MIAMI UNIVERSITY

A summary report of ultraviolet radiation (UV) transparency and other water quality measures at Crystal Shores West (2007-2009)

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Introduction

Ultraviolet radiation (UV) and temperature are two important factors that can influence the distribution of aquatic organisms, including fish. For example UV, which causes sunburn and skin cancer in humans, is capable of inducing high levels of DNA damage in sensitive fish eggs and larvae. Excessive DNA damage eventually results in egg and larval mortality in fish that are unable to repair or effectively protect against such damage. Consequently, high levels of underwater UV can reduce the suitability of clear water habitats for certain fish species. Likewise, temperature is an important factor controlling the development and even survival of fish eggs and larvae. Some species favor warmer water while others can thrive in colder lakes and streams.

In 2007 our lab at Miami University began working out of the Tahoe Center for Environmental Sciences (Incline Village, NV) to explore whether these factors are important in controlling the distribution of non-native fish in Lake Tahoe. Non-native warmwater fish (so called because of their reproductive requirement for warmer waters), including largemouth bass and bluegill, were introduced into the lake in the 1980s. Currently self-sustaining populations of these fish are constrained to a few areas in the southern end of Lake Tahoe. These areas tend to have reduced water clarity, relative to the rest of the lake, and also provide the necessary warm water temperatures required for successful reproduction. Based on experiments with larval fish in high and low UV (i.e. clear and turbid) nearshore sites we have determined that water clarity is an important factor limiting the distribution of these warmwater fish. Temperature is also important, in that it constrains these warmwater fish to the shallow nearshore areas where UV light levels are highest and where water is warm enough for fish reproduction and development. We have submitted a paper describing this research that will be published in the journal Ecology.

As part of our research effort we have collected UV and temperature data at the Crystal Shores West marina from 2007 to 2009. Our long term goal is to use these data and similar data from other sites around the lake to predict habitat suitability and the potential for non-native warmwater fish invasion in nearshore habitats throughout Lake Tahoe. This report summarizes the UV and temperature data that we have collected from Crystal Shores West over the last three years. I have also included a brief summary (adapted from the Ecology paper) that suggests that Crystal Shores West is not suitable habitat for bluegill, given the relatively high underwater UV levels in the marina. In addition, there is a short discussion of dissolved organic carbon (DOC) and chlorophyll levels in the marina based on data collected for these parameters in 2007.

<u>UV and Temperature Data (2007-2009)</u>

UV and temperature data were collected once a month in both June and July in 2007/2008. In 2009 UV and temperature data were collected monthly May through August. We used a Biospherical Instruments UV/PAR radiometer (Biospherical Instruments Inc., San Diego, CA USA) to collect our temperature and UV data (Figure 1). This instrument quantifies incident solar irradiance at three different UV wavelengths (305, 320, and 380 nm) as well as visible wavelengths of photosynthetically active radiation (PAR, 400-700 nm). In June and July 2008, we incubated "i-button" temperature loggers in the marina at 1 meter depth for three days. This allowed us to estimate average daily temperature fluctuation at the lake bottom during these months. Temperature is in degrees Celsius. To convert to degrees Fahrenheit multiply by 1.8 and add 32.

Figure 1. Using the Bioshperical Instruments radiometer to collect UV and temperature data at Emerald Bay.

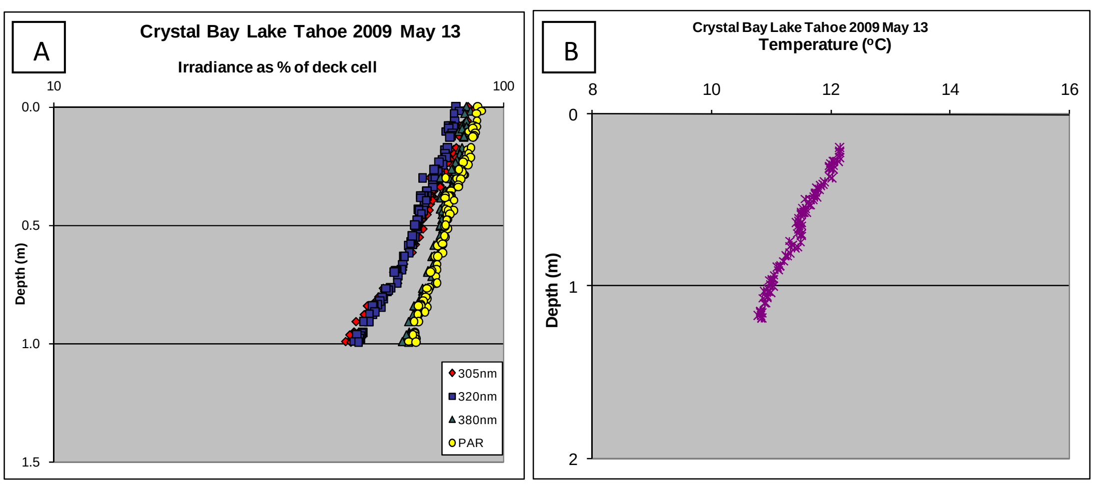

Figure 2. These are representative plots from a single UV/temperature profile taken in mid-May 2009 with the Biospherical Instruments UV/PAR radiometer. Panel A is a plot of UV irradiance as a function of depth. At the marina bottom (approx. 1 meter depth) 305 nanometer UV light (the highest energy most damaging UV wavelength) is still present at almost 50% of surface UV levels. For comparison, 305 nm light levels in the Tahoe Keys are essentially zero at 1 meter depth. Panel B shows temperature, in degrees Celsius, as a function of depth. Surface temperature is near 12 ° C (~53 ° F). At the marina bottom water temperature is nearly 1.5 ° C cooler than at the surface.

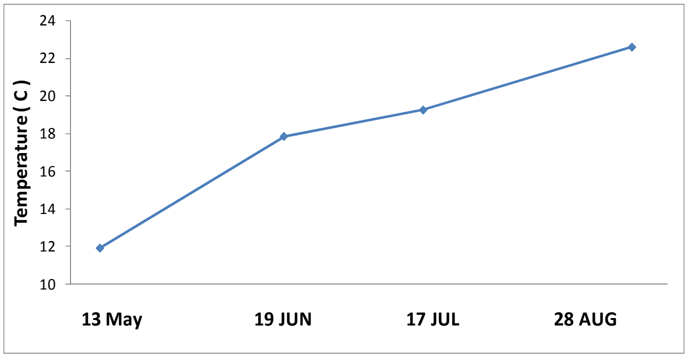

Figure 3. Seasonal surface temperature at Crystal Shores Marina. This figure shows a gradual increase in surface temperature over the course of the summer, with late August temperatures nearly 10 degrees Celcius warmer than in mid-May.

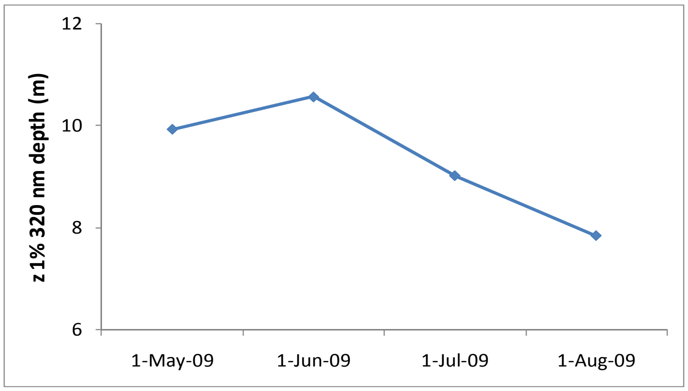

Figure 4. Seasonal UV transparency May-Aug 2009. z 1 % depth is the depth where 320 nm UV is predicted to reach 1% of surface UV levels. The greater the z 1% depth the clearer the water. These data suggest that UV transparency (i.e. water clarity) peaks in June and slowly decreases throughout the rest of the summer.

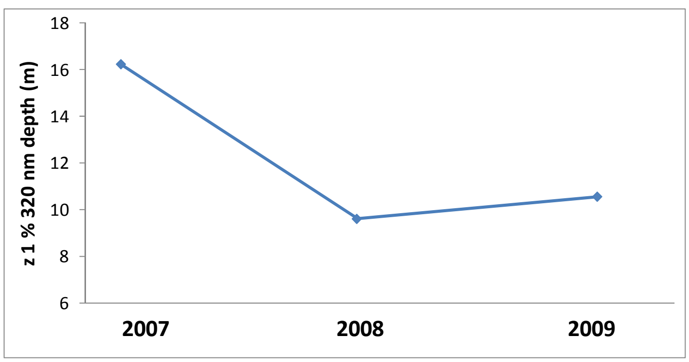

Figure 5. Annual UV transparency measurements (June 2007-2009). Z 1 % depth is the depth where 320 nm UV is predicted to reach 1% of surface UV levels. The greater the z 1% depth the clearer the water. This figure suggests that UV transparency in 2007 was substantially higher than in 2008 or 2009.

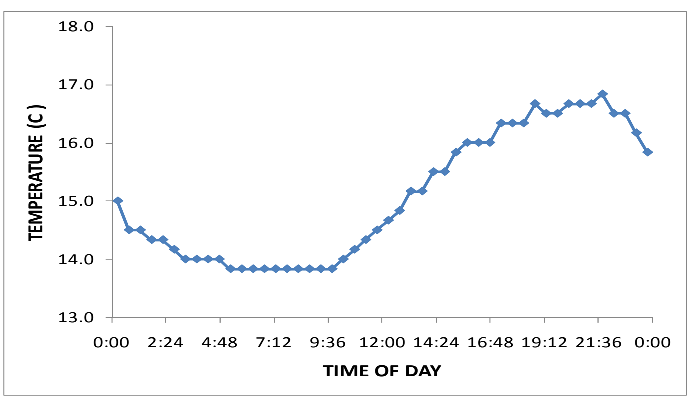

Figure 6. Average daily temperature fluctuation at 1 m depth. Data are from a temperature logger deployed 18-20 JUNE 2008. Maximum temperature occurs around 10 PM. Minimum temperatures prevail from approximately 5-9 AM.

Habitat Suitability for non-native bluegill

In 2007 we incubated larval bluegill in Sand Harbor and Tahoe Keys. In both sites larvae were incubated in both UV transparent plastic sleeves and UV blocking plastic sleeves. By isolating the effect of UV in this way our goal was to determine whether or not larval bluegill could tolerate the high UV levels present in a clear water site like Sand Harbor. We also incubated DNA dosimeters in the same kind of plastic sleeves at both sites. DNA dosimeters are small quartz tubes of raw DNA that measure the amount of DNA damage that is induced by UV exposure. By comparing larval bluegill mortality to DNA dosimeter damage levels in each kind of sleeve at each site we were able to estimate the relationship between DNA damage in dosimeters and larval bluegill mortality. This allowed us to place DNA dosimeters alone at a number of sites around the lake, including Crystal Shores West marina, and make predictions about whether or not larval bluegill could survive at a given site. Our analysis suggests that most nearshore sample sites in Lake Tahoe (including Crystal Shores West) are not suitable habitat for bluegill because of the high levels of underwater UV. Some summary figures from this work are presented below.

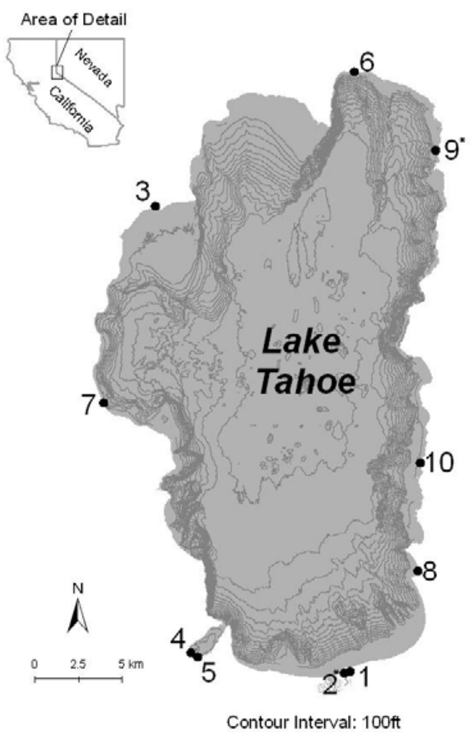

Figure 7. Map of Lake Tahoe indicating the location of nearshore sites where DNA dosimeters were deployed. Site # 6 is Crystal Shores West.

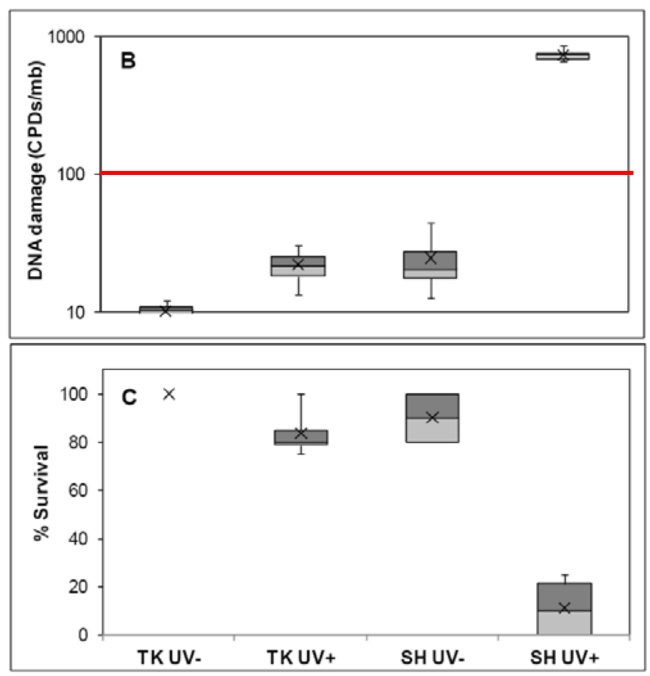

Figure 8. DNA damage in dosimeters (B), and survival of bluegill larvae (C) in experimental bags. TK=Tahoe Keys and SH=Sand Harbor. UV shielded bags (-) and unshielded bags (+) are indicated. Symbols are X for average values in panels B and C. Bars indicate maximum and minimum values within treatments. Boxes indicate the median and 25th and 75th percentiles. The red line indicates a DNA damage value at which bluegill survival is predicted to be low.

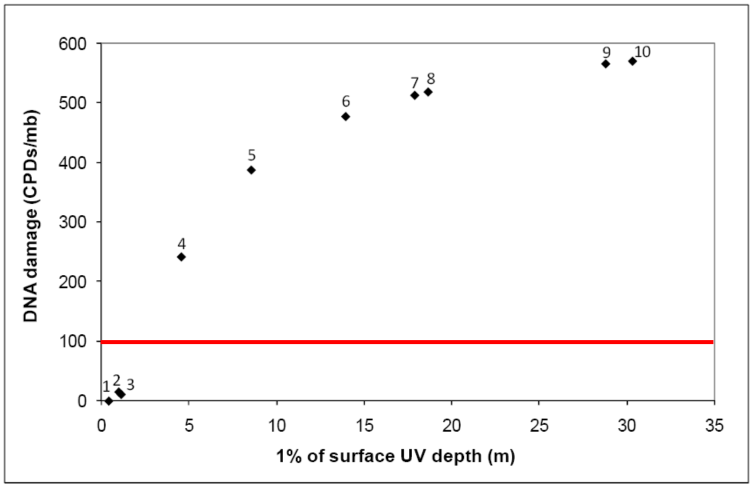

Figure 9. This figure shows the relationship of DNA damage, measured with DNA dosimeters at each site, to UV transparency (as the 1 % of surface UV depth). As UV transparency increases DNA damage is also greater. The red line indicates a DNA damage threshold where we expect high mortality in larval bluegill. Crystal Shores West (site #6) is well above the red line, suggesting that bluegill survival is unlikely in the marina.

DOC and chlorophyll data

In 2007 DOC and chlorophyll data were collected as part of an effort to model what factors are most important for controlling UV transparency in Lake Tahoe. DOC (dissolved organic carbon) is a broad classification for organic compounds of varied origin in lakes and streams. It is generally thought of as an indicator of terrestrial loading in freshwater. It is helpful to think of DOC as something analogous to a tea bag- organic matter that when placed in water will dissolve and color the water. In lakes high DOC concentrations can color the water and reduce the underwater transmission of UV light. Chlorophyll is a green pigment found in most plants. In aquatic systems measuring chlorophyll is often used as a method to estimate the concentration of algae in the water. High chlorophyll levels can also reduce underwater UV light, since algae are able to absorb UV light in the water column. A table of DOC and chlorophyll values collected from nearshore sites around the lake in 2007 is included below.

Table 1. DOC and chlorophyll (Chl *a*) values in nearshore sites. Site #6 is Crystal Shores West. Underwater UV light levels are greatly reduced at DOC concentrations greater than 1 mg/L but remain relatively constant below 1 mg/L. Chlorophyll levels at Crystal Shores West are very low.

Site Number	$Z_{1\%320nm}$ (m)	DOC (mg/L)	Chl *a* (µg/L)
1	0.4	1.77	2.47
2	1.3	1.24	12.20
3	1.1	1.00	144.70
5	8.6	0.66	0.95
6	14.0	0.53	1.81
7	17.8	0.58	0.42
8	18.6	0.58	0.58
9	28.8	0.53	0.32