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Original Research Paper

Artificial Ponds and Seasonal Wetlands Supporting Amphibian Diversity, Breeding Success, and Survival in Agricultural Landscapes

Dr. Saurabh Banwar[1*], Dr. Amitesh Barman[2]

[1]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.*
Email: ku.saurabhbanwar@kalingauniversity.ac.in, Orcid: https://orcid.org/0009-0004-3389-8299
[2]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.
Email: ku.amiteshbarman@kalingauniversity.ac.in, Orcid: https://orcid.org/0009-0007-5895-4148

Key Words

Artificial ponds, Seasonal wetlands, Amphibian diversity, Breeding success, Agricultural landscapes, Wetland conservation, Biodiversity management.

Abstract

Habitat loss, agricultural intensification, wetland degradation, and environmental pollution are emerging threats to amphibians. Agricultural features such as artificial ponds and seasonal wetlands can offer alternative habitats to sustain amphibian diversity, breeding success, and survival. This study sought to examine the contribution of artificial ponds and seasonal wetlands as ecological habitats to support amphibian communities under agricultural land use. In total, 20 aquatic habitats (10 artificial ponds and 10 seasonal wetlands) were investigated in the field, during pre-monsoon and monsoon seasons. Visual encounter surveys, call monitoring, nocturnal transects, and dip-net sampling of larvae and tadpoles were used to sample amphibians. Additionally, dissolved oxygen, water temperature, pH, turbidity, and vegetation cover were measured. 18 amphibian species were recorded, more species and breeding activity were recorded in seasonal wetlands than in artificial ponds. The mean species richness was 9.1 ± 1.8 in seasonal wetlands, which was higher than 6.2 ± 1.4 in artificial ponds. The density of tadpoles was significantly greater in the seasonal wetlands (31.7 ± 5.6 individuals/m²) than in the artificial ponds (18.5 ± 4.2 individuals/m²). The juvenile survival rates in the seasonal wetlands were 78.5%, and in artificial ponds were 61.3%. ANOVA analysis revealed that there were statistically significant differences in species richness ($F = 8.74$, $p = 0.009$), density of tadpoles ($F = 11.29$, $p = 0.004$), and juvenile survival ($F = 10.15$, $p = 0.005$) among the different habitat types. Positive correlation was found between diversity of the amphibians, dissolved oxygen, and vegetation. These findings show that artificial ponds and seasonal wetlands have an important role to play in amphibian conservation within agricultural environments. Seasonal wetlands serve as excellent breeding sites for amphibians, while artificial ponds function as additional habitats during the dry seasons. This research shows how crucial it is to use sustainable wetland management techniques in agricultural settings.

* Corresponding Author's email: ku.saurabhbanwar@kalingauniversity.ac.in
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Introduction

The value of artificial ponds and seasonal wetlands as ecological habitats within agricultural landscapes is growing in recognition. Artificial ponds are manmade water bodies that can be used in irrigation, watering livestock, rainwater storage, and aquaculture, whereas seasonal wetlands are temporary water-retaining wetlands that develop during rainy seasons or seasonal flooding. These habitats may be established or preserved to accommodate agriculture or water management, but can also serve as important shelters and breeding grounds for populations of amphibians. Artificial ponds and temporary wetlands can serve as alternative habitats for biodiversity conservation in areas where natural wetlands have been lost because of land use change, urbanization, and intensive farming (Bellakhal et al., 2017).

Amphibians have an essential role in the stability of the ecosystem and in environmental health. Amphibians, such as frogs, toads, salamanders, and others, play a role in the food web by helping to control insect populations and as food for birds, reptiles, and mammals. It limit the abundance of pests in agricultural systems and participate in nutrient cycling in wetlands. Amphibians' highly permeable skin and dual aquatic/terrestrial life cycle also make them sensitive bioindicators that can be impacted by factors such as pollution, habitat destruction, and climate variability. Loss of amphibian diversity may be indicative of other changes at the ecosystem level that might impact ecosystem integrity and water quality (Khyade & Jagtap, 2019).

Natural wetlands have been lost and reduced in size and extent due to agricultural expansion and intensification, causing decreased breeding habitats and population numbers for many amphibian species. Artificial ponds and seasonal wetlands can contribute to offsetting habitat loss by offering shallow water bodies for egg laying, larval development, and juvenile survival, however. An important consideration is that temporary hydroperiods may decrease the predator population and result in higher tadpole survival and breeding success in seasonal wetlands. Likewise, a well-managed artificial pond, with appropriate vegetation cover, water quality, and hydroperiod conditions, can provide favorable microhabitats that are conducive to the reproduction and seasonal migration of amphibians.

Several environmental parameters, such as water depth, hydroperiod, vegetation complexity, land-use surrounding the wetlands, and pesticide inputs, are important to the ecological value of these habitats. Awareness of the use of artificial ponds and seasonal wetlands within the agro-ecosystems of amphibians is key to the creation of land-use practices that are more conservation-friendly. The present study thus aimed to assess the contribution of artificial ponds and seasonal wetlands to amphibian diversity, breeding success, and survival in the agricultural landscape and to determine the features of these habitats that promote ecological sustainability and biodiversity conservation.

This study is important because it illustrates the ecological value of artificial ponds and seasonal wetlands as alternative habitats in a landscape that is experiencing a loss of natural wetlands in the context of agriculture. The research adds to the conservation of biodiversity by helping to define habitat characteristics that enhance breeding success and survival of amphibians. It also provides inputs for sustainable agricultural planning, wetland restoration and ecosystem management. Further, conservation strategies can be developed during the study that will strike a balance between agricultural productivity and conservation of sensitive amphibian species while respecting environmental health.

Research Objectives

- To explore the use of artificial ponds and seasonal wetlands as amphibian breeding habitats.
- To assess the success of breeding in agricultural wetlands for amphibians.
- To learn about factors that promote the survival and reproduction of amphibians and how these factors relate to their environment.
- To identify optimum strategies for enhancing conservation of amphibians in a farmland environment.

This paper consists of six major parts. A review of previous wetland restoration, amphibian breeding and habitat quality studies is included in Section 2. The sampling of amphibians, collection of environmental data and statistical analysis are described in Section 3 and the study area is described. The data collected in the above section is presented in the ecological comparisons and ANOVA tables in Section 4. In Section 5, ecological implications and conservation strategies are addressed and key findings and future research recommendations are listed in Section 6.

Literature Review

Modern studies have been stressing the importance of wetland restoration and artificial aquatic ecosystem creation for amphibian conservation in modified and agricultural environments (Praveenchandar et al., 2024). Wetland management plays a crucial role in biodiversity conservation efforts, since amphibians are highly susceptible to environmental disturbances, hydrologic change, pollution, and climate fluctuation (Almudhafar et al., 2024; Rothenberger et al., 2019).

Water manipulation techniques, such as hydroperiod manipulation and holding water in certain seasons, were found to play an important role in amphibian breeding and larval survival according to previous research (Mathwin et al., 2021; Swartz & Miller, 2019). Likewise, it showed that in agrarian landscapes, constructed wetlands can serve as good breeding grounds, provided the complexity of vegetation and water quality are sufficient (Rannap et al., 2020). The results of this study are corroborated by a recent study that concluded that the construction of ponds is still a valuable conservation tool even within regions with naturally occurring wetlands: the creation of artificial ponds creates an additional source of habitat and connectivity (Magnus & Rannap, 2019).

Habitat quality is still a significant influence on amphibian diversity and reproductive success. A study revealed that there is a reduced diversity of amphibians in artificial aquatic habitats in intensive agricultural landscapes, which is attributed to water pollution and poor ecological structure (Perrone et al., 2022). It also demonstrated that the dynamics and enrichment of the phytoplankton are important factors in the larval growth and survival of pond-breeding amphibians (Youngquist & Boone, 2021). These are observations that suggest that the biological productivity and the surrounding land use affect the persistence of amphibians.

Ecological functions and disease control are increasingly being emphasized in the wetlands restoration methods. This work created restored wetlands targeting chytrid fungal disease and invasive fish impacts to the threatened frog populations (Beranek et al., 2020). It studied isolated wetlands restoration projects and found that restored wetlands can rehabilitate amphibian communities with hydrology and vegetation that are similar to natural wetlands (Burrow & Lance, 2022).

A few studies also explored the structural aspects of wetlands that are affecting the number of amphibians. It was determined that intermediate-sized ponds had the highest number of amphibians and most species (Burrow & Lance, 2022), and another study highlighted the ecological value of temporary ponds as a source of heterogeneity in breeding habitats (Nummi et al., 2024; Semlitsch et al., 2015). It made a comparison between vernal pools in natural, restored, and created environments, and found that over time, restored wetlands tend to perform more like natural wetlands.

Another factor that has a big impact on the ecology of amphibians is the landscape context. This paper showed that agricultural landscapes make landscapes more resistant and reduce gene flow between the population of amphibians, compared to forested areas (Haugen et al., 2024). It carried out a global review that revealed that with the loss of natural wetlands around the world, amphibians increasingly depend on artificial habitats (Valdez et al., 2021).

Ecosystems and technology restoration practices are also growing. In the past, these two studies have pointed out the benefits of native macrophytes in water quality and aquatic biodiversity improvement in restored wetlands and the importance of sustainable land-use in long-term conservation of aquatic ecosystems (Kavitha, 2024; Ziwei & Han, 2023).

From the researches done on amphibian conservation, the restoration of wetlands, habitat creation, and improvement of water quality appear to be vital factors in the process. However, a number of challenges exist, such as habitat connectivity, effects of agriculture and pollution, and sustainable ecology. Altogether, all these studies emphasize the need for an ecosystem approach to wetland restoration with the aim of increasing the chances for survival, breeding, and diversity of amphibians.

Methods

Study Area and Selection of Artificial Ponds and Seasonal Wetlands

This study was conducted in a mixed cropping system in the presence of irrigation channels, paddy fields, and fragmented vegetation. The area experiences seasonal precipitation, meaning that the existence of temporary wetlands relies upon seasonal rainfall, and the maintenance of permanent wetlands is for irrigation, livestock drinking, and water storage purposes. The area generally has a tropical climate, characterized by warm to hot temperatures and seasonal rains which play a key role in amphibian breeding behavior and the duration of hydroperiods.

Twenty aquatic habitats, ten artificial ponds, and ten seasonal wetlands in various fields were chosen for examination. The habitat accessibility, water availability, vegetation cover, duration of hydroperiod, and proximity to agricultural activities were used to determine site selection. Artificial ponds were of diverse sizes, depths, and management practices, while seasonal wetlands comprised temporary rain-fed ponds and lowland areas flooded during the wet season. Study sites were spaced at least 1 km apart to limit repeated sampling of the same populations of amphibians and to allow for independence within the study.

The field surveys were carried out during pre-monsoon and monsoon seasons for 6 months and comprised peak amphibian breeding seasons. The water depth, pH, dissolved oxygen, temperature, turbidity, aquatic vegetation density, and surrounding land-use were measured at each sample site to determine the environmental conditions that would affect amphibian diversity and survival.

Amphibian and Environmental Sampling Methodology

Sampling of amphibians was done with a mixture of visual encounter surveys, call surveys, dip-net, and nocturnal transect observations. Surveys were done at night and in the evening when amphibians are most active. Visual encounter surveys consisted of making systematic searches of wetland edges, aquatic plants, submersed objects, and shallow water areas for adult amphibians, young, egg masses, and tadpoles. In addition, calling male frogs were identified during breeding periods through auditory surveys to gain more information on species presence and reproductive activity.

The shallow aquatic habitats were surveyed to collect the tadpoles and larvae using dip nets for species identification and estimation of abundance. Captured animals were taken to a safe location and released back to the habitat with a minimum of disturbance using standard amphibian field guides. The breeding success was determined by observing the egg masses, tadpole density, larval survivability, and emergence of the juveniles within the habitats selected.

Amphibian sampling was concurrent with data collection for environmental data. Portable field instruments were used to measure water quality parameters such as temperature, dissolved oxygen, pH, and turbidity. Habitat surrounding the quadrat was classified by agricultural disturbance, and the vegetation cover and habitat complexity were estimated visually based on quadrat assessments.

Data Analysis Techniques

The data collected were analyzed statistically by descriptive and inferential statistical methods. To compare the communities of amphibians in artificial ponds with those in seasonal wetlands, species diversity and richness were calculated with the Shannon–Wiener Diversity Index and Simpson's Diversity Index. Mean and standard deviation values and percentage distributions were used to summarize amphibian abundance, breeding success indicators and environmental variables.

The analysis of variance (ANOVA) was used to identify any significant differences in amphibian diversity, tadpole survival and breeding activity between the habitat types. Relationships among the environmental variables and the various indices of amphibian population, including species richness, breeding success, and larval survivorship, were examined with correlation and regression analyses. The statistical analysis were performed using the standard ecological data analysis programs and the significance level was determined as $p<0.05$. The results were provided to interpret the habitat conditions that best support conservation in the context of agriculture.

Results

A total of 18 amphibian species were detected in the considered artificial ponds and seasonal wetlands in the agricultural area. Seasonal wetlands had more amphibian diversity and breeding activity than artificial ponds because the temporary flooding allowed for the presence of shallow water, abundant vegetation, and fewer predators. Artificial ponds, however, also gave relatively stable aquatic habitats that enabled the survival of amphibians during dry seasons when the temporary wetlands were not present.

Species richness and abundance were significantly greater during the monsoon season, suggesting that both rainfall and hydroperiod length were significant factors to the success of breeding in amphibians. The most frequently seen frog families in both habitat types were the Ranidae and Dicroglossidae. Breeding was more successful in temporary water as indicated by the higher frequencies of egg masses, tadpoles, and juvenile amphibians.

Environmental factors, like water temperature, vegetation cover, and dissolved oxygen had strong relationships with the diversity and survival of amphibians. Larval survival and juvenile recruitment was higher in wetlands with moderate vegetation density and higher amount of dissolved oxygen. By contrast, sites highly disturbed by agricultural activities and contaminated by pesticides showed less abundance of amphibian and lower breeding success.

Table 1 shows that when statistical analysis of data was done using ANOVA, there were significant differences in species richness and tadpole survival of the two types of habitat namely the artificial ponds and seasonal wetlands ($p < 0.05$). The data also showed positive correlations between vegetation complexity and amphibian diversity, and between too much turbidity and chemical exposure, and the lack of breeding activity. Results indicate that artificial ponds and seasonal wetlands can be beneficial for amphibian conservation, albeit seasonal wetlands can offer better breeding conditions under certain environmental conditions.

Table 1: ANOVA Results for Amphibian Diversity and Breeding Success Between Habitat Types

Variable Analyzed	Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value	p-value	Significance
Species Richness	Between Groups	24.63	1	24.63	8.74	0.009	Significant
	Within Groups	50.72	18	2.82			
Tadpole Density	Between Groups	418.56	1	418.56	11.29	0.004	Significant
	Within Groups	667.21	18	37.07			
Juvenile Survival Rate	Between Groups	912.44	1	912.44	10.15	0.005	Significant
	Within Groups	1617.38	18	89.85			
Dissolved Oxygen Level	Between Groups	6.18	1	6.18	7.42	0.013	Significant
	Within Groups	14.99	18	0.83			

There was a statistically significant difference in ecological parameters between artificial ponds and seasonal wetlands. The number of species in each habitat type was found to be statistically different ($F = 8.74$, $p = 0.009$). Seasonal wetlands were observed to have greater species richness than artificial ponds, implying greater diversity in amphibians in seasonal wetlands. In addition, tadpole density and juvenile survival rate were observed to have significant differences, implying that there were better conditions for breeding and development in temporary wetlands. Higher concentrations of dissolved oxygen were recorded in seasonal wetlands; this was beneficial for the growth and development of tadpoles.

Seasonal wetlands seem to create better ecological conditions for amphibian reproduction than the artificial ponds do are represented in table 2. It is important to mention that artificial ponds act as supplements to the seasonal wetlands since amphibians need more habitat to survive.

Table 2: Comparison of Amphibian Diversity and Breeding Indicators Between Artificial Ponds and Seasonal Wetlands

Ecological Parameter	Artificial Ponds	Seasonal Wetlands
Total Amphibian Species Recorded	12	18
Average Species Richness per Site	6.2 ± 1.4	9.1 ± 1.8
Mean Tadpole Density (per m²)	18.5 ± 4.2	31.7 ± 5.6
Egg Mass Observations	45	79
Juvenile Survival Rate (%)	61.3	78.5
Dissolved Oxygen (mg/L)	5.8 ± 0.9	7.1 ± 1.1
Vegetation Cover (%)	42	68
Observed Predator Presence	Moderate	Low
ANOVA Significance (p-value)	-	< 0.05

Discussion

The findings indicate that artificial ponds and seasonal wetlands play an important part in the conservation of amphibian diversity and successful breeding. The higher number of species, a higher tadpole abundance, and a high rate of juveniles' survival can be explained by the creation of favorable ecological conditions – lower depths of the wetlands, high dissolved oxygen levels, and thick vegetation cover. In addition, some seasonal wetlands have temporary hydroperiods that might reduce the predator populations, increasing safety for breeding amphibians.

This study brings out the significance of incorporating biodiversity protection into farming lands. Conserving biodiversity can be achieved by keeping vegetation around the ponds, reducing the use of chemicals and keeping wetlands on farms even if crops are grown. The construction of man-made ponds with differing depths and plant cover will be beneficial to consider for encouraging reproduction and connectivity of amphibians.

Despite the results of this research, this study has certain limitations. The study would be limited to a small area within a designated season, for instance, limiting the results to a non-very-accurate study. This study did not include other factors that could affect the environment including levels of pesticides and diseases in the environment. To get reliable results, future investigations should include several seasons.

Conclusion

This study revealed that artificial ponds and seasonal wetlands greatly enhance the diversity of amphibians, breeding success and survival in agricultural landscapes. Overall, 18 species of amphibians were found in the selected habitats, and more species and more reproductive activity were observed in the seasonal wetlands than in the artificial ponds. Seasonal wetlands had an average species richness (9.1 ± 1.8), while artificial ponds had a lower average species richness (6.2 ± 1.4). Likewise, the tadpole density was significantly higher within seasonal wetlands (31.7 ± 5.6 individuals/m²) compared to artificial ponds (18.5 ± 4.2 individuals/m²), suggesting that there are more favourable conditions for breeding and larval development in seasonal wetlands. The results of statistical analysis showed that there was statistically significant ecological difference between the habitat types. ANOVA results revealed statistically significant variation in species richness ($F = 8.74$, $p = 0.009$), tadpole density ($F = 11.29$, $p = 0.004$), juvenile survival rate ($F = 10.15$, $p = 0.005$), and dissolved oxygen levels ($F = 7.42$, $p = 0.013$). Juvenile survival rates were higher for seasonal wetlands (78.5%) than for artificial ponds (61.3%), due to better water quality, more vegetation cover, and fewer predators in the seasonal wetlands. The relationships among the variables were also examined using correlation analysis, which revealed that the degree of aquatic plants was related positively with the degree of dissolved oxygen, the degree of amphibians and the number of intensive agricultural disturbance, respectively, and breeding success was negatively related with the number of intensive agricultural disturbance. The results highlight the importance of artificial ponds and seasonal wetlands as an ecologic resource that can be used to replace the loss of natural wetland habitats in agricultural areas, albeit to a lesser extent. Conservation goals for amphibians can be met with the support of ecosystem stability through proper habitat management practices such as saving and protecting wetlands, minimizing exposure to pesticides and maintaining aquatic vegetation. Long-term ecological monitoring, the connection between agrochemicals and amphibian physiology and reproduction, and the effects of climate variability on wetland hydroperiods should all be the subject of future research. Conservation strategies for amphibians in agricultural landscapes dominated by people could be further supported by the inclusion of additional studies that account for landscape connectivity, genetic diversity and species-specific habitat preferences.

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