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LETTERS

Western toad at high noon?

Field experiments show that ultraviolet (UV) light can damage amphibian eggs. Field observations show a decline in many populations of frogs and toads, such as this threatened toad *Bufo boreas.* But to what degree is solar radiation a factor in the decline? The latter, more complex, question is of a global scale. Many letters praising the UV light experiments of Andrew Blaustein and his colleagues were received in response to the 21 July special section "Frontiers in Biology: Ecology." How the media, including *Science*, report on such experimental findings, and what kind of studies should be done next, are more problematic for these writers.

WILLIAM LEONARD

Ecological Research

Our recent work showing that ultraviolet (UV) radiation can contribute to amphibian egg mortality is criticized by Joseph Bernardo and William Resetarits in a news article for, as Bernardo says, being "very poorly grounded in long-term, quantitative field data" ("When rigor meets reality," by Wade Roush, in a special section: Frontiers in Biology: Ecology; 21 July, p. 313). These criticisms are unfounded. We have collected and published data (including yearly egg mortality estimates) on the ecology of northwestern amphibians for 15 years. Moreover, we have about 40 years of background data on northwestern amphibians from Robert Storm and his numerous students.

With this natural history basis, we became concerned in the mid-1980s when we observed unprecedented mortality of amphibian eggs in the Cascade Range. After systematically analyzing pond water for pollutants, acidification, and many other factors, we found only one factor associated with egg mortality—a pathogenic fungus (*1*). Bernardo ignores relevant issues when he presents the fungus as an alternative to UV for high egg mortality without acknowledging that I proposed this explanation (*1*). We also noted that dying eggs were laid in shallow, open water, an observation consistent with the view that mortality is related to UV radiation. Thus, after 8 years of observing dying eggs, conducting preliminary experiments, and after ruling out many potential mortality factors, we designed field experiments to test the hypothesis that amphibian embryos are sensitive to ambient UV-B radiation.

Eggs of several species were placed in enclosures in a randomized block design at natural oviposition sites. This design allows experimental and control treatments to be conducted simultaneously, side by side, after randomly assigning enclosures to positions along the shore. Each block had three treatments (not just filtered and unfiltered treatments, as stated by Roush): enclosures (i) open to natural sunlight including UV-B, (ii) covered with a UV-B blocking filter, or (iii) covered with a filter that transmitted UV-B (a control for placing a filter over eggs). Each block was replicated four times. To ensure that our results were not unique to a specific site, each species was tested at two sites. Experiments were conducted in both 1993 and 1994. Our published papers (*1*, *2*), those in press, and those in review suggest that in certain species both UV radiation and the fungus contribute to egg mortality, and that is all we have stated in our papers. We do not know how continued egg mortality will affect amphibians at the population level. But we do know that our experiments had the potential to invalidate the view that UV radiation contributes to egg mortality. We have not claimed that UV radiation is the single worldwide cause of amphibian population declines, as is implied in the news article. We have repeatedly stated that habitat destruction is the main cause for the declines (*3–5*); that they do not lend themselves to single explanations is a point that we have made in several papers (*3–5*). However, this statement

is mistakenly attributed to David Reznick, apparently because Reznick paraphrased one of my papers (5) on amphibian declines to Roush (6). It is unfortunate that Bernardo and Resetarits appear not to have read our papers carefully and have criticized us for what some of the popular press has said about our work.

Instead of being poorly grounded in long-term field data, as Bernardo alleges, we believe that our work demonstrates how long-term observations point the direction toward relevant, realistic experiments.

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6. D. Reznick, personal communication.

I wish to express my concern over the quote attributed to me in the article by Roush. The quote (which gives the incorrect impression that I am critical of Blaustein's work) was actually derived from Blaustein's own writings (*1*). Blaustein is at the forefront of the worldwide investigations into all the potential causes of amphibian decline, including UV radiation. In view of his clear statement of likely multiple causes of the amphibian decline, I interpreted Blaustein's experiment as a test of the plausibility of UV radiation as one of those possible causes. The fact that the experiment was performed without the benefit of prior long-term data indicating an increase in UV radiation should not be a concern because, in a rapidly changing world, it is impossible to foresee what the important changes might be. Rather than criticize the work for not being motivated by such data, I instead view it as contributing to the motivation for collecting such data in the future.

More generally, it is ironic that Roush featured criticism of two such fine papers. Both Dolph Schluter (*2*) and Blaustein were working on systems for which there are abundant ecological data. Both took these prior observations into account when designing and executing their experiments. Both studies represent novel approaches to a problem and produced interesting results that should be of interest to a general, critical audience such as *Science*'s readership. Both studies incorporated complexities that merit some open debate, so it is not unreasonable that one of them has been discussed in *Science*'s Technical Comments section (*3*); however, the tone of Roush's news article in no way represents the subtleties of this kind of work or the costs and benefits of alternative experimental approaches to a problem, such as the role of density or the use of hybrids in Schluter's work. In my opinion, Schluter made the right decisions. For all of these reasons, I feel that Roush's article presents an inaccurate, destructive view of the scientific process.

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I am appalled and dismayed by the views attributed to Bernardo and Resetarits in the article by Roush. Experiments in ecology, as in all branches of biology, must be well grounded in an understanding of the natu-

ral world, but to attack Blaustein for not having followed this principle is absurd. The declines in amphibian populations that have recently been observed in many parts of the world are disturbing to many biologists, and increased UV radiation resulting from ozone depletion is an obvious candidate as a cause of at least some of these declines. Blaustein's experiments were a simple, well-designed, and carefully carried out test of this hypothesis, and they yielded strong and persuasive results in its support; they should be judged on their merits as experiments, and it is for the biological community to evaluate their wider significance. They do not solve the mystery of the declines, and Blaustein has never claimed that they do; they do, however, open up important new areas of investigation. Blaustein's decision to study the effects of UV radiation on amphibian eggs may have been a largely intuitive one, but where would science be if researchers ignored their intuition?

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Who would have anticipated 10 years ago that collecting long-term data on UV might be important now? The point of Blaustein's research is that UV exposure *does* affect amphibian egg survival and that changes in UV radiation *have the potential* to contribute to declines in some populations.

Most ecologists recognize that the two approaches to studying ecology are not in opposition, but are complementary. Long-term field experiments of the type advocated by Bernardo and Resetarits have the advantage of retaining some of the complexity of natural systems. Disadvantages include (i) a lack of control of factors that may affect the population under study; (ii) little replication of results; and, in many cases, (iii) little power to prove or disprove inferences about causality. Laboratory or controlled field experiments have the advantage of larger numbers of replicate studies, greater statistical power, and more power to reveal causality. The primary sacrifice made in the latter approach is the elimination of possibly relevant factors.

I agree with Bernardo and Resetarits on the general point that it is critical to articulate biological hypotheses and to collect precise experimental or observational data that distinguish among alternative causes, although I suspect that most ecologists would agree that this should be standard operating procedure.

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Response: Some of the experiments discussed in my news article—studies by Andrew Blaustein and colleagues and by Dolph Schluter—had generated discussion and debate among ecologists well before I wrote about them. The article reflected that debate. It also allowed the scientists to refute the critiques; for instance, Blaustein's initial point in his letter, that he had 15 years of data on his study population, is also made by him in the news article.

The criticisms of Blaustein's work conveyed in the news story focused on a specific paper [A. R. Blaustein *et al.*, *Proc. Nat. Acad. Sci. U.S.A.* **91**, 1791 (1994)]. That paper did not include the qualification that a pathogenic fungus might be another source of egg mortality, nor did it contain any reference to the 1991 paper in *Biological Conservation* that Blaustein cites in his letter above. Nevertheless, the news article should have acknowledged that Blaustein himself had raised the fungal hypothesis elsewhere.

The 1994 paper by Blaustein *et al.* did include the statement that "There is no known single cause for the amphibian declines, but their widespread distribution suggests involvement of global agents—increased UV-B radiation, for example." David Reznick, when interviewed by me, noted several alternatives to the view that a global UV increase was responsible. It was not clear in our discussion that his statement, "These global patterns don't lend themselves to a single easy explanation," was derived from Blaustein's own writings. I regret the error, and apologize for the misunderstanding.—***Wade Roush***

■

Dioxin and Advisory Board

We take strong exception to Richard Stone's summary of the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB) meeting and the accompanying headline, ("Panel slams EPA's dioxin analysis," 26 May, p. 1124), as members of the panel in question. At the conclusion of the meeting, one of us (D.O.) characterized the panel's recommendations as "in no way a repudiation," but rather a judgment that two of the nine chapters (parts of chapter eight and chapter nine) of the health assessment document needed "clarification and ripening." No one on the 39-member panel disagreed publicly with that judgment, and there were several concurrences on the record.

As noted by Stone, we did commend the agency for considering dioxins and related compounds as a class, and many of us were highly supportive of the work reflected in the first seven chapters of the health assessment document. In particular, we do not agree with Stone's assertion that "Other board members say EPA also ignored data that fail to support its conclusion that dioxin is harmful to human health." The only board member Stone cites in this context is Michael Gough, a microbial geneticist at the Office of Technology Assessment of the U.S. Congress, and we disagree with him and think he is not representative of the full group. Moreover, his long-held views on this subject are well known.

Finally, we point out that the one public comment on the agenda in the 2-day meeting from an organization not representing industry also commended the EPA for its work to date. We think it is likely that when the EPA redrafts the health assessment document for the molecule TCDD, it will maintain the scientific core of the ev-