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A review on natural hunter frog population declines in an ecosystem

Newton Paul *

Department of Zoology, Isabella Thoburn College, Lucknow-226007, Uttar Pradesh, India.

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Abstract

Amphibians are very important in an ecosystem because it can survive in both water and land. They are highly evolved and have a remarkable power of regeneration among the different animal phylum. Different genera of Amphibians play a significant role in transfer of energy and nutrients from small animal to large animal groups in an energy flow. Frogs are considering as a natural pest controller, without harming anyone in an ecosystem, maintain ecological balance. There are large numbers of frog species which disappear in last two decades (10-20 years) and many species recorded under threatened category by *International Union for Conservation of Nature (IUCN)*. A prominent reason identified by the researcher in last decades that a Chytridiomycosis infectious disease, caused by chytrid fungus (*Batrachochytrium dendrobatidis*) are responsible for decline in amphibian population worldwide. When unfavourable condition (winter, drought etc.) come, amphibian hibernate them self as protective mechanism encoded in their genes during evolution. During hibernation period, the chytrid fungus grows and forms a coat on frog skin and affects cutaneous respiration process, due to which water supply cuts off and make it difficult to breathe. After some time, the frogs are facing dehydration problem and then die. Beside fungal infection there many other factor which cause decline in frog population including bacterial and viral disease, habitat destruction, pollution and pesticide use etc.

Keywords: Amphibian; Ecosystem, Hunter; Regeneration; Hibernation; Chytrid fungus

1. Introduction

India is fortunate in the world that it has all type of weathers like summer, spring, autumn and winter and also have continuous flourishing biodiversity in the different areas like desert, ice and snow and rain fall in one season. Due to which India has very rich biodiversity among different country of the world. There is large number of amphibians genera recorded in different parts of India. India is also known as frog exporting country in the world. There are some genera hunted and captured for export across world like *Rana tigrina*. Time to time continuously ecologists and expert in the field of environment have warned that the extensive frog export would create imbalance in ecosystem, due increase in vectors and pest population (Arthropoda).

In many countries like Europe and USA, frogs are used as food, so they import large quantity from Asia. Dishes made from frogs legs are considered as delicious food. Beside human food, frogs are also used as food for fishes, birds and mammals. Large numbers of amphibians are capture from natural habitat and export for medicinal use, bait (capturing fishes), food, pet and most important use in experimental biology (teaching) as a traded to different countries. Over exploitation in the form of trade of different parts of frogs mainly legs continuously in different countries of world like USA, Pakistan, India and Bangladesh has been major cause of decline in amphibian population.

Reductions in Amphibian species were first time noticed at global level in the years of 1990s (Dinesh et.al. 2023). Recently amphibian population have been declined due to habitat disturbance (like pollution, use of pesticides, fish introduction and habitat destruction). There are some factors like waterborne infection in frogs cause their decline in

* Corresponding author: Newton Paul.

natural habitat. The anurans population is declines due to infection caused by fungus, *Batrachochytrium*. It is noticed that *Batrachochytrium* has a broad range of amphibian as host. In wild habitat, there are several pathogens recognised responsible for decline in amphibian population, these are types of viruses and bacteria, platyhelminthes worms, protozoan mainly parasitic and different species of fungus.

2. Significance of amphibians

Amphibians are the only animals in evolutionary process of vertebrate, who have developed various adaptation mechanisms according to habitat both in aquatic and terrestrial which make them higher from all other vertebrate and more ecologically significant.

2.1. Importance in maintenance of an ecosystem

2.1.1. Biological indicators

Amphibians are very sensitive and give quick response in order to any change in an ecosystem as it live in both aquatic and terrestrial habitat. Due to thin skin, premature stages of amphibians like eggs and different stages of larvae and adults are very sensitive to any alteration in water and soil quality and ultraviolet radiation. Amphibian can indicate any change ecosystem through quick and delayed response. Green tree frogs are a good indicator of any change in the hydrological cycle (water fall in rainy season). All amphibian uses their skin for respiration, due to this they can easily detect level of pollution in water or land. The dual mode of life cycle in amphibian can be useful for detection of pollution in both terrestrial and aquatic habitat (Van Meter 2018). Different genera of Amphibians are considered as potential biological indicator in ecosystem, their presence can reveal the current status of quality of wild habitat and environmental contamination but more research need in this area.

2.1.2. Food web and energy dynamics

Amphibians are evolved from fishes so they are not total adapted for terrestrial mode of life; they have to need water for completing their lifecycle. This dual mode of survival of amphibians makes them highly beneficial for both aquatic and terrestrial habitat in maintaining the food web and energy flow (energy dynamics) throughout ecosystem. Different stages of amphibian life cycle like larval stages and adults, wisely selected food in habitat and maintain energy flow and energy dynamics in an ecosystem. In this way, frogs maintain availability of resources for other organism and minimize intraspecific competition among them. The amphibian genera are important for ecosystem as they act as a regulatory or inhibitory animal in both water and land. Larvae of anuran are herbivores therefore they maintain aquatic flora of different water bodies whereas adults of anurans, urodeles and caecilians are mainly carnivores so they control population of invertebrates in an ecosystem (Wells 2007). The faecal content of tadpole larvae is a main source of energy for detritivores in wetlands and aquatic habitats.

2.1.3. Energy conservation and transformation in consumers

Amphibians are poikilotherms or Ectotherms for maintaining body temperature they depend on the environment. Amphibians maintain their body temperature by regulating metabolic process and behavioral adaptation. Due to this they use less energy for maintaining body temperature and convert more food in organic form as compare to birds and mammals. The position of amphibian at trophic level makes them unique for both predator of a primary and secondary consumers and a prey for higher carnivores. The energy store in the form of chemical, conserved for higher level consumer in an ecosystem. Amphibian can modify and alternate their physiology activities like metabolic activities, oxygen consumption for their survival in adverse environmental condition like drought and extreme winter (Gibbons et. al. 2006). The resilience and resistance power of amphibian make them highly significant for an ecosystem.

2.1.4. Burrowing habit maintain soil properties

Due to burrowing habit, large genera of amphibian spend their most of time in burrows during their lifecycle to protect themselves from unfavourable environmental condition like winter, droughts, availability of low water and high temperature. There are some amphibians live in arid weathers as fossorial mode of life like *Opisthodon spenceri*. Many temperate amphibians like *Anaxyrus americanus*, *Scaphiopus holbrookii*, *Pseudacris maculata*, *Rana capito*, and *Ambystoma talpoideum* spend almost their live in burrow (hibernation). This burrowing behaviour of amphibian maintains and regulates air ventilation in soil and also adds nutrients, moisture and increase soil quality (productivity) and significantly important for an ecosystem as biological engineer's role in making network of interconnected burrows which finally give passage to air circulation and improving soil nutrient quality (Wells 2007).

2.1.5. Regulation of prey populations

Different species of frogs and toads mainly feed on invertebrates especially arthropods like insects and maintain their population in natural condition by acting as biological hunter (Wells 2007). This role of amphibian reduces interspecific and intraspecific competition among the different species. Both larval stages and adults control vector born disease by feeding on different species of mosquitoes and their larvae. It maintains arthropods population in environment and act as a prey (energy carrier) for higher chordates like snakes and bird. Amphibians are considered as an eco-friendly biological control agent of an ecosystem. Anthropogenic activities are considered as a cause of decline like extensive uses pesticides, herbicides, and fungicides for enhancing crop production extremely damaging all stages of amphibian life cycle. Through food chain via amphibian the synthetic chemical can bioaccumulate in different consumer of trophic level which adversely affect physiological and reproduction activities of animals. Some chemical remains sustain in soil for many years and affect detritivores food chain due to toxics properties. Amphibian can be used as a natural biological control agent will be more beneficial than any pesticide.

3. Importance for humans

3.1. Controlling vector born disease

In natural condition, frogs are important in controlling the vectors population like different genera of mosquitoes (like *Anopheles*, *Aedes* and *Culex*) and pest (like *Hieroglyphus banian*, *Oxya velox*). Both larvae stages and adults amphibian mainly feed on different species of mosquitoes and flies in the form of both larvae and adults. The species of mosquitoes and flies are important for human as they act as a vector in spreading various diseases among human population like malaria, yellow fever, African sleeping sickness, dengue etc. and domestic animals. The amphibians are significant predator in the field of medical and *veterinary* science by removing large quantity of mosquitoes from environment. The tadpoles of different species of amphibians have reported to feed eggs of *Aedes aegypti*, and minimize the risk of disease spread during the dry season (Bowatte et. al. 2013).

3.2. Predation on agricultural pests

Amphibians are useful predator for agriculture pests. The frogs and toads are constantly feeder of locust in the agriculture field. Through this beneficial process they enhance crop production for farmer and show their friend nature towards human welfare. The predator practice of amphibians develops a resistance power against some toxic chemical secreted by invertebrates. In the Netherland, native species of frogs and toads develop a protective mechanism against toxic alkynes, secreted by lady bird beetles of the family Coccinellidae to eat crops and fowl small around them to avoid the risk of being consumed by predators (Sloggett 2012). The pest belonging to the order, Orthoptera, Isoptera, Lepidoptera, Hemiptera and Coleoptera form bulk of food in agriculture sector for frog population. It is clear that frogs serve as farmer friends in controlling pest population, which destroy farmer crops (Paul, 2021).

3.3. Source of food for humans

With proper culture practices, amphibian can be useful as a good source of food for human as they contain high amount of varied protein, vitamin and minerals. The amphibians are well developed to use ectothermic strategies in converting consumed energy in to somatic growth. Due to this property, production of amphibians may be more as compare to other animals like mammals and birds in a given periods under favourable condition. The herpetoculture is a breeding of amphibians and reptiles, practice currently in many parts of world require low area, economic, resources, generate less waste and their food easily available. Dishes made from frog's legs are delicious and consumed by many peoples of the world. The frog legs are imported in Europe and USA from frog farms in Asia, China and Indonesia (Gratwicke et. al. 2010).

3.4. Recreational activities

Recreational activities like hunting and fishing are important in many parts of the world. In USA, fishing and hunting is a fun activity during weekend or vacation and availability of amphibians, makes them as a food source of capturing animals. The largemouth bass (*Micropterus salmoides*) is a carnivorous freshwater game fish, mainly food on amphibians. The predatory merganser or goosander (*Mergus merganser*) is a large sea duck of rivers and lakes in areas of Europe and America consume mainly amphibian (Mallory and Metz 1999). Therefore, conservation of amphibian is also important for protecting game species.

3.5. Opportunity in ecotourism

Amphibians are very beautiful with colourful skin due to varied chromatophores. Beautiful appearance of amphibians attracts the tourist in natural habitat like national parks and sanctuary. Ecotourism is a new idea in tourism in which tourist visits to protected natural areas. It develops new area of interest in tourism. The International Ecotourism Society (TIES) in 2015 reframe the definition of ecotourism as “*responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education*”. Tourist movement in protected area give good incentive to local's people to maintain the protected areas rather than destruction (Hausmann et. al. 2016).

3.6. Medical and pharmaceuticals

Amphibian species under infection circumstances produced a specific antibiotic by the immune system to target a specific pathogen, in this way they develop broad range of defense against variety of pathogens. Scientists are trying to isolate antimicrobial chemicals against pathogen secreted by amphibian skin. The amphibian skin secreted polypeptide compound called Gaegurin 4 is very significant against both gram positive and gram-negative bacteria. The antibacterial chemicals are also species specific with respect to specific pathogens. Some unique antibodies produced by amphibians could be useful to develop immunity against several bacteria in humans (Table-1) (Govender et. al. 2011).

Table 1 List of Chemical extracted from amphibian and their medicinal use

Chemical	Amphibian species	Medical value
Dermaseptins B	<i>Phyllomedusa bicolor</i> (South American frog)	Antimicrobial peptides (used against bacteria, fungi, yeast, and protozoa infection)
Peptide DV-28 amide	<i>Bombina orientalis</i> (Oriental fire-bellied toad)	Prevents arterial smooth muscle relaxation: treats low blood pressure
Histamine-releasing pipinin-1	<i>Rana pipiens</i> (Northern leopard frog)	Releases insulin: treat diabetes/metabolic disorders
Gaegurin 4	<i>Glandirana emeljanovi</i>	Antibacterial peptide
Magainins peptides	<i>Xenopus laevis</i> (African clawed frog)	Antimicrobial peptides

(Source: West, J. 2018)

3.7. Power of regeneration

Amphibians are only known class in vertebrae with power of regeneration. The larval and adult stages of salamanders (axolotls and hellbenders) possess a unique feature in which they are able to heal damaged tissue without fibrosis. It is well observed phenomenon that adult salamanders can regenerate their damaged limbs and tails and also an organs and tissues including brain, spinal cord, heart, jaws, retina and lenses. With the help of specific immune cell signaling to suppressor inflammation and scar tissue formation, amphibians can regenerate their lost or damaged part. Healing of wound start with the covering of the wound with epithelial cell called as an apical wound cap followed by innervations of the wound cap, with nerves dedifferentiation into pluripotent cells that are capable to elongate and proliferate. At this stage nerve send signals back to local differentiate cells into undifferentiated cell called mesenchymal cells and develop structure known as blastema, after that organ or tissue reforms in a same way as they originally formed during development (Brockes and Kumar 2008). Immune system plays an important role during regeneration. The cells of immune systems regulate development of new tissue by controlling signaling chemicals that regulate or maintain gene function and chromatin organization and also inflammation (Godwin and Rosenthal 2014).

3.8. Educational value

Besides a continuous disturbance in natural habitat of amphibian, they were cultivated and utilized in India from 1956 and 1967 in the field of education sectors and export sectors respectively. As per deep studies it was estimated that the syllabus of Indian universities demands approximate 10 frogs by a biology students to complete his or her higher studies like graduation and post-graduation. It was also notice that a large number of frogs used in experiment in all over the universities and colleges in India as the most favourable animal for teaching biology especially internal anatomy. Due

to ubiquitous nature, amphibians are considered as best animal model for research and teaching. The life cycle stages are easily available in water bodies, makes them favourable animal for study and experimental model for external and internal morphology. In vertebrate, there are many similarities in both amphibian and Mammalia especially humans therefore they are excellent model of anatomical study for students (Wünschmann et. al. 2017).

4. Factors responsible for decline in amphibian population

4.1. Habitat modification

Alteration in habitat is one of the most important factors of decline in amphibian population. As the population of humans increases continuously in the different parts of world, they need space or piece of land for different reasons like space for house, agriculture to get more crops to meet high demand of food, recreation activities, domestication of economically important animals like cattle, sheep, construction of road for transportation, dam for electricity generation and establishment of different factories etc. The modification of vegetation in forest has a quick influence on amphibian population. In Florida, the amphibian population decline in urban due to modification in terrestrial and aquatic habitats of these animals used for breeding for others. Alteration in natural habitat of amphibians has an important role in reduction of their population (Smith et. al., 2009).

4.2. Ultraviolet radiation

Due to high level of air pollution, ozone layer gets affected and does not prevent ultraviolet radiation coming from sun to the earth surface. Perforation in stratosphere layer is increasing chance of ultraviolet B radiation on earth (Kerr and Mcelroy, 1993). The amphibians are live in water and they are highly vulnerable at their tadpole's stage for radiation due to thin skin, easily radiation cross through their body. Ultraviolet radiation may cause higher level of embryonic mortality that leads to decline in population and also cause damage at DNA level in tadpole larvae of amphibian. The continuous exposure to ultraviolet radiation may reduce the amphibian's population through other variety of disease like damage in eyes, increased chances of tumors that leads to a cancer and reduces immunity against diseases in animal (Alford and Richards, 1999).

4.3. Predation

The amphibian population maintain the population dynamics in ecosystem by biotic interaction with other organisms living in water and land. The larval stages of any amphibians are highly vulnerable to predators like invertebrates and vertebrates in water. Both fishes and amphibian are living together in water but larval stage of amphibian have evolved hide and escape mechanisms against fish predators. In the rainy season by mistake a carnivores fish introduce in water bodies that cause severe damage in frog population both stages (larval and adult). The population of *Rana muscosa* have decrease after fish introduction in water bodies. It was observed that the population of larval newts, *Taricha torosa* decreases in Californian water bodies after the introduction of fish (*Gambusia affinis*) and crayfish (*Procambarus clarki*), both of predators feed on eggs and larvae of newts (Gamradt and Kats, 1996). Competition at survival level among the amphibians is also one of the important causes of their population reduction. In the North America, adult bullfrogs (*Rana catesbeiana*) have consumed other native frogs and cause reduction in their numbers (Alford and Richards, 1999).

4.4. Physicochemical factors

The physicochemical factors of waters like acidity, has significant impact on survival of amphibian in natural condition. Due to thin payer of skin, amphibians are very sensitive to low pH in water bodies and interaction of other factors like aluminium concentration caused lethal effects. Due to sudden change in chemical nature of water bodies, both embryonic and larval stages face high mortality by affecting yolk physiology and deformation in larval stages. Besides mortality, pH change also affects delayed or early hatching in larvae with reducing body size and alteration in swimming behaviour, capture pray mechanism. Low pH and high metal concentration have adverse effect on salamanders' population like *Desmognathus quadramaculatus* and *Eurycea wilderae*. Farmer is extensively utilized chemical fertilization, insecticides; herbicides etc. to increase crop production, but chemical present in these directly or indirectly affect large population of amphibians. During rainy season many chemical (not targeted to kill amphibians) mixed with water and reach to water bodies, a house for amphibian eggs and larvae, have severe toxicant effect on the eggs and larvae. Chemicals can kill the any stage of amphibian life cycle directly or indirectly disturbed the development (affect the metabolic process), reproductive cycle (alternation the function of endocrine glands), influence the development of immune system. In India, every farmer wants to get good quantity of crops in a season for that they used different pesticides, available in market. But pesticides have non-targeted effect on other organism especially frogs also. During the rainy season, pesticide sprayed on crops, washed with rainy water and run-off to different water bodies in which pesticides accumulated in eggs of frogs and disturbed their development (Khan and Law, 2005).

4.5. Climatic condition

The climatic condition is one of the important decline factors that affect many amphibian populations directly or indirectly in all over the world. In the race of industrialization in many parts of country is main cause of air and water pollution which finally affected natural habitat of amphibians. During rainy season, several chemicals present in air fall down with water droplet on ground and water bodies that alter the physicochemical quality of both soils as well water. In Britain, change in temperature of water bodies during spring season significantly affects spawning of *Bufo calamita*, *Rana esculenta*, and *R. Temporaria* from 1978 and 1994 (Beebee, 1995). In Canada, amphibian's population decline due to some climatic factors like low precipitation in summer, increased temperature and rainfall in winter seasons (Ovaska, 1997). The regular increased in temperature and delayed rainfall increased dryness in soil, which alter life cycle of many aquatic animals, when rain come and pond fill with water than competition and predation among amphibian or other organism is a common phenomenon that responsible for population decline. Frogs have chance to get infection that develops in to a deadly disease from to parasites when prolong exposed to environmental stresses. Mainly frogs are more vulnerable under such condition.

4.6. Diseases

As the amphibian are mainly live in water bodies, the prolong stress condition due to some physicochemical factors responsible for low immunity in this way it may easily get infected by number of bacteria and fungus. The fungus develops on amphibian skin, associated with keratinized tissues, in some frog and salamander, fungus inhibit the secretion of antimicrobial peptides which fight against any skin infection (Rollins-Smith et. al. 2005). The fungus, Chytridiomycete is a large group and found in nature, mainly it act as bio-degraders in an ecosystem, because they live freely in water and soil and digest or degrades dead matter like chitin from insects, cellulose from vegetables, keratin from hair and skin etc. Some of species causes deadly disease. There are some physic-chemical factors like temperature changes, water pH, light, nutrition and dissolved oxygen affects the epidemiology of chytrid. *Batrachochytrium* zoospores are waterborne and capable to survive over 24 hours' meanwhile cause infection to tadpoles and frogs. Zoospores produce an adhesive substance to stick on host skin in an encysted condition. *Batrachochytrium* Sporangia can grow in the keratinised epidermis of amphibians. Few chytrids can survive for long periods (decades) in unfavourable condition due to presence of thick wall as protective sheet around spores but *Batrachochytrium* is a very fragile species. Infected frogs with chytridiomycosis show some clinical feature like lethargy, skin discolouration, excessive sloughed skin and abnormal sitting posture, death occurred in a few days after onset of symptoms. The histological observation reveal that the chytrids fungus influence the outer layer of keratinised epidermis and also responsible for thickening and ulceration of skin. There are several researchers who reveal the decline status of amphibian population. Due to dual survival techniques amphibians are exposed to variety of factors that causes their decline. The amphibian skin is very sensitive to toxins which are present in water, causes disturbance in skin functions (Pereira et.al. 2013). Environmental factors act as stressor for amphibian and which are responsible for suppression of immunity in many amphibians through directly or indirectly way. Bacterium *Aeromonas hydrophila* are responsible agent for declines in toad, *Bufo boreas* populations between 1974 and 1982. High mortality reported in larval stage of *Rana sylvatica* due to Bacteria *Aeromonas hydrophila*. The pathogenic fungus are responsible for mortality in eggs of mainly mortality in *Bufo boreas* population in Oregon under environmental stress. Viruses are also causing mass mortality in amphibian population, isolated from dead bodies of frog (Cunningham et. al. 1996).

5. Conclusion

Amphibians are highly sensitive to any change in environment due to their anatomical properties, therefore they are considered as good indicators of ecosystems like pollution in water and land, habitat degradation etc. Due to dual feeding nature of amphibians control both flora and fauna of both water and land, at larval stage they behave as herbivores (feeding aquatic flora) and carnivores at adult feeding different stage of arthropods. In this way they control level of biotic communities in an ecosystem. Imbalance in ecosystem may cause serious damage to both flora and fauna of aquatic and terrestrial. That will finally affect human welfare. There is need of more investigation on the regeneration in amphibian will give a broad way to medical science to treat medical complications like heart attacks, spinal cord or tissue damage and inflammation. It will also be useful in future in regenerating mammalian organ like heart, kidney, glands, limbs etc.

Every country want success at any cost, due to which they enormously encourage industrialization in their country, in return they affect climatic condition by releasing huge amount of gasses and impurities in air and water respectively. Due to rise in temperature i.e. global warming increase the chance of survival of mosquitoes and that will affect the people all over the world. Therefore, there is a need to ensure the conservation of amphibian as a biological controller in environment, in controlling deadly disease. It is also important to know that if amphibian disappears will have significant impact on those invertebrate and vertebrates in an ecosystem who mainly feed them not others that will

affect different trophic consumers in an ecosystem. Conservation is not only a matter of concern for any government but is a duty of every person to realize its role in preserving or conserving natural fauna around us. Government has pass conservation order not able to observe preservation at each small level; therefore, it is necessary for every human being to realize its role in conserving natural fauna at each trophic level in an ecosystem.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no any conflict of interest for publishing this article.

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