Sunlight Research May Lead to Invasive Fish Species Management Tools in Lake Tahoe

Researchers from Miami University (Ohio) are exploring whether solar ultraviolet radiation (UV) can control warm-water fish invasion in nearshore Lake Tahoe. In recent decades human disturbance such as shoreline development has altered nearshore water clarity and reduced UV exposure in some locations (Fig 1). This decline in water clarity has coincided with the introduction and establishment of the warm-water fish species. Amanda Gevertz and Andrew Tucker, two Miami University graduate students working with faculty members Jim Oris and Craig Williamson, have been testing the idea that declining water clarity in nearshore habitats creates a refuge from damaging UV and effectively opens an “invasion window” that allows UV sensitive non-native fish to reproduce in areas where they may have previously been excluded.

Warm-water fish were introduced into Lake Tahoe during the 1980’s. These fish, including largemouth bass and bluegill, compete with and prey upon native fish in the nearshore environment. In areas where non-native fish populations have become established, native minnow species (e.g. Lahontan redside and speckled dace) have virtually disappeared. As a critical component of the lake food web and as some of the last remaining native fish species in the lake, the disappearance of these native minnows would be detrimental to the ecology and diversity of Lake Tahoe.

Historically, water clarity (and therefore UV exposure) in nearshore Lake Tahoe was exceptionally high. The native minnows that occur in the nearshore environments in the lake are apparently adapted to life in these very clear waters and are able to survive and successfully reproduce under high UV conditions. Bluegill and largemouth bass on the other hand are adapted to lower UV environments and may be more sensitive to high UV levels. Bluegill and bass also require warm water temperatures to reproduce. Consequently, in a high elevation cold-water lake like Tahoe these warm-water fish must nest in shallow nearshore habitats where temperatures are warm enough to permit survival of developing eggs and larvae and where UV exposure is low.

Tucker and Gevertz have conducted experiments to test whether native species are indeed more UV tolerant than non-native warm-water fish and to examine whether nearshore water clarity affects the suitability of habitats for non-native fish reproduction and survival. The results show that the native species are much more UV tolerant than the non-native fish (Fig. 2). The endpoint of these experiments was the UV exposure level that resulted in the death of 50% of the test organisms (the “median lethal dose” or “LD_{50}”). The LD_{50} for the native minnow species was approximately 7 times greater than that of the non-native bluegill. This indicates that the native minnow is much more tolerant to, and suited for the UV exposure which results from Tahoe’s clear waters.

Gevertz and Tucker have also identified some of the important mechanisms underlying this increased UV tolerance in native minnows. Skin pigmentation formation and development in the native minnow differs dramatically from that of the non-native bluegill (Fig. 3). The native minnow hatches with a significant amount of protective pigmentation around vital organs, with pigmentation spreading rapidly to the rest of the body as the larva age. In stark contrast, the non-native bluegill hatch without pigment, and further development of pigmentation is slow. Another example of a protective mechanism lies in goblet cell production. These cells are found in the surface layers of the larval skin, or epidermis, secreting mucus that contains photoprotective compounds (Fig. 4). The native minnow produces these protective cells in response to UV exposure, whereas the non-native bluegill does not. Additional incubation experiments suggest warm-water fish establishment (i.e. larval fish survival) is currently limited to a small number of sites where water clarity is unusually low relative to the rest of nearshore Lake Tahoe (Tucker et al., 2010).

The current goal of the Miami University researchers is to develop a water clarity threshold, based on measured UV tolerance levels of non-native versus native fish, which could be used by lake managers as a target water clarity measure to prevent the further spread of non-native fish and to limit their negative impact in the lake. The good news is that the rate of water clarity loss in Lake Tahoe has declined in recent years, so if efforts to "Keep Tahoe Blue" succeed then a full scale warm-water fish invasion could be avoided.

More broadly, the findings of the Miami University research group suggest that ultraviolet radiation (and therefore water clarity) could control biological invasion of fish and other UV sensitive species in clear lakes. Invasive species are one of the leading causes of global biodiversity loss and are estimated to cost as much as 120 billion USD annually in environmental damages and loss. Given the substantial ecological and economic costs of exotic and invasive species, the Miami University research is important in that it expands our understanding of the factors that control biological invasions, and it represents an opportunity to better manage species invasion in lakes.

Reference:

Tucker, A.J., C.E. Williamson, K.C. Rose, J.T. Oris, S.J. Connelly, M.H. Olson, D.L. Mitchell. 2010. Ultraviolet radiation affects invisibility of lake ecosystems by warm-water fish. Ecology 91(3): 882-890.

Figure 1. A comparison of nearshore habitat in Lake Tahoe shows the dramatic differences in nearshore water clarity. Decreased water clarity significantly reduces potential UVR exposure in some sites.

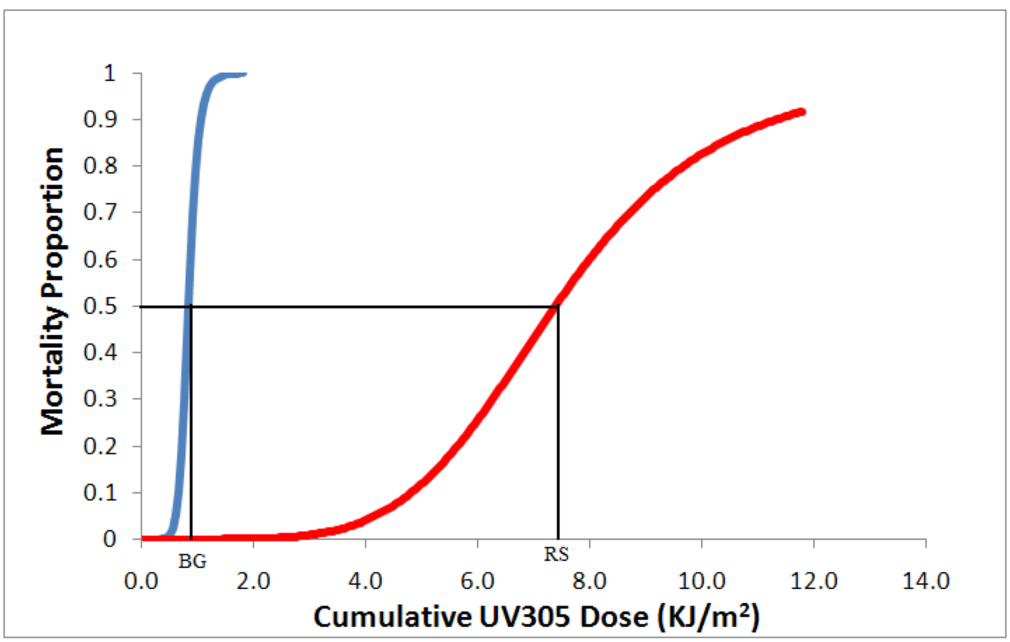

Figure 2. Mortality of bluegill (blue line) and Lahontan redside (red line) larvae exposed to UV radiation. The black lines intersecting the response curves show the estimated LD_{50} values for bluegill (BG) and redsides (RS), where a higher LD_{50} value indicates increased UV tolerance. Redside larvae are substantially more UV tolerant than bluegill.

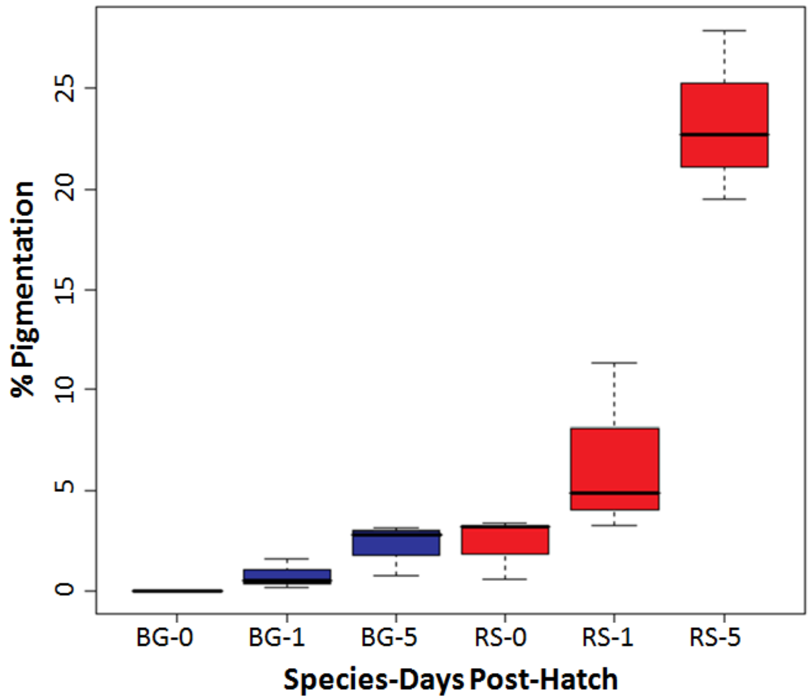

Figure 3. Larval pigmentation comparisons of the bluegill (BG) and the Lahontan redside (RS) across ages. Development was tracked over a period of 5 days immediately following hatching. Time is indicated as 0, 1, or 5 days post-hatch. The redside is visibly pigmented upon hatching and continues pigment development rapidly in relation to the bluegill. This trend indicates the redside possesses increased protection against UV exposure.

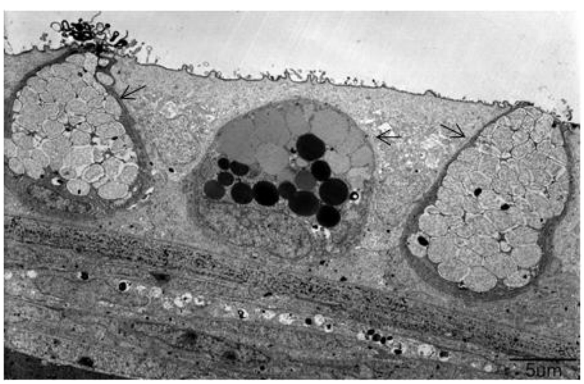

Figure 4. Transmission electron micrograph of three goblet cells, indicated by arrows, in the epidermis of a native Lahontan redside. These cells excrete photoprotective compounds and were abundant in the epidermis of redside larvae exposed to UV. Conversely, bluegill larvae in the same treatment did not exhibit increased goblet cell formation, indicating that the redside is better equipped to combat UV exposure.