ENVIRONMENTAL BIOLOGY

UV-B Effects: Bad for Insect Larvae Means Good for Algae

At the end of the 1990 summer field season, ecologist Max Bothwell left an experiment running at his field station on the banks of the South Thompson River in British Columbia. He'd already collected 2 weeks worth of data—enough to show that in his system as in many others, ultraviolet light slows the growth of algae. But out of curiosity, while a technician finished up another experiment, he left river water flowing through troughs covered by either UV-shading glass or UV-transparent Saran Wrap.

Two weeks later, back in his office in Saskatoon, Bothwell got a status report by phone from a colleague: There were more algae beneath the Saran Wrap than beneath the glass. Somehow, exposure to UV light was allowing more algal growth. Bothwell couldn't believe it. He insisted on holding the phone for several minutes while his colleague went back outside to double-check the experiment. The result was the same. "Right then, on the phone, it was like a red light flashed on in my mind that something very unusual was going on," recalls Bothwell, a researcher at Canada's National Water Research Institute. "I'll never forget it."

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Spelling it out. Algae growth is inhibited where UV light is let in *(letters)*, but will eventually rebound where UV-B light kills insect larvae.

For the next three summers, he went back and systematically reproduced the results he himself considered "bizarre," carefully separating out the effects of different wavelengths of UV light. Now, on page 97 of this issue, Bothwell and his students Darren Sherbot and Colleen Pollock provide an explanation for the paradox of how exposure to UV light may lead to larger algal populations: UV-B, the most damaging form of UV light, curbs populations of insect larvae—which graze on algae—more than it inhibits the algae themselves. Freed from grazing pressure after several weeks, the algae rebound.

These results don't imply that we should write off the potential ecological damage of UV-B, Bothwell says. On the contrary, his experiments suggest that exposure to UV-B may stress some parts of the ecosystem even though the plants at the bottom of the food chain, the primary producers, seem healthy. That's a timely finding because UV-B is selectively absorbed by stratospheric ozone, and UV-B exposures may rise as the global ozone layer continues to thin.

What's more, these experiments highlight the shortcomings of current UV research and may force marine biologists to rethink the way they study the effects of UV-B. Bothwell's results suggest that the most common types of studies—short-term analyses of primary producers—may miss the point. Ecologist Craig Williamson of Lehigh University in Pennsylvania recalls that when Bothwell presented some of his data last summer at a NATO meeting in Gainesville, Florida, he was greeted with stunned silence. But those who have seen the data now admit Bothwell makes a good case. Says Williamson, "Past studies looked at short-term growth rates in single groups of organisms. Bothwell's experiments looked at multiple levels in the food chain simultaneously and gave unexpected results. I'll bet that within the next year, this work will act as a catalyst for longer-term studies at multiple trophic levels. It's a real paradigm shift."

Bothwell and co-authors were able to study both algae and grazers in a natural setting thanks to his riverside setup, which is much easier to manipulate experimentally than, say, the Antarctic high seas beneath the ozone hole. Bothwell pumped river water into experimental troughs or flumes lined with styrofoam. Algae (mostly diatoms) and insect larvae (mostly midges) colonized the styrofoam just as they would a patch of river bottom. Different light regimes were created with natural sunshine and filters that absorbed light of various wavelengths.

For the first 3 weeks, Bothwell says, UV-A light slowed the growth of algae, while UV-B had little effect. Bothwell surmises that UV-B levels were too low to damage the algae because most UV-B was absorbed by the relatively intact ozone layer over British Columbia in the summertime. Yet even relatively low UV-B exposures were sufficient to harm midge larvae: As the days went on, larval populations in flumes exposed to both types of UV light decreased more than those exposed to UV-A but shielded from UV-B.

After 35 days, this differential sensitivity to UV-B created a more detailed picture of the paradox that had confronted Bothwell back in 1990. Flumes shaded from all UV light had "gobs" of algae, says Bothwell. Flumes exposed to UV-A light had much less algae. And flumes exposed to both UV-A and UV-B had a moderate amount, as UV-B reduced the numbers of midge larvae and allowed algal populations to rally. In fact, in terms of algal density, exposure to UV-B had an effect similar to dosing the chambers with the insecticide malathion.

If organisms up and down the food chain often have such differential sensitivity to UV light, then those who measure only short-term UV-B effects on algae—as most researchers do—may be missing significant repercussions of UV exposure, concludes Bothwell. Furthermore, he warns, insect larvae seem to rely on UV-A and visible light as cues to move away from the perilous presence of UV-B. By increasing UV-B exposure without changing the amount of visible light and UV-A, ozone loss may deprive organisms of the signals they use to avoid UV-B damage.

Much of the concern over ozone loss is centered on marine ecosystems, in particular those of the southern oceans below the seasonal Antarctic ozone hole. It's hard to extrapolate to the open ocean from data gathered in 1 centimeter of flowing fresh water. But marine biologists agree that Bothwell's study provides a pointed reminder of an ecological principle that many talk about but few apply: Physical stresses such as UV-B light may have intricate and unexpected effects in different parts of the food web.

So far, most marine work has focused only on phytoplankton, the one-celled primary producers of the oceans. Many studies have shown that on short time scales, both UV-A and UV-B can inhibit phytoplankton growth to some degree, although there's debate about how much. But few studies have looked at longer time scales, and until very recently, the direct effects of UV on higher organisms were all but ignored, says marine biologist Deneb Karentz of the University of San Francisco. "Most of us have thought that the main effect on the zooplankton would be through their food source, phytoplankton, whether in absolute numbers or in more subtle changes," says Karentz. "Now we need to go back and rethink that."

–Elizabeth Culotta