treatments (Zar 1984).

In addition to light measurements, secondary variables were measured, consisting of pier orientation, minimum height of pier above the waterline, sun angle, and shade created by the semi-temporary placement of personal items on the deck surface (*e.g.*, kayaks, storage lockers). Anecdotal (nonstatistical) comparisons of these variables were made and are presented in the discussion.

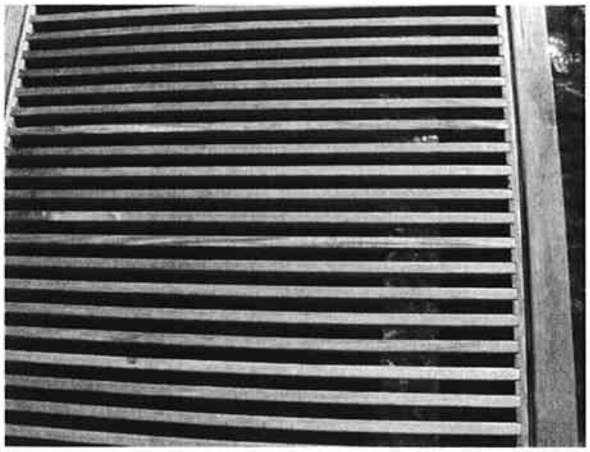

Figure 4.-50% open-spaced grating (ironwood).

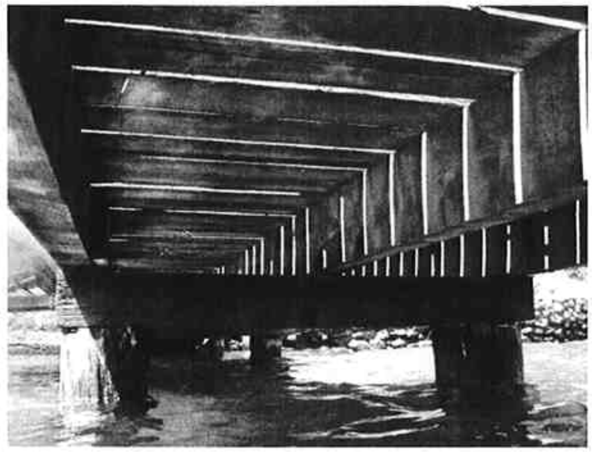

Figure 6.-Traditional decking.

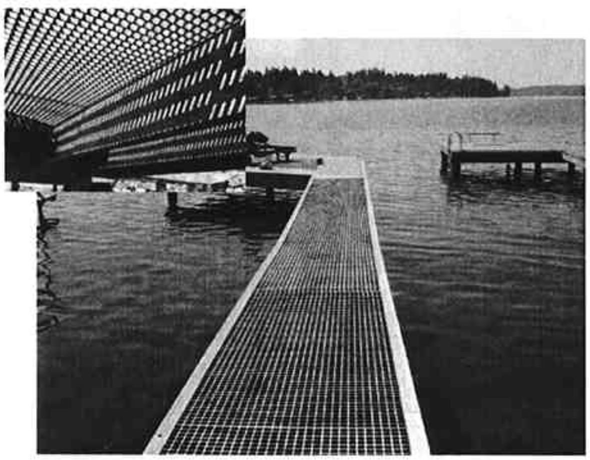

Figure 5.-58% open-spaced grating (Chemgrate®).

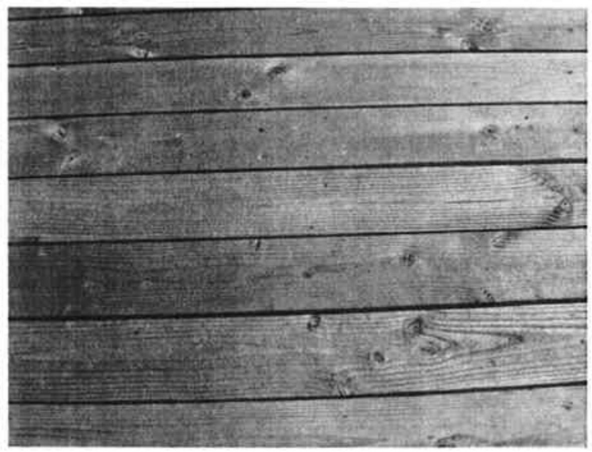

Figure 7.-Solid decking.

Results

The mean percentage of full sunlight transmitted through grating (7.5%) was significantly greater than the percentage transmitted through prisms (0.7%), traditional decking (1.5%), and solid decking (0.2%; $p<0.001$). Additionally, traditional decking transmission was significantly greater than solid decking, but acrylic prism transmission (at the typical construction densities) was not (Fig. 8).

Discussion

While grating transmitted the greatest amount of sunlight to the water below, significantly more than prisms, traditional decking or solid decking, the lack of skirting on piers also appeared to have an effect on the amount of available sunlight beneath the piers. The light environment beneath raised piers was brighter than beneath those close to the water surface or with support structures (*e.g.*, beams, stringers) or boat bumpers around their perimeter. Such structures obstructed sunlight from reaching the water surface immediately below the pier. Also, temporary items such as kayaks, rafts and storage containers placed on or adjacent to any of the treatment types (*i.e.*, positioned in such as way to cast shadow on the grating) also appear to have an effect on the amount of transmitted sunlight.

Most piers with structural support components below the decking have many large-diameter wood pilings, support stringers (*i.e.*, lengthwise beams) and joists (*i.e.*, cross-support beams), while others had electrical conduit as well. These sub-decking structures restrict the amount of sunlight that can pass between any transmittance treatment and the water surface. Glue-laminated beams (Glu-lams), often used

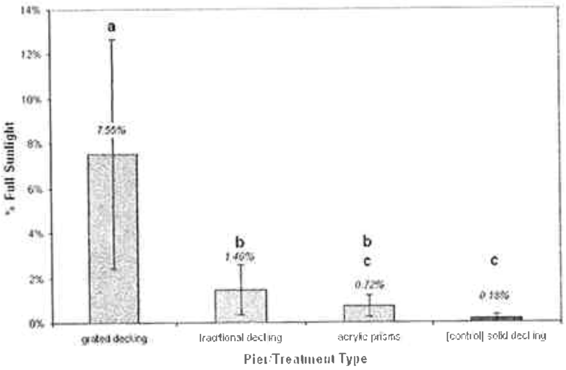

Figure 8.-Mean light transmission percentages for each category, in descending order. Different alphabetic descriptors (*e.g.*, "a", "b" and "c") indicate statistically different means (ANOVA with Tukey *a posteriori* test). Error bars represent +/- one standard error.

as support stringers, are placed along the outside edges of piers and typically extend to within 19 cm of the water, thus restricting illumination under the pier from the side. Increasing the height of the pier from the water, especially along its perimeter, orienting the lengthwise portion of the pier in a north-south direction, and minimizing pier width increases the amount of light able to reach the submarine environment directly beneath the pier (Burdick and Short 1999).

Lastly, while we evaluated three types of grating, we noted that thicker grating material with east-west load bars or mesh restricted the passage of direct sunlight to the water's surface at low sun angles.

Recommendations

The effective goal to maximize the amount of natural light beneath over-water structures is to minimize the effects of human development on Chinook salmon and the natural biota (*i.e.*, to strive for invisibility to biota in the design of man-made structures). Some recommendations to maximize light penetration include:

- maximize the amount of open space in the decking (*e.g.*, install grating with maximum open spacing) and ensure that the open space is kept uncovered or unshadowed by other pier features or gear;
- increase the distance between the bottom of support stringers and water surface (*i.e.*, raise the effective distance of the pier from the water);
- design walkway widths and/or the body of the pier to be as narrow as possible;
- minimize the number of pilings and use the smallest diameter piling as possible; and
- if native aquatic vegetation is of concern (in addition to salmonid migration and health), then pier orientation in a north/south direction will maximize the mean available sunlight to any single point beneath the pier.

Acknowledgments

We thank Brian Missildine (USFWS), Eric Nelson (USCOE), Karla Reece (NOAA Fisheries), Marcy Reed (USCOE), Dr. Thomas Sibley (NOAA Fisheries), and Roger Tabor (US-FWS) for their review and assistance with this manuscript.

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