Review on use of amphibian taxa as a bio-indicator for watershed health and stresses

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ABSTRACT: Intensive agriculture, climate change and urbanization accompanied by a collection of other factors which directly or indirectly cause documented decline of wide range of native fauna and flora. Clearing of forested lands alters terrestrial habitats and results in variation of watershed hydro-dynamics such as decrease of natural storage of water, replacement of native species with invasive species, change in resource availability, increased sediment loads and nutrient inputs, chemical and light pollution, etc. in receiving waters. Even though, many vertebrate and invertebrate taxa have been proposed as indicators for environmental quality, taxa with longest life-history requirements with trees or moisture are more vulnerable to riparian damages and other unfavorable water quality conditions than terrestrial-based taxa. Amphibians are considered as a surrogate taxa for ecological quality and stresses. Urban watersheds have significantly lesser amphibian diversity than other watershed types as urbanization in watersheds alters small streams from closed canopy shallow water features of the forest landscape favored by amphibians to features associated with open vegetation and deeper, warmer waters. occurrence of amphibians were determined by physical habitat factors which correlates with the watershed health such as water temperature, blank-full discharge, flashiness, substrate embeddedness and canopy cover. Use of amphibians as indicator species for assessing environmental stresses are superior to conventional measures such as species richness which combine species with different responses to the stress gradient.

1 INTRODUCTION

The general decline of amphibian population is apparent worldwide and the responsible factors include habitat loss, introduction of exotic species, overexploitation, disease, climate change, and decreasing water quality.

Although, aquatic toxicology has focused mainly on fishes and invertebrates, certain studies conducted to compare the responses of amphibians to other aquatic species found that amphibians are often more sensitive to aquatic contaminants than other species (Boyer and Grue 1995). Amphibians are considered as a surrogate taxa for ecological quality and stresses as a result of possessing a sensitive thin semi permeable integument coupled with other factors such as dependence on both aquatic and terrestrial habitat due to bi-phasic life cycle, eggs with gelatinous membrane, reduced larval survival due to alteration of hydrological cycle, etc. (Duellman and Trueb, 1986; Dunson et al., 1992, Blaustein *et al.* 1994).

This paper briefly presents a review of data which support the use of amphibians as an indicator for watershed health and stresses.

2 CONTRIBUTING FACTORS TO THE DECLINING OF AMPHIBIANS

Among the several key reasons for the perceived decline in amphibian populations, the most widely recognized and documented is habitat loss and the agricultural expansion is one of the major causes of amphibian habitat loss (Gallant et al., 2007). Since the near permanent availability of water in the agricultural land uses, many amphibian species have been able to persist in the agricultural lands. Provision on water by groundwater extraction or other irrigational water suppliers such as irrigational channels, dams, etc. inadvertently provided breeding habitats for the amphibians. The ability to colonize by overland dispersal coupled by the absence of less mobile predators such as fish have provided the opportunity for amphibians to exploit these water bodies (Manna at.al.,2009: Marsh et al., 2004; Vasconcelos and Calhoun, 2004).

Since amphibians utilize wetlands extensively for breeding, changes in the quality of wetlands have the potential to influence breeding distributions of amphibians. The loss of wetlands is directly associated with a decrease in the numbers of breeding populations, a factor that can influence populations on local and regional scales. The value of a wetland as breeding habitat to amphibians, however, is also susceptible to changes in within-site factors such as degradation in water quality, etc. that can act as stressors, altering biotic interactions and species survival. Therefore, understanding how urbanization influences wetlands at both the landscape and the local level is paramount to understanding the factors that determine the breeding distribution of amphibians along urbanization gradients (Michel and Joseph, 2005).

Even though the habitat destruction is considered as a major cause for amphibian population decline, the population decline of amphibians in relatively undisturbed areas is still debated. However, it may be due the habitat alteration beyond the suitable environmental limits of the amphibians. For example, a change in the water quality may affects the amphibian population negatively (Priyadarshani et al, 2015).

Water quality of a reservoir or a lake is both affected by internal and external processes. Watershed disturbances such as expansion and intensification of agriculture, deforestation, etc. can alter external nutrient and sediment inputs and thereby changing the water quality. On the other hand, biogeochemical processes add nutrients to the water bodies through internal recycling (Prepas at al., 2001).

Contamination of water bodies and prevailing poor water quality have been discussed extensively in recent years due to the escalated need of sharing scarce water sources among different users, including wildlife. Water quality needs of the wildlife have been generally neglected and it is particularly true to amphibians as well (Hall and Henry, 1992).

Agricultural chemicals are receiving increasing attention as a potential cause of amphibian declines, acting singly or in combination with other stressors (Relyea and Mills, 2001). Fields are often fertilized in spring at the same time that amphibian eggs and larvae develop (Hecnar 1995; Watt and Jarvis 1997). Surveys of natural populations have shown correlations between population declines and proximity to agricultural lands (Rouse et al., 1999; LeNoir et al., 1999; Davidson et al., 2002; Houlahan and Findlay, 2003;). Many malformed amphibians have been reported to occur in agricultural areas where pesticides and fertilizers are applied extensively (Ouellet et al., 1997; Taylor et al., 2005) Studies on amphibian responses to pesticides have been conducted, and the results of these studies of single compounds have documented effects that range from temporary and reversible to delayed growth and death (Power et al., 1989).

Environmentally realistic ammonia or nitrate concentrations in water bodies are likely to damage amphibian eggs and larvae in agricultural regions (Rouse *et al.*1999).

According to the Manuel E Ortis et al., 2002, static experiments were conducted to assess the effects of ammonium nitrate fertilizer on embryos and larvae of six European amphibians: sharp-ribbed salamander (*Pleurodeles waltl*), Iberian painted frog (*Discoglossus galganoi*), western spade foot toad (*Pelobates cultripes*), common toad (*Bufo bufo*), natterjack toad (*Bufo calamita*), and common tree frog (*Hyla arborea*). Embryos were exposed to different and environmentally relevant concentrations of ammonium nitrate (0 to 200 mg NO_3/L) for 15 days. Hatching took place during the experiments. *H. arborea* was extremely sensitive and had high mortality after 8 days of exposure even at the lower fertilizer levels. *D. galganoi* and *B. bufo* were also very sensitive and had significant mortality after 15 days of exposure. The rest of the species did not suffer lethal effects but suffered abnormalities or decreased growth at the highest fertilizer concentrations. Chemical fertilizers or manure could have contributed to the observed decrease of *B. bufo* and *D. galganoi* in agricultural areas of the Iberian Peninsula during recent years. *H. arborea* was the most sensitive species studied. The results of this study showed that environmentally relevant levels of ammonium nitrate can induce mortality and might affect population dynamics of this species in agricultural environments. (Manuel E Ortis et al., 2002) A study conducted by Marco et al. in 1999 found that addition of nitrate or nitrite ions to the water caused reduced feeding activity, less vigorous swimming, disequilibrium and paralysis, abnormalities and edemas, and eventually death in some larvae of some species. The study was focused on newly hatched larvae of five species of amphibians, namely *Rana pretiosa, Rana aurora, Bufo boreas, Hyla regilla,* and *Ambystoma gracile.*

Research on amphibians exposed to organochlorine compounds, which were widely applied to fields in the 1960s and early 1970s, indicated that these compounds were lethal to many amphibians. (Cooke, 1981). However, researchers in Canada have recently used flow cytometry to assess frogs for effects from exposure to organophosphates. These researchers have observed increases in the coefficient of variation in the size of genomes in individual frogs as well as higher adult mortality and developmental malformations in the frog populations adjacent to the agricultural fields.

Water draining from intensive agricultural lands also consist of herbicides which affect non target organisms in the water bodied by modifying the structure and functionality of freshwater ecosystems (Vera et al., 2009; Pionke H.B et al., 2000).

Studies have indicated that increased amphibian embryo mortality or malformations in the western United States, may be associated with frequently resulting in highly eutrophic conditions, elevated pH, water temperature, and un-ionized ammonia (Boyer and Grue 1995). Acidic conditions can alter the physiological ionic balance of amphibians and reduce their growth and survival. Further, low pH mobilize aluminum from sediments and it is observed to decrease embryo survival in many amphibian species.

Some evidence in evaluations of biological effects associated with water quality at the Klamath Refuges in USA, indicated that the irrigation drain water was either lethal to, or caused significant malformation of, developing frog embryos. The agro ecosystems surrounding the refuge use a variety of agrochemicals, including a number of herbicides and organophosphate and carbamate insecticides, for crop production. Concentrations of these compounds in the water sampled were at or below detection limits (nano grams per liter). The study concluded that poor water quality (elevated pH and un-ionized ammonia) and/or pesticides may be contributing to the decline of indigenous frog populations (Boyer, 1993).

Owing to the intimate association with the wetland ecosystem through diverse life-stages and other vulnerable traits, amphibians appear to be particularly sensitive to xenobiotics, including heavy metals. Heavy metals being the most ubiquitous pollutants particularly influence sensitive species, such as aquatic amphibians by affecting their health, altering their behavior, physiology and anatomy which eventually pose adverse impacts on their survival (Farombi et al., 2007). Heavy metals disposed through industrial and domestic wastes and effluents are amongst the most abundant pollutants, posing severe threats to biota in the wetland ecosystems (Rai, 2009).

In a study conducted in the central United States, researchers found that heavy metal contamination from mine tailings that entered acidic waters cause the death of many embryos and severe malformations (Boyer and Grue, 1995; Hopkins et al., 2007; Gürkan et al., 2014; Zhelev et al., 2013). Studies of this nature have been conducted in Sri Lanka as well. A study investigating the impact of heavy metal toxicity on the immune system of the Indian green frog (*Euphlyctis hexadactylus*), have observed that significantly higher accumulation of selected heavy metals, Cu, Zn, Pb, and Cd were detected in frog liver and gastrocnemius muscle in Bellanwila Attidiya Sanctuary, an urban wetland polluted with high level of heavy metals, compared to a reference site, in Bolgoda (Priyadarshani et al., 2015). Moreover, malformed larvae from the most contaminated site had decreased swimming speeds compared with those of normal larvae from the same site. This outcome suggests role of heavy metals as immunosuppressants. The immune system of *E. hexadactylus* was affected by altering the weight and cellularity of lymphoid organs, the quantity of the peripheral blood leukocytes and bone marrow, and finally modulating cellular functions such as phagocytosis. In vitro exposure of heavy metals to phagocytic cells, expressed similar immunosuppressive effects as those reported from the amphibians naturally exposed to heavy metals in the polluted site. This eco-immunotoxicological prototype study further ramified the significance of immunotoxicologic tests such as phagocytosis, as potential biomarkers for evaluating heavy metal related health issues in wetland ecosystems. However, limited information is currently available on the effects of heavy metals on the immune system of adult and larval amphibians (Jayawardena et. al., 2013).

Within the remaining wetland habitats, numerous other factors may be contributing to the decline of amphibian populations, such as the introduction of exotic species that may outcompete indigenous species for food and breeding sites or that may prey upon the indigenous species. For example that, exotic fish species introduced into the waters of California may have foraging behaviors that increased predation upon the eggs and tadpoles of native amphibian species (Pieter and Jonathan, 2004).

The potential role of stormwater ponds as wildlife habitats are particularly relevant for pond-breeding amphibians. Pond-breeding amphibians mate and deposit their eggs in pond and wetlands where the embryonic and larval stages develop before metamorphosing into semi-aquatic or terrestrial juveniles. Use of stormwater ponds by pond-breeding amphibians has been documented in a number of areas (Joel et al.2007; Rouse et al., 2000a;), Recently, links among the number of amphibian species utilizing a pond, metal levels in sediments, and land cover surrounding ponds have been developed (Simon, 2006). However, the relative roles of pond pollution and loss of upland habitat in restricting amphibian use of ponds have not received much attention (Joel et al., 2007).

Disease is another factor suspected of contributing to declines of amphibian populations. Opportunistic pathogens may overwhelm native species in a short time, or noninfectious disease can enter amphibians via their permeable skin. Drastic reduction of amphibians due to disease outbreaks in contaminated habitats is suggestive of xenobiotic driven immunosuppression that increased their disease susceptibility. (Jayawardena U.A et al 2013) In a high-risk disease situation, devoting resources for reproduction may decrease at the cost of immune system functions whereas during reproduction, immune function may be compromised to allow the individual to maximize its reproductive effort. However, fast-paced environmental changes may pose immense pressure on the immune system of wildlife species, at the cost of population level damage. The alternative to withstand environmental stress conditions is to have a higher number of offspring to replace the immune impaired population that is more vulnerable to infections and disease. Therefore, as an evolutionary trade off, female frogs in the polluted Bellanwila site may have a higher rate of reproduction and oviposition than their counterparts from the reference site (Hayes et al., 2010, Priyadarshani S. et al, 2015).

The effects of global climate change on amphibian populations is also currently under investigation. Recent researches have demonstrated decreased hatching success of eggs of some amphibian species associated with increased levels of UV radiation, specifically UV-B radiation (290-320 nm light), whereas other species seem to be less affected. Amphibian malformations also have recently received much attention from the scientific community, but few studies have provided evidence linking environmental aquatic pollution to larval amphibian malformations. Examination of terrestrial life stages allows quantification of conspicuous appendicular malformations such as missing or supernumerary limbs and digits, many malformations can also be detected in larval anurans (Hopkins et al, 2007, Johnson and Chase, 2004; Taylor et al., 2005). The rise in amphibian malformations may have resulted through complex changes within wetland food webs. Specifically, as anthropogenic factors such as agricultural fertilizers, cattle grazing, etc. lead to increased nutrient loading in freshwater ecosystems, particularly stagnant water bodies (Johnson and Chase, 2004).

3 CONCLUSION

Decreased water quality is a major cause of the global decline in amphibian populations. Protecting wetland habitat is critical, but alone it is insufficient for the survival and reproduction of all wetland species including amphibians. Contamination of heavy metal wetland biota, induce amphibian decline and malformations as several studies demonstrate heavy metal mediated immunomodulation in amphibian species, exposed to Cd, Zn, Cu, and Pb. These findings are in conjunction with the global amphibian decline. Hence, amphibians can serve as a potential indicator of ecosystem health and quality, specially in heavy metal contaminated urban wetland habitats.

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