Insecticides and Their Effects on Amphibians

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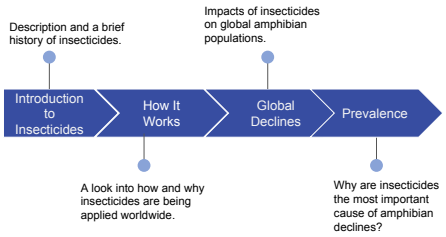
Synopsis



What are insecticides?

"Insecticides are pesticides that are formulated to kill, harm, repel, or mitigate one or more species of insect."

-National Pesticide Information Center

Brief History

Insecticides have been around since 1000 B.C.

Beginning in the 19th century, insecticide use become more efficient and widespread in an effort to feed a quickly growing population and to improve public health

With the increased efficacy of modern insecticides, spillover effects of these insecticides have become greater

Impacts

Common Uses:
- Commercial
- Agricultural
- Household
- Public Health

Common Consequences:
- Malformations
- Species Specific Die-off
- Reductions in Overall Diversity
- Developmental Consequences

Case Studies

- Significant reductions in both Species richness and individual species abundance

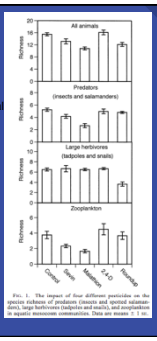


FIG. 1. The impact of four different pesticides on the species richness of predators (insects and spotted salamanders), large herbivores (tadpoles and snails), and zooplankton in aquatic mesocosm communities. Data are means ± 1 SE.

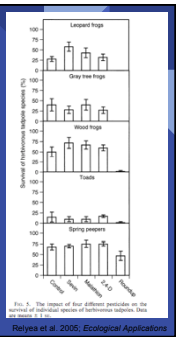


FIG. 5. The impact of four different pesticides on the survival of individual species of hatchlingtadpoles. Data are means ± 1 SE.

Relyea et al. 2005, *Ecological Applications*

Case Studies

Boone et al. 2004; *Ecological Applications*

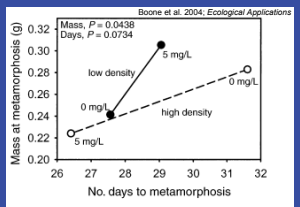


FIG. 2. The trade-off between mass at metamorphosis and days to metamorphosis of the Woodhouse's toads (*Bufo woodhousii*) reared in low- and high-density ponds at 0 and 5 mg/L carbaryl.

- High density ponds were significantly negatively affected from the insecticide carbaryl
- In high density ponds exposed to carbaryl, larvae metamorphosed much earlier than those that were not exposed
- Earlier metamorphosis was correlated with less mass at metamorphosis

Case Studies

- TIme to death varies greatly among populations, but is significantly short
- Not even incredibly dangerous pathogens such as *Bsal* or *Bd* have such short time to death periods

Hua et al. 2013; *Environ. Contam. Toxicol.*

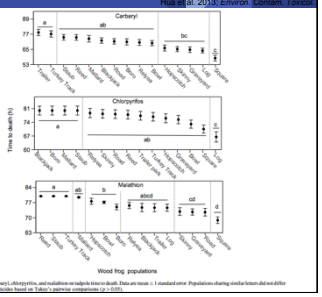


Fig. 1. Effects of carbaryl, chlorpyrifos, and malathion on tadpole time to death. Data are mean ± 1 standard error. Populations sharing similar letters did not differ in sensitivity to insecticides based on Tukey's pairwise comparisons ($p > 0.05$).

Case Studies

- Both low (below normal dose) and high levels of insecticide treatment resulted in more than 25% mortality
- Any amount of insecticide used resulted in almost 90% of the population developing some sort of malformation

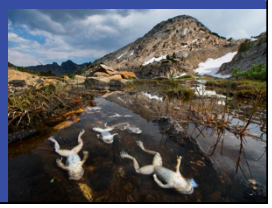
Alvarez et al. 1994; *Environ. Contam. Toxicol.*

Table 3. Percent of mortality, normal and abnormal animals (animals with limb deformities, tail deformities, and both simultaneously) in the control group and in those treated with pesticides. Percents of normal and abnormal animals are related to the number of survivors. Means in a column without a common subscript are significantly different ($P < 0.05$)

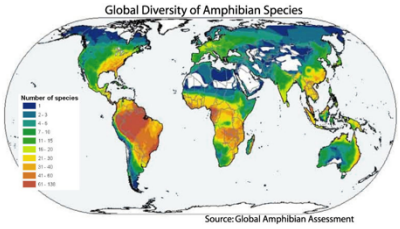
Treatments	Mortality %	Normal %	Abnormal Limb %	Abnormal Tail %	Abnormal Both %
Control	13.6 a	94.47 a	1.24 a	0.74 a	3.05 a
Low A	34.08 b	0 b	20.00 b	3.33 b	76.66 b
High A	38.75 b	0 b	4.35 c	8.69 c	86.96 c
Low F	28.00 b	12.22 b	9.74 c	3.24 b	74.7 b
High F	26.09 b	0 b	0.00 a	12.5 c	87.5 c

How much do insecticides impact declines?

- Amphibians represent ⅓ of global biodiversity *loss*
- Amphibians are heavily reliant on clean air and water sources
- Heavy chemicals in their environment alter their development and overall function
- Defense: predation and disease
- Survival



International Insecticide Usage

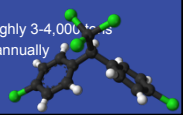


Developing countries = developing problems

- Near the equator or in tropical areas
- Areas that amphibians are known to exist in high densities
- Insecticides used to improve developing economies, agricultural industries, and public health

Dichlorodiphenyl… what?

- The most commonly recognized insecticide is DDT (dichlorodiphenyltrichloroethane)
- An organochlorine, used to target vectors of malaria and typhus from the 1940's - 1970's
- Currently produced in India, China, and Korea
- Today, roughly 3-4,000 tons produced annually



The biggest challenges are:

- A lack of legislative action and regulations on use
- Poorly trained personnel
- Overuse and improper use of insecticides
- Cheaper option by buying DDT products than compounds like pyrethroid esters
- Aerial application directly impacts adults, larvae, and eggs

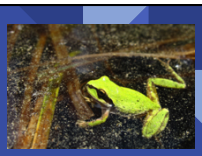
Table 1. Annual global production and use of DDT (in 103 kg active ingredient) in 2003, 2005, and 2007.

Country	2003	2005	2007	Comment	Source
Produce DDT for vector control					
China *	450	490	NA	For export	Pd
India*	4,100	4,250	4,495	For malaria and leishmaniasis	Pd, Ws, Dc
DPRK	NA	NA	5	> 150 metric tons for use in agriculture	UNITAR
Global production	< 4,550	< 4,740	> 4,500		
Use DDT for vector control					
Cameroon	0	0	0	Plan to pilot in 2009	WHO
China	0	0	0	Discontinued use in 2003	SC
Eritrea	13	15	15	Epidemic-prone areas	Qs, WHO
Ethiopia	272	398	371	Epidemic-prone areas	WHO, Ws
Gambia	0	0	NA	Reintroduction in 2008	Dc
India	4,444	4,253	3,413	For malaria and leischmaniasis	WHO, Dc
DPRK	NA	NA	5	> 155 metric tons used in agriculture	UNITAR
Madagascar	45	0	0	Plan to resume use in 2009	Qs
Malawi	0	0	0	Plan to pilot in 2009	WHO
Mauritius	1	1	<1	To prevent malaria introduction	Qs
Morocco	1	1	0	For occasional outbreaks	Qs
Mozambique	0	308	NA	Reintroduction in 2005	WHO
Myanmar	1	1	NA	Phasing out	WS
Namibia	40	10	40	Long-term use	WHO
Papua New Guinea	NA	NA	0	No recent use reported	SC
South Africa	54	62	66	Reintroduction in 2000	Qs, WHO
Sudan	75	NA	0	No recent use reported	Qs, WHO
Swaziland	NA	8	8	Long-term use	WHO
Uganda	0	0	NA	High Court prohibited use, 2008	SC, Dc
Zambia	7	26	22	Reintroduction in 2000	Ws, Qs, WHO
Zimbabwe	0	108	12	Reintroduction in 2004	WHO
Global use	> 4,953	> 5,210	> 3,950		

Abbreviations: Dc, Direct communication with national authorities; NA, not available; Pd, project proposals submitted to the Global Environment Facility; Qs, questionnaires on DDT by the Secretariat of the Stockholm Convention; completed by national countries; SC, documents published by the Secretariat; Ws, workshop presentations by country delegates in the context of the Stockholm Convention. Further information was obtained from the WHO and UNITAR reports, as indicated. *The figure for 2005 was extrapolated from the total production in addition to production for vector control, DDT is produced for Dicofol manufacture (~ 3,000 metric tons per year) and for antifouling paints (~ 200 metric tons per year). "DPR" is also produced for dicofol manufacture (~ 200 metric tons per year).

Insecticide Prevalence

- Approximately 2.5 billion kg/year are applied worldwide
- Increase in amphibian contact with insecticides
- More agricultural practices taking place
  - Leads to more insecticide use to protect crops



Why are insecticides the most important

- Used globally, especially in areas with high amphibian populations
- Very quickly absorbed through skin
- Increasing effectiveness of insecticides
  - Greater potency to amphibians
- Decreased immune response
  - Leads to increased disease risk

References

"Insecticides." *National Pesticide Information Center*. Web. 16 Apr. 2017.

Relyea, Rick A. "The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities." Ecological applications 15.2 (2005): 618-627.

Hua, Jessica, et al. "Cross‐tolerance in amphibians: Wood frog mortality when exposed to three insecticides with a common mode of action." Environmental toxicology and chemistry 32.4 (2013): 932-936.

Alvarez, R., M. P. Honrubia, and M. P. Herraez. "Skeletal malformations induced by the insecticides ZZ-Aphox® and Folidol® during larval development of Rana perezi." Archives of Environmental Contamination and Toxicology 28.3 (1995): 349-356.

Kiesecker, J. M. (2010). Global stressors and the global decline of amphibians: tipping the stress immunocompetency axis. *Ecological Research, 26*(5), 897-908. doi:10.1007/s11284-010-0702-6

Stuart, S. N., J. S. Chanson, N. A. Cox, B. E. Young, A. S. L. Rodrigues, D. L. Fischman, and R. W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306: 1783–1786.

Hof, C., M. B. Araujo, W. Jetz, and C. Rahbek. 2011. Additive threats from pathogens, climate and land-use change for global amphibian diversity. *Nature* 480: 516–U137.