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Benefits of introducing amphibians and fishes in paddy ecosystem, harmful effects of neonicotinoids on amphibians and fishes

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Abstract
Amphibians and their ancestor fishes have flourished eons of years ago; their presence in paddy ecosystem is lot more beneficial as frogs and fishes help to promote exponential yield. This is achieved by their ability to control insects, pests, weeds and chironomid larvae, mosquitos. Apart from these their presence facilitates rise in soil permeability, aeration, soil nutrient uptake. The need for using fertilisers which are source of Greenhouse gases (GHG) are also minimized. Thus addition of aquatic organisms like fishes, amphibians promotes more sustainable, eco-friendly farming. However these animals are threatened by variety of chemicals such as Neonicotinoids. These pesticides increase the animal's susceptibility for pathogens, render them open to predators. They also cause morphological, anatomical, histological changes thus contributing to global amphibian decline. Current review focuses on the ecological services rendered by fishes and frogs and harmful effects of Neonicotinoids on these aquatic animals.

Keywords: Amphibians, fishes, paddy ecosystem, neonicotinoids

1. Introduction
With extensive use of pesticides round the globe residues are becoming a major part in all water bodies' *viz*. rivers, oceans and in urban areas. (Guruge & Tanabe, 2001; Sanchez- Bayo, 2012) [31]. Although the insecticides do control variety of insect pest, the repercussions are undoubtedly faced by the society. The effects are manifested in form of toxicity on non-target animals thus affecting them in various degrees (Sanchez-Bayo, 2012; Aliko & Baba, 2011) [1]. In general the toxicity arises when the insecticides do show their effect on physiological functioning of animal (Sanchez-Bayo, 2012). Different insecticides have got different mode of action. Some are neurotoxic some are respiratory inhibitors thus impeding the process of oxidative phosphorylation in mitochondria (a mechanism found in all organisms). Some act as growth regulators thus barricading the arthropods from commencing metamorphosis. But when it comes to aquatic organisms, the tables are turned. Aquatic organisms mostly invertebrates are ancestral. Despite sharing common respiratory and digestive systems with hat of land dwelling insects, the former have poor detoxification systems (Sanchez-Bayo, 2012; Walker, 2011) [71]. Land dwelling insects have highly efficient iso-enzymes that facilitate efficient removal of toxins from the body. (Sanchez-Bayo, 2012). One such example is the use of propargite, a miticide is highly toxic for aquatic life as compared to terrestrial arthropods due to later developing highly advanced detoxifying systems. Speaking of aquatic systems, rice is most widely known man made agriculture system. Water that runs from oceans, lakes, rains, along with aerial drift of spraying contaminates all the forms of life. Many articles have been proposed that state the presence of pesticides in the water bodies. (Goulson, 2013; Tapparo *et al*., 2012; Marzaro *et al*., 2011; Krupke *et al*., 2012) [30, 65, 46, 39]. The sad reality is that still now these insecticides are being applied in tropics illegally. The most targeted organisms that succumb to these chemicals directly or indirectly (Ayoola, 2008 and Framnklin *et al*., 2010) are fishes. In the fishes gills which are the major source of respiration and osmoregulation. They also aid in assessing the quality of water (Fanta, 2003) [22]. Hence by histopathological analysis damage to cells can be screened at the targeted organs. Apart from fishes amphibians are other organisms that atone for indiscriminate use of pesticides. It is imperative to know that since 1970 most of amphibians are subjected to population decline. Although many reasons attribute to their decline such as climate changes (Pounds *et al*., 2001) [54] pathogenic microbes (Carey, 2000; Johnson *et al*., 1999) [9, 36] and losses of habitat

(Blaustein *et al*., 1994; Dunson *et al*., 1992) [6, 18] pesticides are yet another reason for their decline. Although more studies need to be documented, however many studies on other animals depict that most of the agriculture pesticides can cause significant changes in morphology or functional immune system of amphibians (Leubke *et al*., 1997; O'Halloran *et al*., 1996; Zelikoff *et al*., 1996) [45, 53, 74]. When contaminants affect the animals, behaviour is altered by immunomodulation thus defensive functions are supresed against variety of pathogens. (Fournier, 1998; Krzystynaik *et al*., 1985) [25, 40]. To understand their impact knowledge of these animals in rice ecosystem needs to be fully understood. Hence the review focuses on the importance of introducing frogs and fishes into rice ecosystem and use of chemical pesticides as detrimental factor determining their survival (Fulton and Chambers, 1985; Berril *et al*., 1994; Sparling *et al*., 2001) [28, 4, 64].

2. Importance of Paddy in India

Being consumer by over half of world's current population, paddy is then principle staple cereal crop (Xia *et al*., 2016, p.13, 4569-4579; Zhou *et al*., 2017, p. 115, 21-34) [72, 76]. India has been exporting 44, 14,562 Metric Tons of Basmati rice in the year of 2018-2019 whose worth can be accounted to 32.8 crores of Rupees (www. apeda.gov.in). This proves that India has enough rice area making itself reliant as well has symbolizing its strength in agrarian economy. Talking in terms of area India stands first and in terms of production it is below china making it second largest (Saha, 2006, p. 51(4):304-06). Dey *et al*. (2020) [57, 17] reported the increasing trend of area, production and productivity of paddy with its growth rate of 0.5 percent, 2.4 percent and 1.9 percent. Hence being one of most intensively crop grown especially in India, paddy is also subjected to large number of pest attacks. As per DWR. Vision 2050 Losses by pest, weed, insect, diseases and other pests did contribute to about 33%, 12.5%, 9.5%, 6.5% and 4.5% respectively. Mondal *et al*. (2017) [49] had conducted experiments estimating yield loss assessment of rice due to different biotic stress under SRI system and as per their estimates of crop losses, weeds occupied highest losses followed by insects later by in diseases. Hence forth taking all these above foresaid data, we conclude that management practices are therefore essential in increasing the productivity of paddy in India. However increase in use of pesticides and fertilizers are paving way for bio- accumulation, bio-magnifications. One of classical example is Handigodu syndrome caused by non-judicious usage of arsenicals in Karnataka. This diseases affects joints, deformities in joints, hips etc. Besides putting human beings life at risk it also causes threat to biodiversity as in case of kasargod disaster where aerial spraying of endosulfan has vanquished most of aquatic, amphibian and caused many herbivores to become deformed. Apart from all the risks the pesticides and fertilizers pose to the environment, paddy fields are again important source of greenhouse gas emissions. Carlson *et al*. (2017) [10] has estimated that by releasing nitrous oxide and methane, paddy fields do account for 48% of global scale of greenhouse gas emissions. To tackle all these problems demand for use of eco- friendly management practices is called for. Research all over the world over use of frogs, fish and shrimp has being done and benefits have been evaluated as well. This practice results in excess production of both fishes and frogs and also it is assumed that both weeds and pests are controlled by frogs (Teng *et al*., 2015) [66].

3. Effects of introducing fishes and frogs in paddy ecosystem

The practice of rice fish farming dates back to 1200 in china. While some resources say that it was practised 1700 years back (Li K, 1992; Cai *et al*., 1995) [8]. However rice frog fish system has been a recent practise in south part of Asia. Rice fish farming system is a practise that is believed to augment the yields by ecological sustainable agriculture. (Jintong, 1996) [35]. Fishes and frogs serve as additional benefits by serving as a predator of insects, weeds. In addition to it they nourish the soil by their excrement. (Shugen *et al*., 1995: Lightfoot, 1992; Frei and Becker; 2005) [60, 26]. Thus making a more profitable and sustainable countries like Africa, Zimbabwe are gaining momentum quickly thus raising the standards of living farming system. Detailed benefits of introducing frogs and fishes are discussed below.

3.1. Effect on CH_4 emissions

Rice fields are the major contributors to the global CH4 and N_2O emissions (Carlson *et al*., 2017) [10]. Such drastic increase in the climate changes can have detrimental impact on the humanity (Mora *et al*., 2017) [50]. Main contributor to the GHG (greenhouse gasses emissions) is the addition of soil fertilizers (Liang *et al*., 2013) [41]. In rice fields, IRFF dramatically enhanced Do (Dissolved oxygen), soil Eh, TOC (Total organic) content, and soil C:N (carbon nitrogen) ratio (Fang *et al*., 2019) [21]. Yuan *et al*. (2018) Xu *et al*. (2017) and Zhan *et al*. (2009) [75] investigated the GWP of GHG from an integrated rice-duck farming system. While the introduction of ducks in paddy fields can raise N2O emissions from duck faeces, it also increases the concentration of DO in the water layer and reduces CH4 emissions, according to their findings. Overall, the integrated rice-duck farming system reduces GWP in rice fields, according to their research. Frei *et al*. (2004), Datta *et al*. (2009), and Bhattacharyya *et al*. (2013) [26, 14, 5] on the other hand, found that carp generation in paddy fields boosts CH4 diffusion and discharge through the river.

3.2. Effect on insect pests

Liu *et al*. (2013) [43] carried out an experiment of raising bullfrogs in paddy fields. The results showed that the application of 900 and 1500 bullfrogs per hectare decreased the plant hopper population by 60% to 70% in paddy fields. Bull frogs specifically target insect pests such as *Spodoptera, Hieroglyphus, Melantis* and especially paddy stem borer thus increasing the yield considerably (Kharat, 1985) [37]. Fishes especially carps feed on the chironomid larvae (responsible for stealing soil nutrients) (Ikiwama & Otsuki, 1991) [34]. Plant hoppers which were responsible for rice sheath blight was controlled by using exotic frogs (Teng, 2015) [66]. Thereby augmenting the yield by controlling the actual fungi. Various researcher who have documented the various Genera of frogs and fishes and their prey insects listed order wise are briefly entailed in summarised way in Table.1.

Table 1: Different species of fishes and frogs controlling various insect orders

Aquatic organism fish /frog	Insects preyed	Documented by
Unnamed frogs (exotic) reared from frog breeding farm in Zhejiang province	*Cnaphalocrocis medinalis* (rice leaf folder) Plant hoppers(not specified scientific name) causing sheath blight of rice	(Teng *et al*., 2015) [66]
(*Channa* spp.) murrels	Mosquito larvae	(Usha, 2018)
Aquatic organism fish /frog	**Insects preyed**	**Documented by**
Crucian Carp (*Carassius* spp.)	Insects belonging to Hemiptera, Ephemeroptera, Aphididae, Lycaneidae, Diptera, Tipulidae, chironomidae, Ichneumonidae, Formacidae and Braconidae of Hymenoptera	(Tsurata *et al*., 2010)
Rana tigrina (Bull frog)	*Spodoptera mauritia* (Boisd.), *Pelopidas mathias* (F.) (*Parnera mathias*), *Rhinyptia* and *Holotrichia* spp., *Melanitis leda ismene* (Cram.) (*M. ismene*), *Hieroglyphus banian* (F.) and *Scirpophaga incertulas* (Wlk.) (*Tryporyza incertulas*).	(Kharat, 1985) [37]

4. Neonicotinoids

Neonicotinoids represents chemical class with systemic nature and offering long time crop protection because of their extended half-life in soil (7-6931 days, Goulson, 2013) [30] aquatic systems 30-120 days, Lewis *et al*. (2016). They contribute to 25% of insecticide sales throughout the world (Jeschke *et al*., 2011; Sparks 2013) [19, 44]. Their traces have been reported across wider geographic range throughout the world on account of their worldwide usage and persistency (Sanchez-Bayo *et al*., 2016). Since last decade there has been exponential increase in usage of neonicotinoids against wide range of pests. Neonicotinoids on account for their high solubility as in imidacloprid (EPA 2003) [20] have higher potential for exposure for amphibians. Among all aquatic life particularly invertebrates suffer consequences despite having same, yet deficient detoxification, neurological, respiratory systems as that of terrestrial insects (sanchez-bayo.2012). Neonicotinoids along with widely used fipronil are agonist to acetylcholine for nicotinic receptors. As fipronil binds to gamma amino butryic acid receptors, neurons fire continuously thus exhausts cell energy and results in death of insect (Simon-delso *et al*., 2015; Velisak & Stara, 2018) [62,]. Detrimental effects in terrestrial ecosystems are targeted on bees impairing their ability to discriminate floral scents (mustard *et al*., 2020) [52], affecting navigation (Tison *et al*., 2016) [68] etc. Vertebrates and invertebrates although show differences in sub units for nicotinic receptors, former has low receptors with high affinity as opposed to latter (Simon-delso *et al*., 2015) [62]. In aquatic environments, Neonicotinoids concentrations frequently surpass standards for protection against short-term acute effects (0.2 g/L). Chronic long-term effects (0.035 g/L) on aquatic invertebrate populations (Morrissey *et al*., 2015). Although vertebrates are assumed to be immune to neonicotinoids, a growing body of research has found that exposed fishes had lower activity (Crosby *et al*. 2015; Finnegan *et al*. 2017) and growth (Hayasaka *et al*., 2012; DeCant &Barrett, 2010) [13, 24, 32, 16]. Neonicotinoids are most likely introduced to amphibians through their very permeable skin (Van Meter *et al*., 2014) [69]. Hence amphibians are considered as ideal indicator species in determining overall health of ecosystem (Mason *et al*., 2003; Rios *et al*., 2017) [47, 55]. Despite tadpoles having high LC 50 values for neonicotinoids (100-219 mg/L, Feng *et al*., 2004; Sanchez- Bayo 2012; Anderson *et al*., 2015) [23, 2], sub lethal doses can have dire consequences (Boone & semlitsch, 2002) [7]. Holtswarth *et al*. (2019) [33] had shown that exposure to concentration of neonicotinoids even at lowest dosage 0.25ug/L, tadpoles became less active with little swimming distance. Such less reactive behaviours can be detrimental as it makes them susceptible to predation due to less foraging; (Boone and semlitsh, 2002) [7]. Apart from these assessing corticosterone concentrations has become popular tool in determining the stress levels and immune systems of amphibians (Belden and kiesecker, 2005; Davis *et al*., 2008; Mcmahon *et al*., 2011) [3, 15]. When an animal encounters stress glucocorticosteroids suppress the important functions and mediates energy requirements (Romero, 2002) [56]. When the concentrations of chemicals with long half-lives of 7-353 d for thiamethoxam and 148-6932 days, energy needed for other body functions is depleted affecting immunity as well (Belden & keisecker 2005) [3]. Davis *et al*., 2008 [15] has reported that both neutrophils whose response to stress, inflammation (Davis *et al*., 2008; Shutler *et al*., 2009) [15] and leucocytes antibody producer (Davis *et al*., 2008; shutler *et al*., 2009) [15] account for 80% of leukocytes.

5. Conclusion

Thus amphibians and fishes help in rice field ecosystem in plethora of ways. The use of IFF integrated rice fish frog farming has proven to be the best in terms of increasing the yield, reducing the insect pests however ecological re-habitation of frogs should be taken care of because most of the frog species are subjected to foreign trade. Hence by adding both the fishes and frogs raises rice yields significantly can thus contributing to a sustainable agriculture.

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