Electronic Journal of Biology, 2023, Vol.19(3): 1-9

Role of Amphibians to Ecosystem Services: A Review

Nalinaksh Pankaj* and Bhrigu Nath

Department of Zoology, Magadh University, Bodhgaya, Bihar, India

***Corresponding author:** E-mail: herpetologistmishra@gmail.com

Citation: Pankaj N, Nath B (2023) Role of Amphibians to Ecosystem Services: A Review. Electronic J Biol, Vol:19 No:3

Received date: November 29, 2022, Manuscript No. IPEJBIO-22-15038; **Editor assigned date:** December 02, 2022, PreQC No. IPEJBIO-22-15038 (PQ); **Reviewed date:** December 16, 2022, QC No. IPEJBIO-22-15038; **Revised date:** February 23, 2023, Manuscript No. IPEJBIO-22-15038 (R); **Published date:** March 03, 2023, DOI: 10.36648/1860-3122.19.3.071

Review Article

Abstract

Amphibians play pivotal role in ecosystem services and are very beneficial for human beings. These services of amphibians include provisioning, regulating, cultural, as well the supporting services. Amphibians provide provisioning services by acting as a food source for some human societies, as in north east India and some parts of world also. They also serve as model organisms in medical research and important for pharmaceuticals such as production of analgesics and anti-viral drugs derived from their skin secretions. Amphibians contribution to regulating services by reducing mosquito and controlling other pest species directly through predation indirectly through predation of insect pollinators. Ecosystems also provide cultural services to human societies that increase the quality of human life through recreation, religion, spirituality, and aesthetics. Because of abundant, diverse and lovely creature amphibians also play very prominent roles in the culture of human societies such as mythology, literature and art.

Amphibians have great contribution to ecosystem services. Supporting services have structural (e.g., Habitat) and functional (e.g., Ecosystem functions and processes) components. Amphibians can affect both ecosystem structure through soil burrowing and aquatic bioturbation and ecosystem functions such as decomposition and nutrient cycling through waste excretion and indirectly through predatory changes in the food web. They also contribute for control of primary production in aquatic ecosystems through direct consumption and nutrient cycling. Unfortunately, amphibians are facing major declines and humans may losing associated ecosystem services. It is important to understand how declines affect ecosystem services for human societies, but these declines may also act as natural experiments to understand the role of amphibians in ecosystems. In present study we have conducted a comprehensive literature review to investigate the importance of amphibians, including medical applications such as tissue regeneration, biomimicry of pharmaceutically useful compounds, direct socio-economic benefits, and overall ecosystem values. It is our intention to

promote amphibian conservation by detailing various ecosystem services provided by amphibians and their uses to human beings.

Keywords: Amphibians; Culture; Ecosystem functioning; Food; Medicine; Regulating service

Introduction

Amphibians are unique group of vertebrates represented by 8,419 described species (7437 Anura, 767 Caudata and 215 Gymnophiona) worldwide [1]. The amphibians evolved 365 milllion of years ago. Among all amphibians, anurans show the widest distribution across different biogeographical realms with the highest diversity in the oriental, neotropical and afro-tropical regions; diversity of urodelans is highest in the nearctic and neotropical realms; caecilians are restricted mainly to tropical wet biomes and mostly diverse in the oriental and neotropical regions.

Amphibians require moist conditions and high humidity. Therefore, amphibian diversity is highest in regions with high precipitation and/or lower evaporative water loss. Many of them require freshwater habitats to breed and develop into adulthood [2]. A few amphibian clades have independently evolved to breed in foam nests; some clades have completely lost their larval stages and live an entirely terrestrial mode of life. Amphibians have radiated into terrestrial, aquatic (streams, cascades, and wetlands), scansorial (arboreal, phytotelms, rock outcrops) and fossorial (leaf litter, organic top soil) habitat [3]. Amphibians are undergoing global scale population declines due to various anthropogenic factors. Habitat destruction and fragmentation, overexploitation, environmental pollution, climate change, and introduction of invasive species has all contributed to catastrophic amphibian declines across many biomes; however, these threats are disproportionately high in biodiversity hotspots such as tropical and humid ecosystems. The most critical factor leading to amphibian population declines are habitat destruction and fragmentation, Pathogenic attack such as the chytrid fungus and parasitic trematode genus *Ribeiroia*. The chytrid fungus is considered the leading cause of enigmatic amphibian decline while the *Ribeiroia* causes limb malformation leading to the infected amphibians to a greater risk of predation. Global environmental change such as climate change, acid precipitation, ozone depletion, increased UV-B exposure, and altered biogeochemistry and unintentional anthropogenic interference have make amphibians more vulnerable to diseases [4]. At global scale approximately one third of all amphibian species are threatened with extinction, and almost half are experiencing precipitous population declines. In recent decades, the extinction rate of amphibians worldwide has exceeded 200 folds. According to the global amphibian assessment, approximately 34 amphibian species have gone globally extinct and many of them were endemic to those particular regions they were found in. Amphibian decline is a key to global environmental concern that requires immediate conservation attention.

Literature Review

Ecosystem services

Ecosystem services of the amphibians are divided into four categories: provisioning, regulating, cultural, and supporting services [5]. All these services are the components of ecosystems that greatly influence all the human well-being. Provisioning services involve the production of useable products including food, fresh water, fiber, genetic resources, and medicine. Regulating services include water purification, erosion control, climate regulation, disease control, pest species regulation, pollination, control and dampening of natural disasters. Frequently underappreciated in economic analyses, cultural services increase the

quality of human life through recreation, religion, spirituality, and aesthetics [6]. These services improve human psychological well-being and social attachment. Finally, supporting services are essential for maintaining the three other services. Supporting services generally consist of ecosystem physical structure and ecosystem functions including nutrient cycling, soil formation, and food chain and primary productivity. Recent study draw attention how all these ecosystem services are important for human beings [7]. However, our knowledge about how various species interact to contribute to ecosystem services is still in its infancy.

Recent studies have tried to determine how biodiversity (or species richness) contributes to the regulation of ecosystem services and functions [8]. Though amphibians play prominent roles in provisioning, regulating, cultural, and supporting services, a comprehensive review of amphibian contributions to ecosystem services is lacking. We have just tried to address this gap by making a comprehensive review and highlighting research needs that would greatly advance the knowledge of amphibian contributions to ecosystem services [9].

Provisioning services of amphibians

Amphibian's provisioning services includes its uses as food and medicine. Frog legs are consumed in many parts of the world, mainly in Southeast Asia; more than 10 million frogs may be shipped illegally from India each year to other frog consuming country [10]. The chorti peoples of Honduras consume *Lithobates sps*. In West Indies large frog *Leptodactylus fallax* is known as the Mountain Chicken, and annual consumption of 9000-40000 frog individuals annually. The United Nations FAO estimated human consumption of about 5.000 metric tons of frog legs annually. However, it is minor portion of global food consumption, but it may be important protein source in some regions of the world. Harvesting and trade associated with amphibian consumption is very detrimental for amphibian population decline. Amphibians cultivated in pond for local market often have problems with disease, water quality and ethical treatments of the animals. Sometimes amphibian face decline in population due to spread of disease and invasive species [11]. Some amphibians may act as suitable protein source for certain regional populations but all these current practices are detrimental for amphibian populations. Unlike traditional animal husbandry such as cattle or swine farming, herpetoculture (husbandry of amphibians and reptiles) requires less physical space, less resources, generates little waste, and their feed can be easily and locally obtained, thus the overall ecological footprint, particular the carbon footprint, might be very low.

In addition to consumptive value amphibians also have medicinal use also. The amphibia *Xenopus laevis*, are used to test human pregnancy. Amphibians are used for treatments of different ailments as warts to heart disease. In neotropical region about 60 herpetofaunas are used in traditional medicines. The skin and fat of *Rhinella jimi*, *Leptodactylus labyrinthicus*, and *Leptodactylus vastus* are used to treat asthma, skin ailments as well as tumors. In modern times different medicines are made from various natural chemicals. Amphibians use a number of chemicals for a variety of purposes as mating activity, territorial marking, predator defense, and combating microbial infections and these chemicals are used now a days for production of new drugs [12]. Antimicrobial peptides from frog skin secretions have potential to inhibit infection and transfer of the human immunodeficiency virus. This amphibian derived peptides could be significant for Africa as HIV related deaths are more here. Epibatidine molecule is a toxin isolated from the Ecuadoran poison dart frog *Epipedobates tricolor* works as a painkiller in mice and rats. Scientists are optimistic and engaged for such nontoxic, synthetic variants of this molecule as an alternative to opiates that have great side effects including drowsiness, addiction, and potential digestive

and respiratory distress. Other pharmacologically similar compounds are also derived from a variety of frogs from other parts of world [13]. Amphibians are very useful an important for human society. Australian frogs are also providing medically relevant provisioning service. The Gastric- Brooding Frogs (*Rheobatrachus* spp.) have capacity to turn off the production of stomach acid for the purpose of raising offspring in the stomach. The mechanisms associated behind this provide medical insights to help people suffering from severe acid reflux and stomach ulceration. Amphibians may also provide additional insights into medically relevant physiology, especially for regeneration of limbs and tails. A recent study found that sodium ion transport to damaged cells is critical for tadpole tail regeneration. Scientists hope that knowledge of this mechanism and associated ion channels can be applied to human medical advances.

Regulating services of amphibians

Amphibians play important roles as regulating services controlling the disease transmission and pest outbreaks. Predatory amphibians can help in reducing the spread of mosquito borne diseases through predation of mosquitoes [14]. Mosquitos and biting flies carry many diseases, many of which can be fatal to the host, including malaria, yellow fever, African sleeping sickness, eastern equine encephalitis, and dengue (brain hemorrhagic) fever. Amphibians are efficient predators of medically important pests, as multiple life history stages of amphibians can prey on all life history stages of vector pests across different habitats in many biomes. DuRant and Hopkins have demonstrated the ability of newts (genus *Notophthalmus*) and mole salamanders (genus *Ambystoma*) to reduce mosquito larva abundance in aquatic habitat [15]. Tadpoles of the frog *Osteopilus septentrionalis* reduce populations of mosquito populations in laboratory and field experiments. Similarly, the frog *Lysapsus limellus* feeds on flies of the family Ephydridae, which carry human diseases in the neotropics. The cane toad (*Rhinella marina*) derives this common name because it was brought to Australia to combat the cane beetle (*Dermolepida albohirtum*) and protect sugar cane crops. Like most capricious introductions of non-native species, the control was ineffective. The Cane Toad is now itself a major pest species in Australia. However, the idea behind the cane toad introduction was born with the knowledge that toads are major invertebrate predators. Although the decision to introduce the cane toad was ill conceived, it highlights a potentially important role of amphibians as invertebrate predators. In Argentina, *Rhinella arenarum, Leptodactylus latinasus, Leptodactylus chaquensis*, and *Physalaemus albonotatus* consume arthropods known to damage soybean crops, but the extent of natural biological control in these agricultural systems remains untested. Research should be undertaken to test whether species do provide valuable control of invertebrate pest species within their native ranges. Amphibians also have the potential to affect pollination and seed dispersal. Most adult amphibians prey on a variety of arthropods including flies, butterflies, moths (mostly larvae), and beetles, which can be important pollinators for many plants including some agricultural crops [16]. Although rare among amphibians, some frogs are also known to consume fruit and disperse the seeds. The tree frog, *Xenohyla truncata*, consumes whole fruits and defecates viable seeds in Brazilian forests. It is likely that seeds dispersed by these frogs have higher germination rates because of moist microhabitat selection by the frogs. It largely remains to be tested where and when amphibians can influence seed dispersal and pollination sufficiently to affect plants on an ecosystem scale.

Cultural services of amphibians

Cultural services of amphibians are also very important as they find a place in the culture and awareness of many human societies. Frogs, which are very brightly colored and conspicuous and are often more vocal than another group of amphibians as salamanders or

caecilians. For example, the *Coqui* (*Eleutherodactylus coqui*) is celebrated in its native Puerto Rico, although it is considered a noisy, invasive nuisance in Hawaii Hawaiians lose sleep over tiny frog with big voice. The Red-Eyed Treefrog (*Agalychnis callidryas*) and numerous poison-dart (family Dendrobatidae) frogs due to visually appealing find their place into calendars and nature magazines. It is not difficult to find examples of amphibians in literature, music, art, jewellery, and in decorations. Even Shakespeare's witches famously add, "eye of newt, and toe of frog" to their cauldron of "hell broth". Amphibians serve as stuffed animals for children and for most batrachologists accumulate a collection of frog toys, carvings, and pewter figurines, whether desired or not. Frogs and salamanders from around the globe find their way into our lives through zoos and museums and into homes through the television and the pet trade. Amphibians make popular pets because many species are relatively easy to care. Beyond our homes, amphibians also serve an educational purpose through classroom dissections (especially large rana spp. and *Necturus maculosus*) for biology, anatomy, and physiology courses in schools. Now a day's amphibian becomes integral part of our culture. Amphibians have been part of human culture since long before plush frog toys reached American box stores. Toads play a prominent role in Meso American art. In both Chinese and Japanese cultures, toads have historically been associated with magic, wisdom, and eternal life. The example of amphibians, especially anurans, from human culture spans the globe and the centuries. Whether revered or reviled, amphibians play an important and continuing role in the culture of human societies.

Discussion

Supporting services of amphibians

The amphibians also play very prominent role in the supporting services or ecosystem services also. Amphibians mainly contribute to ecosystem services by direct or indirect alteration of the ecosystem structure and functions. Sometimes these amphibian species also alter Physical and structural components of ecosystem as well different habitat types of ecosystems.

Aquatic ecosystems: The role of larval amphibians in aquatic ecosystems is very important as they altered bioturbation, nutrient dynamics and their effects on the food web. However, we still lack such information on food web dynamics affected by amphibian larvae. Salamander larvae are primarily predators but tadpoles known to act as primary consumers, predators, detrivores and even cannibals also [17]. Some of the amphibian species placed themselves for consumption at single trophic level or even feed as specialists whereas some other species are omnivorous with ontogenic, seasonal or opportunistic shifts in diet. Despite uncertainty in diet tadpoles when found in high densities in ecosystems show significant effect on ecosystems functions as primary productivity by altering food web. Tadpoles are known to affect algal and periphyton community structure and biomass in lentic ecosystem also. Tadpoles also affect nitrogen cycling by serving as sink for organic nitrogen. The total organic nitrogen in tadpoles is inversely related and exceeds seasonally, the total suspended organic nitrogen in ponds. Tadpoles also decree the total suspended particle. Further investigation is essential for showing relationship between amphibian communities of pond and inorganic nitrogen level for understanding aquatic nitrogen cycling. Our study on the importance of the amphibians in aquatic ecosystems would benefit for future studies regarding the influence of tadpoles and amphibian communities on primary productivity as well as changes in algal communities and standing crop. This study also provides the role of aquatic amphibians in top-down and bottom-up effect of ecosystem functions including primary production, nutrient cycling as well as decomposition.

Terrestrial ecosystem: Amphibians support ecosystem

services through act as predator prey relationship, regulating invertebrate populations, altering habitat structure and nutrient cycling. Red backed salamanders (*Plethodon cinereus*), bankor toads (*Bufo bankorensis*), and *Coqui* are greatly studied for their role in ecosystem functions. Wyman made an observation regarding red backed Salamanders and found that it reduces decomposition rates by about 11%-17% by predating the leaf fragmenting invertebrates. He suggested that this Salamander exert top-down control on the detritus food web and reduce decomposition rates. Salamander also reduces the abundance and size of many invertebrates including millipedes, fly larvae, beetle larvae, molluscs, as well the spiders [18]. But role of abundance of the salamander in nutrient cycling, primary production, or any other ecosystem function is unknown. Red backed Salamanders is also known to affect detrital invertebrate communities seasonally, probably depend upon leaf litter mass and moisture.

There also has been evidence regarding the role of anurans in terrestrial ecosystem functions. Huang et al. found that toad (*B. bankorensis*) altering leaf litter chemistry by increasing the concentration of phosphorous. But there is no effect recorded on litter C,N,K,Na,Ca, or Mg concentrations, or litter decomposition as well as invertebrate abundances. Contrary to this the *Coqui* is known to decrease the C:N ratio, and increase K and P in leaf litter. They can also reduce abundances of invertebrate and plant herbivore and microbial activity also. Amphibian species along with other different species affect various processes through predatory changes in food web. In terrestrial ecosystem almost all amphibians predate on invertebrates. Ants are also known for their important role in ecosystem functions as nutrient cycling, seed dispersal, plant protection, as well as harvesting plants for farming fungi. Some amphibian species when eat these ant species creating potential indirect effect on ecosystem functions. Salamander populations have contained much amount sodium in forest ecosystem [19]. Much work remains to be done for finding the effect of amphibians on terrestrial ecosystem functioning. The role of amphibians in ecosystem functions depends mainly upon population density, the community structure and form of the limiting nutrient pools in the ecosystem.

Ecosystem engineering: Amphibians along with altering the ecosystem functions, having the potential to contribute the supporting services through alteration of their physical environments around them. Amphibians significantly contribute to physical habitat modification through their various activities. When we talk about aquatic ecosystems, tadpole grazing activity may change the physical structure of aquatic macrophytes and periphyton. In addition to this grazing behaviour can also influence the sedimentation through bioturbation or through ingestion and excretion of particles. However, burrowing amphibians or those that use and maintain the burrows of other species may alter soil bulk density and water infiltration process. Sometimes temporary habitat alteration, such as breeding pools dug in mud along the streams by gladiator frogs (*Hypsiboas* spp.) can serve as habitat for other species such as invertebrate larvae [20] It is clear Regardless of the ecosystem type, that amphibians have the potential to provide supporting services and such study may help in future research.

Conclusion

Amphibians are very important for human societies and provide valuable services to them. They provide food, medicine, and important for various ecosystem services as prevent the spread of diseases by praying the disease-causing organisms. Amphibians because of pretty creature and find ways into our homes, hearts, and arts, contributing to cultural services that are important for social, spiritual, and psychological well-being. Amphibians do various ecosystem services through changes in decomposition, primary production, and nutrient cycling. Much research has done to

understanding the role of amphibians to ecosystem services Researchers of medicine, ecology, ecosystem science, zoology, and other fields engaged in studying the influences of amphibians on ecosystem services. The information gained through this study help in amphibian conservation efforts. Improved techniques, tracking, and policy are very essential for quantify amphibian collection and farming for human consumption. This will help the rural societies for fulfilling their nutritional protein requirement as well as maintaining the amphibian population. Systematic studies on pest control and maintaining proper amphibian population may help in reduction of disease carrying invertebrates, and their influence on human disease. Hairston studied and suggested the role of salamanders in ecosystem functions; however, this fruitful research programmer has no longer been adopted by recent researchers. Our knowledge about the importance of amphibians found in aquatic habitats is markedly better than in terrestrial habitats, but this knowledge is still limited to a very few numbers of species under limited conditions. However, there are good potentialities for amphibian with complex life cycles to contribute to the flow of energy and nutrients between habitats, but this flow remains unclear between different ecosystems. More elaborate and explicit experiment needed for assessment of all amphibian taxa and their role to better understand the role of amphibians in ecosystem supporting services. The primary technique for understanding predation, competition and trophic status will of great use for studying amphibian services. For enhancing our knowledge and understanding amphibian ecologists doing tireless work through the use of creative research methods. Some ecologists, by using stoichiometry and stable isotope approaches give detail about energy and nutrient cycling affected by amphibians. Amphibians are declining at alarming rate due to diseases, climate change and radiations. Death of amphibians associated with chytrid fungus, *Batrachochytrium Dendrobatidis* (Bd), spreads into new areas. If Bd can be eradicated or resistant amphibian species would develop bred, or engineered, we will get benefit from these changes in ecosystem supporting services as species are reintroduced and repopulated. Likewise, the changes in temperature and precipitation affect amphibian populations greatly, experiments may be conducted to determine the associated changes in ecosystem services. Temperature also affects the bed infection and mortality of the species. For maintaining the future ecosystem services, it is very important to understand which species or communities contribute the most and which of these are likely threatened in near future by disease and anthropogenic activities. The most important provisioning services of amphibians as their large bodied species are used as food in Southeast Asia and many species could potentially informative for medical advances. Maintaining taxonomic and genetic diversity of amphibian species is critical for future medical use. As for conservative approach the tropical region supports greatest diversity and mountain region globally support high diversity due to low gene flow. However, major genetic lineage is also found outside these areas so protecting mountain and tropical region is not sufficient for ensuring maximal diversity. Amphibians play very little role in regulating services, but further research make ensure about amphibian control of disease and pest invertebrates would be beneficial for amphibian population especially in tropics. Large, loud, colourful, and diurnal species contribute a lot to cultural services and highly attentive for conservation measures, but many fewer amphibian species also contribute to local cultural services. Amphibians play largest role in supporting services, but the number of species and habitats studied remains quite very limited. Aquatic species have significant effects on supporting services, whereas the effects in terrestrial systems are less understood. Beard et al. suggested that the most abundant species are not functionally replaced when lost, so care should be taken

of those species that have reached highest density in particular habitat. However, sometimes less abundant species have major effects on ecosystem supporting services. Amphibian declines have been very significant in the neotropics and Australasian-Oceanic regions, especially in montane streams. These declines have been largely due to fungal infection Bd. Forest associated amphibians have also declined globally due to deforestation, so due to loss of various microhabitat types amphibian also declines proportionally. Better models forecasting future amphibian declines related to climate change would be useful for directing research to predict future changes in ecosystem services.

References

1. Alford RA, Wilbur HM (1985) Priority effects in experimental pond communities: Competition between Bufo and Rana. Ecology 66:1097–1105

2. Altig R, Whiles MR, Taylor CL (2007) What do tadpoles really eat? Assessing the trophic status of an understudied and imperiled group of consumers in freshwater habitats. Freshw Biol 52:386–395

3. Babbitt KJ, Meshaka WE (2000) Benefits of Eating Conspecifics: Effects of Background Diet on Survival and Metamorphosis in the Cuban Treefrog (*Osteopilus septentrionalis*). Copeia 469–*474*

4. Balvanera P, Pfisterer AB, Buchmann N, He JS, Nakashizuka T, et al. (2006) Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecol Lett 9:1146–1156

5. Beard KH, Vogt KA, Kulmatiski A (2002) Top down effects of a terrestrial frog on forest nutrient dynamics. Oecologia 133:583–593

6. Beard KH, Eschtruth AK, Vogt KA, Vogt DJ, Scatena FN (2003) The effects of the frog *Eleutherodactylus coqui* on invertebrates and ecosystem processes at two scales in the Luquillo Experimental Forest, Puerto Rico. J Trop Ecol 19:607–617

7. Bengtsson J (1998) Which species? What kind of diversity? Which ecosystem function? Some problems in studies of relations between biodiversity and ecosystem function. Appl Soil Ecol 10:191–199

8. Blaustein L, Margalit J (1994) Mosquito larvae (*Culiseta longiareolata*) prey upon and compete with toad tadpoles (*Bufo viridis*). J Anim Ecol 63:841–850

9. Boyce S, Webb JK, Shepheard SL, Russell MGN, Hill RG, et al. (2000) Analgesic and toxic effects of ABT-594 resemble epibatidine and nicotine in rats. Pain 85:443–450

10. Brown JH, Davidson DW (1977) Competition between seed eating rodents and ants in desert ecosystems. Science 196:880–882

11. Burger J, Arizabal W, Gochfeld M (2002) Nesting behaviour of a Gladiator Frog Hyla boans in Peru. J Herpetol 36:640–648

12. Burton TM, Likens GE (1975a) Energy flow and nutrient cycling in salamander populations in the Hubbard Brook experimental forest, New Hampshire. Ecology 56:1068–1080

13. Burton TM, Likens GE (1975b) Salamander populations and biomass in the Hubbard Brook experimental forest, New Hampshire. Copeia 1975:541–546

14. Calvet X, Gomollon F (2005) What is potent acid inhibition, and how can it be achieved? Drugs 65:13–23

15. Cardinale BJ, Srivastava DS, Emmett Duffy J, Wright JP, Downing AL, et al. (2006) Effects of biodiversity on the functioning of trophic groups and ecosystems. Nature 443:989–992

16. Clark VC, Raxworthy CJ, Rakotomalala V, Sierwald P, Fisher BL, et al. (2005) Convergent evolution of chemical defense in poison frogs and arthropod prey between Madagascar and the neotropics. Proc Natl Acad Sci USA 102:11617–11622

17. DuRant SE, Hopkins WA (2008) Amphibian predation on larval mosquitoes. Can J Zool 86:1159–1164

18. Folgarait P (1998) Ant biodiversity and its relationship to ecosystem functioning: A review. Biodivers Conserv 7:1221–1244

19. Gratwicke B, Evans MJ, Jenkins PT, Kusrini MD, Moore RD, et al. (2009) Is the international frog legs trade a potential vector for deadly amphibian pathogens? Front Ecol Environ Front Ecol Environ 8:438–442

20. Hocking DJ, Babbitt KJ (2014) The role of Red backed Salamanders on ecosystem functions. PLoS One 9: 86854