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1. Artificial Nests for Bird Conservation in Intensive Agriculture Ecosystem: A Sustainable Approach

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1.1 Introduction:

In recent time intensive agriculture have resulted in changes in the environmental factors, habitats, abundance and distribution of many species of animals including birds. Decline of the beneficial birds and fragmentation of their habitat has been reported from many parts of the world including India. This leads to significant decrease in population of diverse fauna in agro ecosystem. In reference to avian diversity, considerable changes have been taken place due to intensive agriculture.

A gradual decrease in beneficial bird population was observed which correspondingly resulted in increased insect and rodent pest problems in the crops. Tree cavities are important habitat feature providing breeding sites for many bird species but intensive agricultural practices have a clandestine as well as and direct negative effect on the tree plantations present in agricultural field areas.

Supplementing natural tree cavities with artificial nest has been used as a conservation strategy for many obligate tree hole or cavity nesters or secondary cavity nesters species, with success in halting or even reversing declining populations Artificial nests are being utilized as a co-friendly conservation tool to augment the population of secondary cavity nesting birds that are beneficial to agriculture.

The artificial nests (wooden and earthen) installed in different habitat types in agro ecosystem, proved effective in bird conservation efforts. These artificial nests were observed to be occupied by different bird species i.e. Common Myna *Acridotheres tristis,* Spotted Owlet *Athene brama*, Collared Scops Owl *Otus bakkamoena*, Magpie Robin *Copsychus saularis*, House Sparrow *Passer domesticus* and Blue Jay *Coracias benghalensis*.

Studies involving artificial nests have shown that the birds utilizing theses nests have lower predation rates and larger clutch sizes. Higher number of young ones fledged from nesting in artificial nests as compared to tree cavities and positive relationship between clutch size and artificial nests has been recorded. The successful breeding of beneficial species in artificial nests has the potential to alter the relative abundance of bird species and their reproductive success in agro ecosystem.

1.2 Intensive Agriculture A Cause of Concern for Avian Diversity in Agricultural Ecosystem:

Intensive agricultural practices and related anthropogenic activities resulted in habitat loss, mono-culture cropping system, destruction and degradation of required ecosystem, food scarcity for some specific bird species and food abundance for other specific bird species, are the major threats to avian species richness and diversity in agricultural ecosystem; specifically in north-western region of the country show this type of situation in recent times.

As cities grow and expand, urbanization takes place put a pressure in the agriculture which resulted in adopting the intensive agriculture which in turn replaces native habitats with new man-made mono/poly-culture cropping system where natural and anthropogenic components interact (Parsons *et al.* 2006; Kler and Kumar 2015a, b, Kaur and Kumar 2019).

Decline of the beneficial birds and fragmentation of their habitat has been reported from many parts of the country. Intensive agriculture in Punjab have resulted in changes in the abundance and distribution of many species of birds with pertinent decrease in population of beneficial birds which correspondingly has resulted in increased insect and rodent pest problems in the crops (Parasharya *et al.* 1994; Ahnstrom*et al.* 2008; Siriwardena 2010).

Most of the earlier research directed towards determining the habitat needs of various birds has centered on 'natural' communities, while effects of intensive agricultural have been largely ignored.

Now a days, avifauna in agriculture ecosystem is becoming increasingly appropriate targets for research and conservation efforts (Kler and Kumar 2015a; Jain and Kumar 2021) particularly when human population, social and demographic trends predict further increasing trend for adopting intensive agriculture. Bird communities respond to this environmental variation in several ways.

But there are a number of bird species that survive successfully in the intensive agriculture ecosystem also. Environments involving intensive agriculture are often characterized as supporting a few abundant, generalist species which are best adapted to living alongside humans, and as such, agriculture ecosystem are also seen as agents of biotic homogenization.

Consequently, agricultural environments can no longer be viewed as lost habitat for wildlife, but rather as new habitat that, with proper management, has the potential to support diverse bird communities. Permanent presence of humans and lower densities of native tree species have potential to affect avian nesting behavior (Kler and Kumar 2015b; Kaur and Kumar 2018; Kumar 2022). With the rapid expansion of intensive agriculture, the importance of understanding the relationship between avian fauna and intensive agriculture practices is evident. It draws attention to the fact that there is urgent need to focus on the conservation of bird species, their habitat and native tree species so that there will be up gradation of their conservation efforts and this can further be supported by use of artificial nests in agricultural ecosystems.

1.3 Bird Diversity in Agricultural Ecosystem (Special Reference to Agricultural Ecosystem of Punjab):

The avifauna of India includes around 1314 species including 4.8% endemic to India (Praveen *et al.* 2020). The Punjab state, with an area of 50,362 km^2, is situated in the north western part of the country. It extends from latitude 29°33' to 32°32' North and longitude 73°55' to 76°50' East with an average elevation of 300 m above mean sea level. The state has been classified into five agro-climatic zones i.e. sub-mountain undulating zone, undulating plain zone, central plain zone, western plain zone and western zone on the basis of homogeneity, rainfall pattern, distribution, soil texture, cropping patterns etc.

The climate of Punjab is characterized by extreme hot and extreme cold conditions. Annual temperatures in Punjab range from 1°C to 46°C (min/max), but can reach 49°C in summer and 0°C in winter. It has three defined seasons; summer, monsoon and winter. Summer season tends to be very hot and very dry and it ranges from April through June with average highs in May and June hovering around 40 ℃. A slight decrease in average temperature and an increase in humidity is witnessed in the monsoon season which runs from July through September with an annual precipitation average range between 960 mm in the sub-mountain region and 460 mm in the plains. Average temperature tends to decrease during the months of October and November. The winter months (December to February) are relatively mild with warm days and chilly nights and March is a transitional month from winter to summer.

Punjab has a rich bird fauna comprising 328 species of birds (Toor *et al.* 1982). Compiled checklist of 213 species of birds belonged to 17 orders 62 families and 131 genera in agricultural ecosysytem was given (Kler et al. 2022) which was havning 24 additional species as compared to earlier checklist of 189 species of birds, belonging to 17 orders, 56 families and 117 genera recorded during the surveys conducted in more than 240 villages of 19 districts of Punjab (Kler and Kumar 2015 a,b). Based on different agricultural habitat preferences i.e. Type A (Agricultural Habitat); Type B Residential area - Urban/Rural); Type C (Aquatic Habitat/ponds/ canal/river/wetland) and Type D (Uncultivated area/ forest/barren land), bird species were recorded to be 139, 68, 84 and 34 bird species in Type A; Type B; Type C and Type D, respectively (Kler et al. 2022). Most preferred habitat by theses bird species were agricultural landscape and urban/rural habitation which comes out to be 69.01 %, showing the importance of tree diversity and vegetation as major factor in preference of habitat by the birds. The "Checklist of Birds of Punjab and Chandigarh" by Toor *et. al.,* (1982) which recorded 240 bird species belonging to 17 order, 56 families and 150 genera was reported earlier. Kler and Kumar (2015a, b) reported 111 resident birds' species and 77 migrant species as compared to 147 resident and 93 migrant bird's species reported by Toor *et. al.* (1982). Kler (2005a, b) also recorded 64 species, belonging to 11 orders and 29 families from the crop fields of six districts of Punjab. A total of 97 bird species belonging to 14 orders and 40 families were also reported by Kler (2005a, b) from the villages of Ludhiana districts of Punjab. Kler (2010) had sighted 70 species of birds in different crop ecosystems. Comparative record has shown that there were 65 species common between the former and the present study. There were 5 bird species which were not observed during the present survey. Some species were found to be habitat specific and their future conservation effort can be carried out in specific habitats.

1.4 Role of Native/Indigenous Tree Species in Supporting Bird Diversity in Agricultural Ecosystem:

The most common native/indigenous tree species in the agricultural ecosystem of north-west India specifically Punjab region is Banyan (*Ficus benghalensis*), Jamun (*Syzgium cumini*), Mulberry (*Morus alba*), Neem (*Azadirachta indica*), Pipal (*Ficus religiosa*) and Sheesahm (*Dalbergisa sissoo*) which harbor large number of bird species (Kaur and Kumar 2018, 2019, 2020; Jain and Kumar 2021; Kumar 2022) (Table 1.1).

These tree species provide food opportunity, nesting facilities and roosting provisions to a large number of bird species in addition to other vegetation present in agriculture ecosystems.

A. Jamun (*Syzugium cumini*):

It is also called as Black Plum and belongs to family Myrtaceae. It is a medium sized evergreen tree with dense shady much branched crown. New leaves appear in February and are coppery red in colour. Flowers start appearing from March-April. Ripening of fruits takes place from June-July. Fruits are generally in purplish black in colour with juicy edible pulp which attracts a large number of bird species.

B. Banyan (*Ficus benghalensis*):

It is an evergreen tree of family Moraceae. It has a huge crown with the aerial roots extending to the ground which later on becomes trunk like and supports the crown. It has thick leathery leaves of oval shaped which are round at the tip. Fruiting generally occurs from March-May and also in September-October. Fruits are generally small in size and yellow to reddish brown in colour. More than twenty bird species were observed utilizing banyan tree during different stages of their life.

C. Mulberry (*Morus alba*):

Mulberry is a medium sized fruiting tree. Trees are bare in the month of January till the first week of February. New foliage starts appearing in the last week of February. Fruiting takes place in the month of March. More than thirty bird species were observed utilizing Mulberry tree.

D. Neem (*Azadirachta indica*):

Neem tree belongs to family Meliaceae. Its fruits and seeds are the source of neem oil. Neem is a fast-growing tree that can reach a height of 15– 20 meters. It is evergreen, but in severe drought it may shed most or nearly all of its leaves. Shedding of leaves takes place in the month of January. The branches are wide and spreading. The fairly dense crown is roundish. New foliage appears in month of February. The (white and fragrant) flowering occurs in the month of March and fruiting starts in the beginning of April. The fruit is a smooth (glabrous) and olive-like on which a number of species of birds feed.

E. Pipal (*Ficus religiosa*):

Pipal belongs to family Moraceae. It is a large size tree with heart shaped leaves and spreading branches without aerial root. Figs turn dark purple on ripening and are consumed by flocks of birds. Ripening of fruits takes place in the month of March- April and also in October to November. More than forty bird species were reported using Pipal tree for their activities.

F. Sheesham (*Dalbergia sissoo*):

It is fairly large deciduous tree with dark grey, rough and furrowed bark. It is fast growing tree adaptable and able to stand various temperatures. In the month of January- February tree is leafless and new foliage start appearing the month of March, flowering takes place in the month from March-April. Fruit ripens in the month of October and remain hanging on the trees for several months. Fruits are thin strap-shaped pods with kidney shaped light brown seeds which attracts a large number of bird species.

Table 1.1: Bird Species Preferences for Native Tree Species

Sr. No.	Common Name	Scientific Name	Feeding habits	Banyan	Jamun	Mulberry	Neem	Pipal	Sheesham	Utilizing artificial nest
1	Ashy Prinia	*Prinia socialis*	Insectivorous	-	-	-	-	+	-	-
2	Asian Koel	*Eudynamys scolopacea*	Insectivorous / Frugivorous	+	-	+	+	+	-	-
3	Asian Pied Starling	*Sturnus contra*	Insectivorous / Frugivorous	+	-	+	-	+	-	++
4	Bank Myna	*Acridotheres ginginianus*	Insectivorous	+	-	+	-	+	+	++
5	Barn Owl	*Tyto alba*	Insectivorous	-	-	-	-	+	-	++
6	Bay-backed Shrike	*Lanius vittatus*	Insectivorous	-	-	+	-	-	-	-
7	Black Drongo	*Dicrurus macrocercus*	Insectivorous	+	+	+	+	+	+	-
8	Black Kite	*Milvus migrans*	Carnivorous	+	+	-	-	+	+	-
9	Black-crowned Night-Heron	*Phoenicurus ochrurus*	Insectivorous	-	+	-	-	-	-	-
10	Black Redstart	*Nycticorax nycticorax*	Insectivorous	-	-	+	-	-	-	-
11	Blue Rock Pigeon	*Columba livia*	Granivorous	+	+	-	-	+		-
12	Brahaminy Starling	*Sturnus pagodarum*	Insectivorous / Frugivorous	-	-	+	-	-	-	-
13	Brown-headed Barbet	*Ketupa zeylonensis*	Insectivorous	-	-	+	-	+	-	-
14	Brown Fish-Owl	*Megalaima zeylanica*	Insectivorous / Frugivorous	-	-	-	-	+	-	-
15	Cattle Egret	*Bubulcus ibis*	Insectivorous	+	-	-	-	-	-	-

Sr. No.	Common Name	Scientific Name	Feeding habits	Banyan	Jamun	Mulberry	Neem	Pipal	Sheesham	Utilizing artificial nest
16	Golden-backed Woodpecker	*Dinopium javanense*	Insectivorous	-	+	-	+	+	-	-
17	Common Hoopoe	*Upupa epops*	Insectivorous	-	-	-	+	-	-	-
18	Common Myna	*Acridotheres tristis*	Omnivorous	+	+	+	+	+	+	+
19	Common Starling	*Strnus vulgaris*	Insectivorous / Frugivorous	-	-	+	-	-	-	-
20	Common Tailorbird	*Orthotomus sutorius*	Insectivorous	-	-	+	+	+	-	-
21	Coppersmith Barbet	*Psilopogon haemacephalus*	Frugivorous	-	-	-	-	+	-	-
22	Eurasian Collared-Dove	*Streptopelia decaocto*	Granivorous	+	+	+	+	+	+	-
23	Eurasian Golden Oriole	*Oriolus oriolus*	Insectivorous / Frugivorous	-	-	-	-	+	-	-
24	Eurasian Wryneck	*Jynx torquilla*	Insectivorous	-	-	-	-	+	-	-
25	Glossy Ibis	*Plegadis falcinellus*	Insectivorous	+	-	-	-	-	-	-
26	Greater Coucal	*Centropus sinensis*	Insectivorous	-	+	+	-	-	-	-
27	Grey Wagtail	*Motacilla cinerea*	Insectivorous / Frugivorous	-	-	+	-	-	-	-
28	House Crow	*Corvus splendens*	Omnivorous	+	+	+	+	+	+	-
29	House Sparrow	*Passer domesticus*	Granivorous/ Insectivorous	-	-	+	-	+	-	++
30	Indian Chat	*Cercomelafusca*	Insectivorous	-	-	+	+	-	-	-
31	Indian Cuckoo	*Cuculus micropterus*	Insectivorous	+	-	-	-	+	-	
32	Indian Grey Hornbill	*Ocyceros birostris*	Insectivorous / Frugivorous	+	-	+	+	+	-	++
33	Indian Peafowl	*Pavo cristatus*	Omnivorous	+	-	-	-	+	-	-
34	Indian Roller	*Coracias benghalensis*	Insectivorous	-	-	+	-	-	-	++
35	Indian Shikra	*Accipiter badius*	Insectivorous	-	-	-	-	+	-	-
36	Indian Treepie	*Dendrocitta vagabunda*	Insectivorous	+	-	+	+	+	-	-
37	Jungle Babbler	*Turdoides striatus*	Insectivorous /Frugivorous	+	+	+	+	+	+	-
38	Little Brown Dove	*Streptopelia senegalensis*	Granivorous	+	+	+	+	+	+	-
39	Little	*Phalacrocorax*	Insectivorous	+	-	-	-	-	-	-

Sr. No.	Common Name	Scientific Name	Feeding habits	Banyan	Jamun	Mulberry	Neem	Pipal	Sheesham	Utilizing artificial nest
	Cormorant	*niger*								
40	Oriental Magpie-Robin	*Copsychus saularis*	Insectivorous	-	-	+	-	+	-	++
41	Pied Crested Cuckoo	*Clamator jacobinus*	Insectivorous	-	-	+	-	-	-	-
42	Pied Wagtail	*Motacilla maderaspatensis*	Insectivorous	-	-	+	-	-	-	-
43	Purple Sunbird	*Nectarinia asiatica*	Plants/nectar	-	-	+	+	+	-	-
44	Red-vented Bulbul	*Pericrocotus cafer*	Insectivorous / Frugivorous	+	+	+	+	+	+	-
45	Rose-ringed Parakeet	*Psittacula krameri*	Frugivorous	+	+	+	+	+	+	++
46	Small Bee-eater	*Merops orientalis*	Insectivorous	-	+	+	+	+	-	-
47	Spotted Dove	*Streptopelia chinensis*	Granivorous	+	-	-	-	-	-	-
48	Spotted Owlet	*Athene brama*	Insectivorous	+	-	+	-	+	+	++
49	White-breasted Kingfisher	*Halcyon smyrnensis*	Carnivorous	-	+	-	+	+	-	-
50	Yellow-legged Green-Pigeon	*Treron phoenicoptera*	Frugivorous	+	+	+	+	+	+	-
51	Yellow Wagtail	*Motacilla flava*	Insectivorous	-	-	+	-	-	-	-

("++" bird utilizing artificial nests; ("+" bird species utilizing the tree species and "-" bird species not observed utilizing the tree species; as per various researcher (Kaur and Kumar 2018, 2019, 2020; Jain and Kumar 2021; Kumar 2022)

1.5 Role of Artificial Nests in Supporting Bird Diversity and Acting as A Tool for Bird Conservation in Agricultural Ecosystem:

Tree cavities are important habitat feature providing breeding sites for many bird species (Onodera *et al.* 2013). Supplementing natural tree cavities with artificial nest has been used as a conservation strategy for many obligate tree hole or cavity nesters or secondary cavity nesters species, with success in halting or even reversing declining populations (Malaza 2010, Clark *et al.* 2011, US Fish and Wildlife Service 2008, 2012). To combat the decline of and to conserve the beneficial bird species, use of artificial nests of different material i.e. wooden, earthen and re-cycled hard paper is suggested (Kler 2003; 2005a). The use of insectivorous and predatory birds as natural bio-control agents is a beneficial technique both economically as well as ecologically in controlling rat and insect pests (Ali and Ripley 1983;

Feare and Craig 1998). Artificial nests (wooden, re-cycled hard paper and earthen) can be installed in different habitat types in the agricultural field areas, urban and rural areas.

These artificial nests were observed to be occupied by many bird species i.e. Common Myna *Acridotheres tristis*, Spotted Owlet *Athene brama*, Collared Scops Owl *Otus bakkamoena*, Magpie Robin *Copsychus saularis*, House Sparrow *Passer domesticus*, Blue Jay *Coracias benghalensis* etc. (Table 1). The successful breeding of beneficial species in artificial nests has the potential to alter the relative abundance of bird species and their reproductive success in agro ecosystem. Basic artificial design involves following details i.e. nest measured 25-30 cm height (depth) x 19-24 cm width with an opening of 5.5-8.5 cm at a height of 7.5-14.7 cm on the front cover of nest and with a lid (roof cover) of 18-26 cm x 25-34 cm, with few holes in the base of nest for draining of water accumulated if any during rains; with provision of two hinges at the top of the back cover for hanging/ fixing the nests on the trees.

These nests were installed at heights ranging from 7 to 22 feet on the trunk as well as branches of various trees available in the field areas. Observations had shown the occupation of artificial nest (earthen) by two bird species i.e. Common Myna and House Sparrow *Passer domesticus* at different sites. The occupation preference for artificial nest in reference to direction of opening of the artificial nests was reported as follows north > east = south west > west=north east > south >south east. Bird occupied the artificial nest having maximum visibility as compared to the camouflaged sites. Per cent breeding successes in occupied artificial nests have a high range (80.0-100.0%). It was also recorded that little human disturbance resulted in flight of incubating parent from the artificial nests (Kler, 2005b; 2010; Malhi and Kaur, 2007) thus providing a safe breeding spaces for these bird species.

1.6 Importance of the Bird Species (Ecological/Economic):

The presence of birds in the surrounding ecosystem serves as a barometer of ecological health. Birds are important part of the food chain; because threats like pesticides, habitat loss, and climate change have the most dramatic impact on birds and higher vertebrates, we refer to them as indicator species.

Researching the population trends of birds provides a cost-effective and efficient means to detecting environmental change, allowing us to take conservation action that is driven by the latest scientific data. Rodent eating birds and insectivores also play an important ecological role by controlling populations of rodents, small mammals and insects.

A. Natural Balancer:

Bird of preys feed at the top of many food chains. Mice, field rats, rabbits, squirrels and other rodents, as well as fish, insects, amphibians and reptiles may have their population explodes due to good weather and a surplus of food some time. This is a common experience with fish, amphibian and even snake populations. Birds of prey help to balance the size of these populations.

B. Barometer of Ecological Health:

Birds are also called "ecological barometers" which simply means they help us gauge how healthy a habitat is. Birds of prey are extremely sensitive to many environmental changes in an ecosystem. They can even sense chemical and pollutant levels that can give people an early warning of any impending airborne threats. Pesticides and other chemicals can build up in our environment and are passed on to animals. This can lower raptor populations due to birds ingesting prey riddled with toxins, which in turn signals scientists that a possible problem exists.

C. Farmers Friends:

Since many of the birds feed on insects and some prey on rodents, many farmers truly appreciate them. The Black Drongo, Myna, Indian Roller, Kestrel and some species of owl feed on insects. The great horned owl and Barn owl feed on rodents. Grasshoppers, worms, as well as small mammals including squirrels, field mice are capable of destroying entire fields of crops if left to reproduce freely without any birds of prey to feed on them. Controlling pests through this method is called biological control. If a farmer can control pests by natural predation, he has no need to use pesticides or insecticides, which helps protect the environment.

1.7 Conclusion and Future Aspects:

Artificial nests are being utilized as a common conservation tool to augment the population of secondary cavity nesting birds that are beneficial to agriculture. Artificial nests can be useful in integrating the insect and rodent suppressing activities of birds in the management of pest populations of the agro-ecosystems. Studies have shown lower predation rates, larger clutch sizes and more young ones fledged from nesting in artificial nests as compared to tree cavities. Positive relationship between clutch size and artificial nests has been recorded in some species. The successful breeding of beneficial species in artificial nests has the potential to alter the relative abundance of bird species and their reproductive success in the tree deficit areas. Different bird communities utilize the indigenous trees for roosting, feeding, nesting and other activities, in different ways. For the safe guard of these species and being our moral duty to conserve them for future generation; we must peruse a directed result-oriented approach to achieve the goal in a sustainable way. Awareness and education are the foremost step needed to be taken as soon as possible to avert the catastrophic consequences. In the light of these facts' plantation and protection of native/indigenous trees and supplementing conservation efforts with installing artificial nests in agricultural ecosystem is the needed. Such type of work needs to be expanded in different habitats so as to conserve farmer friendly bird species in agro ecosystem. Therefore, further studies are the need of the hour to support and strengthen this concept.

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