Effects of UVB Radiation on Amphibian Growth and Development: A Meta-Analysis

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Abstract

Amphibians are one of the most threatened group of animals, due to habitat loss, fragmentation, and disease. There is ongoing debate whether an increase in ultraviolet radiation (UV), as predicted due to depletion of atmospheric ozone concentrations, is a contributing factor to amphibian declines. Ultraviolet-B (UVB) can harm the DNA of amphibians and penetrate amphibian eggs. Multiple studies (including a meta-analysis) have been conducted on the effects of UVB on amphibian survivability. These studies leave unanswered questions on the sublethal impact of UVB on amphibians. We aimed to determine whether UVB negatively affects amphibian growth and development, and if so, to what degree. Hedges' *g* was calculated from study statistics to measure the strength of the relationship (i.e., effect size) between UVB exposure and growth, development time, and the incidence of developmental abnormalities. Daily UVB levels in the distribution range of each amphibian species, were extracted and used to calculate total UVB dosage. Our results indicate that UVB may increase growth and developmental abnormalities. In addition, higher UVB levels in the species range correlated with negative overall effects for growth. Future research should consider the sublethal effects of UVB when assessing amphibian declines.

Introduction

Ultraviolet radiation (UV) is a form of electromagnetic radiation that is a part of the sun's energy which reaches the earth's surface. There are three types of ultraviolet radiation: UVA, UVB, and UVC. Ultraviolet-B (UVB) are short invisible rays that range from 290 to 320 nanometers and are the main cause of sunburn. Recent concerns have arisen that climate change could lead to ozone layer depletion causing increased surface UVB levels. Humans are not the only creature susceptible to UVB radiation damage (e.g., melanoma). Amphibians' sensitive skin, as well as their eggs having a lack of shell, makes them susceptible to increased UVB exposure. Increased UVB levels can cause mortality, DNA damage and may cause sublethal harm affecting amphibian growth or development (i.e., developmental time and deformities).

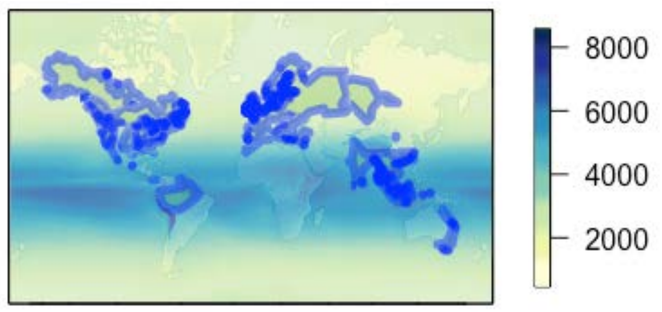


Figure 1. Daily mean UVB radiation (J/m^2/day) over the species range for the different amphibian species.

What is a meta-analysis?

A meta-analysis is a statistical procedure in which multiple studies are combined to analyze and derive new conclusions from previous research. A meta-analysis has been done on the effect UVB has on amphibian survival.

Hypotheses

- As UVB exposure increases, amphibian growth will significantly decrease (caused by an energy cost related to cellular repair);
- The frequency of amphibian developmental deformities (as a result of low photolyase activity) will increase as UVB exposure increases;
- Increased UVB exposure will prolong amphibians' developmental time (due to an energy cost associated with DNA repair);
- When experimental conditions significantly differ from a species original range of distribution than effect size should be larger

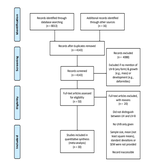
Methods

1 **Search databases**

Google Scholar
WEB OF SCIENCE

Systemically searched for relevant papers
- 4,143 results

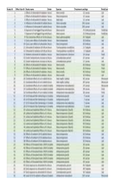
2 **Screen papers**



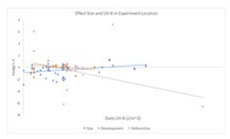
Criteria:
- Mean, sample size, SD or SEM values given
- Distinguished between UVB & UVA
- 27 papers met criteria

3 **Extract & organize data**

Data was extracted from text or graphs using R and WebPlotDigitizer; then imported to Excel. Daily UVB values were obtained for each experiment location and specific species habitat.



4 **Calculating effect sizes & analyze results**



Hedges' d calculated from data

Results analyzed through graphs

Results

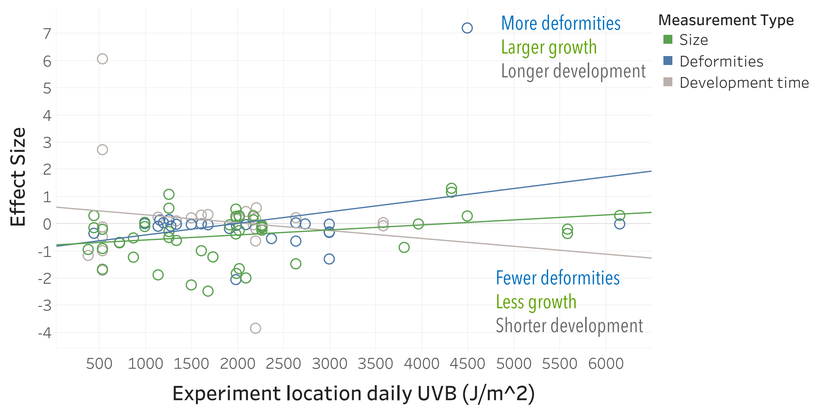


Figure 2. Effect size (Hedges' d) as a function of daily mean UVB in the experimental location.

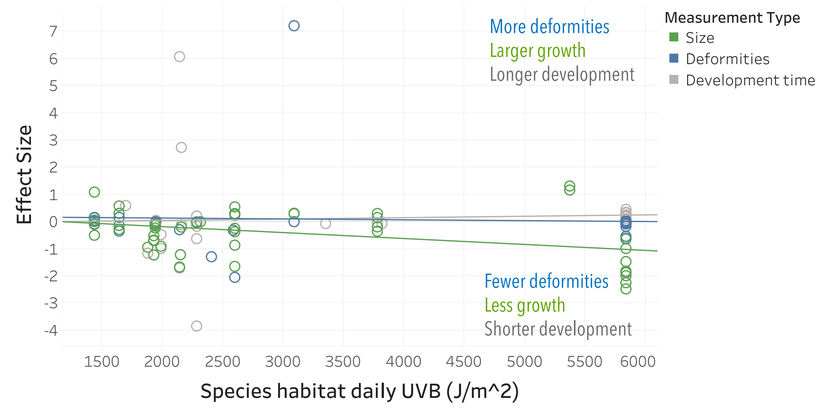


Figure 3. Effect size (Hedges' d) as a function of daily mean UVB in a species' natural range.

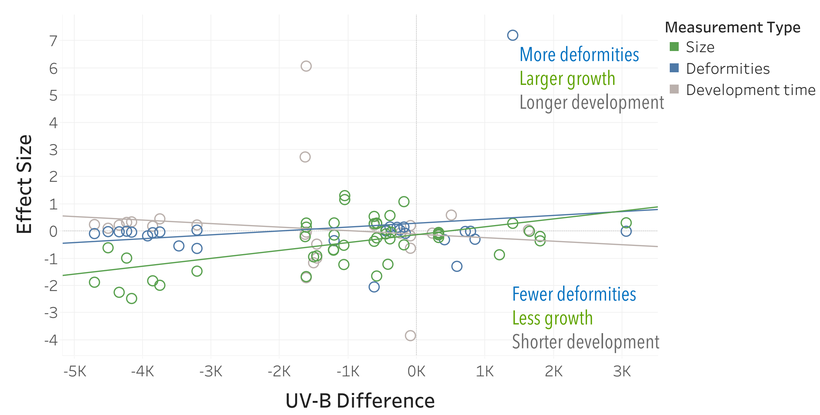


Figure 4. Effect size (Hedges' d) as a function of difference between daily UVB experiment location values and daily values of UVB in the species natural range.

Results (Cont.)

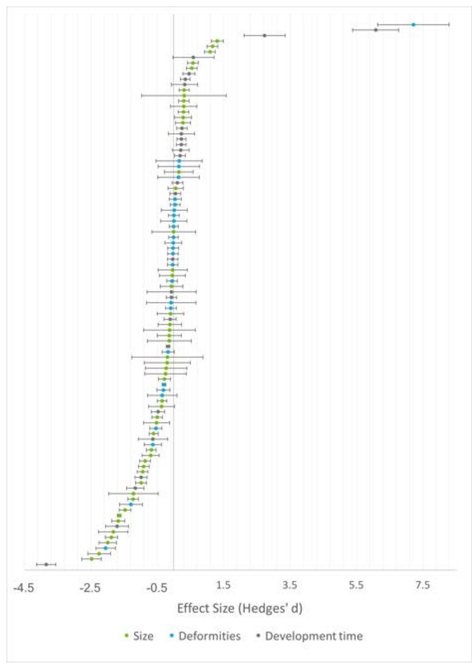


Figure 5. Forest plot of the effect sizes (Hedges' d) for growth and development with 95% confidence intervals

Discussion

- UVB treatment increases deformities, but also seemed to boost growth.
  - However, growth decreased when daily UVB were compared to UVB levels in a species' range;
  - The increase in growth may be due to selective mortality due to UVB exposure, as the small-sized amphibians might not survive treatment.
- UVB treatment does not significantly affect amphibians' developmental time.

Potential future research

- Longer term studies on how UVB affects amphibians
- Compare effects of UVB radiation on aquatic and terrestrial amphibians
- Look at how UVB affects other animal classes sublethally

Figure 6. Black-bellied slender salamander (*Batrachoseps nigriventris*) from garden

References

1. Bancroft, Betsy A., Nick J. Baker, and Andrew R. Blaustein. 2008. A Meta-Analysis of the Effects of Ultraviolet B Radiation and Its Synergistic Interactions with pH, Contaminants, and Disease on Amphibian Survival. *Conservation Biology* 22: 987–996.
2. Beckmann, Michael, Tomáš Václavík, Ameur M. Manceur, Lenka Šprtová, Henrik Von Wehrden, Erik Welk, and Anna F. Cord. 2014. GlUV: a Global UV-B Radiation Data Set for Macroecological Studies. *Methods in Ecology and Evolution* 5: 372–383.
3. Blaustein, Andrew R., and Lisa K. Belden. 2003. Amphibian Defenses against Ultraviolet-B Radiation. *Evolution and Development* 5: 89–97.