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Different strategies adopted by birds to sustain ecosystem: A review

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Abstract

Different types of ecosystem and ecological resources related to them signify their preponderance to mankind. Ecosystem maintains the balance between mankind and other organisms by exerting direct or indirect influence on environment. Birds are most crucial and inseparable components of the earth's ecosystem and play several roles like pollinators, seed dispersers, predators, scavengers etc. and contribute to all the four ecosystem services viz. provisioning, regulation, cultural and supporting services as defined by the United Nations Millennium Ecosystem Assessment. The global loss of avian population implies reduction in ecosystem services and hence affecting the human life. The contribution of birds in our economy and maintenance of sustainable ecosystem remains unaccountable due to lack of information on their ecological value and tangible benefits. The complete evaluation of all the services rendered by avian fauna helps us to understand their significance in ecosystem sustainability and crucial role they play in human's life. The outcomes of scientific study on crucial role of birds to sustain different types of ecosystem will help the public and policy makers to understand the consequences of diminution in bird's population and spreading awareness about their conservation.

Keywords: Assessment, conservation, sustainability, mankind

Introduction

Ecosystem services benefits living beings by natural processes and establishes a relationship between ecosystem processes and living beings. Ecosystem provides services to earth's environment to nurture humans and other living beings directly or indirectly in the form of assets and processes (Deng & Yimam, 2020) [28]. In space and time, there are a variety of habitats connected with each other by several mediators and birds are one amongst them (Lundberg & Moberg, 2003) [64]. Birds as an important component of ecosystem have several roles to play like acting as pollinators, seed dispersers, predators, scavengers and ecosystem engineers are best known class of vertebrates contributing to maintain the integrity of ecosystem (Sekercioglu, 2006) [105]. It was documented that the structure of a forest depends on the population of frugivore birds as they are responsible for the pattern of seed dispersal and extinction of some bird species may lead to extinction of plant species dependent on these avian species for their seed dispersal (Garcia *et al.*, 2009; Silva & Tabarelli, 2000) [37, 106]. Likewise, disappearance of pollinators is affecting the genetic diversity of plants because of pollinator limitation, inbreeding (Anderson *et al.*, 2011; Morante-Filho & Faria, 2017) [3, 75]. The near extinction of species of scavenger and predator birds shows detrimental effects on our ecosystem leading to the slower decomposition; increases in carcasses; increases in undesirable species; disease outbreaks and hence signifies their importance in maintaining the balance of our ecosystem (O'Bryan *et al.*, 2018) [80].

The essence of writing this review is to describe the importance of birds in nature, how crucial they are to sustain our ecosystem by focusing on services rendered by birds and what will be the possible impact on our ecosystem after the extinction of some birds species therefore helping the public and policymakers to design the strategies for conservation of birds and their habitats along with awaring the masses about the consequences of extinction of birds to draw support for maintaining balance in our ecosystem.

Ecosystem services

The first research programme "The Millennium Ecosystem Assessment" was held in 2005 in United Nations to establish a relationship between ecosystem processes and living beings

which are classified into four categories (Dupont *et al.*, 2012) [30].

Provisioning services

Provisioning services refers to the finite, renewable, directly consumed, appropriated and traded tangible resources or goods that are provided by our ecosystem. Irrigation, drinking resources, ores resources and food provisioning are among the most important examples of provisioning services. Domesticated and wild bird species provides provisioning services where they play a crucial role in human diets like: poultry food (meat, egg) and entertainment (Moss & Bowers, 2007) [76].

Regulating services

Regulating services are services that regulate the conditions where humans live and make a living with multiple ecosystem processes resulting from the contribution of ecosystem functioning. These services include the regulation of local or global climate, of disease vectors and incidence, of pests, crop pollination, soil fertility and soil erosion. Birds foraging behavior helps in regulating ecosystem such as pest control, scavenging carcasses.

Cultural services

Cultural services are associated with non-material benefits including a range of capabilities and experiences that arise from the interaction between people and ecosystems and helps to maintain superstitious belief of human like spiritual enrichment, recreation etc. Bird watching and photography

are the famous recreational activities throughout the world and contribute to cultural services (Whelan *et al.*, 2008) [117].

Supporting services

The services include all those services that are necessary for creating suitable environment for living beings by maintaining nutritious balance, soil formation, production of oxygen in atmosphere and the maintenance of all other ecosystem services (Whelan *et al.*, 2008) [117]. Birds also provide supporting services like seed dispersal, nutrient cycling, pollination etc. (Sekercioglu, 2006; Whelan *et al.*, 2015) [105, 116].

Several bird species are found to be contributing to all the four principles associated with ecosystem services in one or the other ways by acting as mobile linker (Sekercioglu, 2006; Whelan *et al.*, 2008; Wenny *et al.*, 2011) [105, 117, 114].

Role of birds as mobile linkers

Movement of organisms is one of the major mechanisms responsible for distribution of gene, species and individual in space and time. A mobile link is defined as an organism that influences dynamics of ecosystem by connecting habitats through an active movement. The assemblage of birds connects different habitats because they actively move from one habitat to another hence are termed as mobile linker species. There are three types of mobile linker named as genetic, process and resource linker. As a mobile linker, avian fauna balances the cycles of ecosystem, resilience and memory (Gilbert, 1980; Nystrom & Folke, 2001; Lundberg & Moberg, 2003) [40, 79, 64].

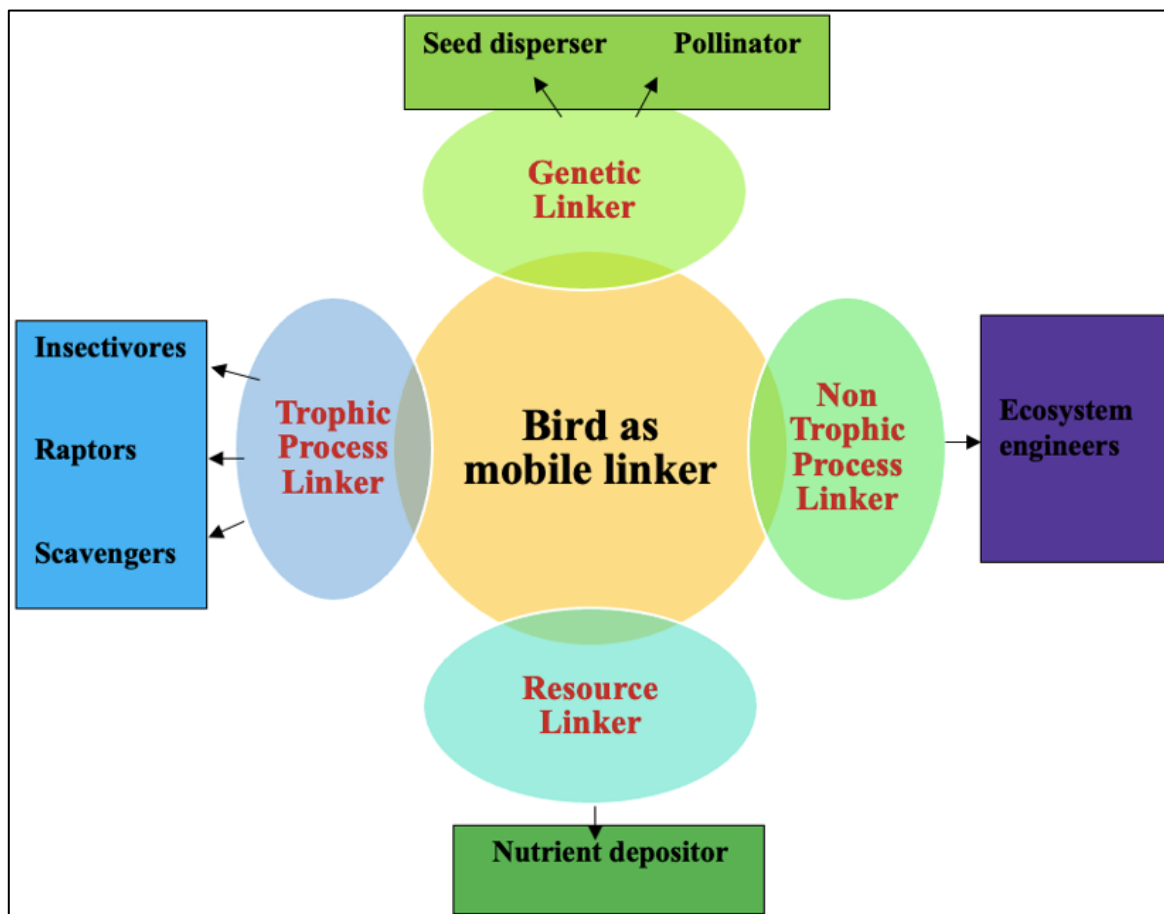


Fig 1: Services provided by birds in an ecosystem



Fig 2: Example of birds provides ecosystem services

(A), (B) Seed disperser: Yellow footed green pigeon and Indian grey hornbill are frugivorous in nature, helps in seed dispersal of many plants.

(C) Pollinator: Purple sunbird feed on nectar of flower and helps in pollination of several plant.

(D) Insectivorous: Black drongo act as bioindicator in agroecosystem and keep potent check on insect population by consuming termite, beetles, moth, spider and ants etc.

(E) Raptor: Shikra control population of birds, mammals and reptiles in agriculture.

(F) Scavenger: House crow helps in waste removal and recycling of nutrient.

(G) Ecosystem engineer: Lesser golden back woodpecker build cavities and these cavities are used by another organism.

(H), (I) Piscivorous: Pied kingfisher feeds mainly on fish but occasionally take small crustaceans, insects etc. little cormorant act as nutrient depositor helps in transfer of nutrient from one place to another. (Photo source-by Kiran research scholar of Chaudhary Charan Singh Haryana Agricultural University).

Genetic linker

Genetic linkers transport mainly 'genetic material' into a community, e.g., by transporting genes within seeds, propagules, microbiota or other organisms. Frugivorous and nectarivorous avian species helps in seed dispersal and pollination and acts as genetic linkers because they indirectly transfer genetic material from one plant to another plant (Sekercioglu, 2006) ^[105].

Seed Dispersal

Plants and birds both are dependent on each other (Gautier-Hion *et al.*, 1985; Kitamura *et al.*, 2002) ^[39, 57] as about 80000 species of angiosperms from which 25000 species are of vines, trees, lianas, woody plants and shrubs (Mahendiran &

Azeez, 2018) ^[66] are dispersed by around 48 bird families by drooping it under the parent tree and from the parent plant to the suitable environment where germination takes place (Herrera, 1984) ^[46] out of which 1/3 are frugivorous whereas around 25% of them are nearly in extinct zone and the dispersal of seeds by birds helps in reducing density dependent mortality of seeds, enables escape from herbivore, seed predator and pathogen, geographical distribution of species, gene flow and biodiversity but this is taken for granted and is not considered into co-evolution, but helps in maintaining the diversity of plants (Sekercioglu, 2006) ^[105]. In return, plants help in providing food such as the pulp of the fleshy fruit, grains, seeds etc. The seeds that pass through the Bird's gut germinate and develop sooner than the seeds developed from whole fruit (Egerer *et al.*, 2018) ^[31]. There are several reports pointing that the loss of frugivores birds may led to elimination of some plant species in some forest (Benjamin *et al.*, 2007; Gabriella & Howe, 2007) ^[10, 36]. On the contrary, the loss of fleshy fruit plants has led to local extinction of frugivorous (Bleher *et al.*, 2003; David *et al.*, 2011) ^[12, 27]. In tropical regions, large frugivorous birds distribute seeds in different areas but their role is not acknowledged by Southeast Asian countries because landscapes are degraded in those areas and number of frugivorous birds is comparatively less. The basic knowledge of seed dispersal process and role played by frugivorous is essential for conservation of endangered species (Corlett, 1998; Silva & Tabarelli, 2000) ^[22, 106]. The major factor for dispersal success can be diversity and number of frugivorous in case of plant species which are dispersed by animals, if dispersal of plant depends on different kinds of frugivorous species than loss of few species will not affect the seed dispersal where other species fulfill the role of extinct species. However, if it depends on specific frugivorous species than it may leads to seed dispersal failure (Bleher & Gaese, 2001) ^[11].

Case studies

Wenny & Levey, 1998 ^[115] studied the seed distribution pattern and seedling survival generated for 1 year by five bird species for shade loving trees. In which four species were

dispersing the seed near to parent tree with in 20 m where as the fifth species (bell bird) was dispersing the seed (>40m) far away from the parent tree. The rate of survival of seedling of fifth species was higher than other species due to fungal pathogens gaps in seedling mortality.

Large quantities of seeds and propagules of aquatic organism are consumed by migratory waterfowl, Flamingo and Coot. Due to long distance migration pattern, waders are well known for their long-distance dispersal of seeds (Figuerola & Green, 2002)^[35].

Frugivorous birds play an important role in germinating the seeds of plant species such as *Corema album*. The viability of seeds and its germination is to a large extent affected by frugivorous birds directly (through the process of ingestion) or indirectly (by dispersal of seed far away from parent tree). Gulls and blackbird have more effective germination power after ingestion of seed than pellets of rabbit. Gulls have more seed dispersal capability than blackbird and rabbit (Calvino-Cancela, 2004)^[16].

Pollination

Mobile organisms pollinate many important crops and other plant species of commercial and social importance. Birds are the most important pollinators of flowers as all over the world there are 500 plant species which are pollinated by around 900 species of birds (Sekercioglu, 2006)^[105] whereas the actual number for plant pollinator species of bird may reach around 1100 (Carstensen & Olesen, 2009)^[17] but the relationship between birds and plants has been unnoticeable for long and it can affect many endangered species of plant if this relationship is broken and some species which are very crucial for ecosystem integrity may extinct from our ecosystem (Robertson *et al.*, 1999)^[98]. In recent times, pollination by birds (ornithophily) is gaining more attention in the scientific world as birds are acting as major pollinators in those areas where insects population is very low such as dry areas, heavy rainfall and low temperature (Regan *et al.*, 2015)^[95]. Bird families like Meliphagidae (honey eaters), Trochilidae (humming bird) and Nectariniidae (sunbird) perform effective role in pollination (Cronk & Ojeda, 2008)^[24] whereas other bird family such as Zosteropidae, Drepanidini, Icteridae, Loriini and Thraupidae are also involved in pollination (Olesen & Valido, 2003; Ortega-Olivencia *et al.*, 2005; Carstensen & Olesen, 2009; Da Silva *et al.*, 2014)^[82, 83, 17, 25]. Pollinator birds are very significant for the environment beyond food production and agriculture, as they increase the genetic diversity of approx. 80% plant by increasing efficiency of reproduction in plants as in case of flowering plant that produces nectar as the flowers have characteristics such as presence of deep bright colors that helps birds to differentiate between nectar bearer and nectar less flowers which increase their feeding efficiency (Baker *et al.*, 1983; Manikandan & Cheravengat, 2016)^[4, 68], presence of corolla tube with high quantity of nectar, a good source of food for many birds and most importantly the presence of capillary system for nectar consumption that helps in easy consumption of nectar by birds whereas birds helps in return by pollinating the plant while receiving its food (Whitehead *et al.*, 2018)^[118].

Case studies

A study performed on *Pavonia bahamensis* in Bahama where pollinators such as Bahama Woodstars birds and Honeycreeper plays an important role in pollination. Where

due to hurricane the density of these birds was declined which caused reduction in fruit setting and seed formation because there is no compensatory pollinator (Rathcke, 2000)^[94].

Rodriguez & Valido, 2008^[99] reported that in Canary Islands *Isoplexis canariensis*, pollination is dependent on the birds which feed on nectar. They found that there are five species visiting the flowers named as (*Fringilla coelebs*, *Serinus canaria*, *Phylloscopus canariensis*, *Sylvia melanocephala* and *Parus caeruleus*) from the recorded observations it was concluded that fruits were lighter in weight from those areas where pollinator birds were excluded whereas in areas where birds visited, flowers and fruits were larger and heavier. Plant species *Psittacanthus schiedeana* in forests of Mexico, pollination and achievement of reproductive potential of this plant is totally dependent on the humming birds (Ramirez & Ornelas, 2010)^[93].

In New Zealand due to mammalian carnivores number of pollinating birds declined and as a result seed output and regeneration of shrub *Rhabdothamnus solandri* reduced by 84% and 55% respectively (Wenny *et al.*, 2011)^[114].

There is one plant (Loquat) in South-East China flowers in winter and for the pollination of this plant two pollinators play an important role, one is *Pycnonotus sinensis* whereas another one is *Zosterops japonicus* if we restrict these two birds for pollination then there will be drastic changes in yield of fruits and seed (Fang *et al.*, 2012)^[34].

Sunbird is frequent visitor of *Camellia petelotii* plant species. Pollination by these birds is significant because the exclusion of sunbird reduced the seed and fruit set by 64% (Sun *et al.*, 2017)^[110].

Observations by many researchers on exclusion of pollinator birds also found similar results in all the cases, so bird pollinators play very crucial role among these plants for pollination (Whitehead *et al.*, 2018)^[118].

Trophic process linkers

Process linkers engage in certain activities that provide new or accelerate existing ecological processes e.g., Predation and grazing. Primary and secondary consumers are trophic process linker links a variety of habitat. Geese plays role as grazers and predatory bird like eagles plays important role in regulation of pest and maintain the population of plants (Mols & visser, 2002; Maron *et al.*, 2006)^[74, 71]. Scavenging birds act as process linkers and helps in disposal of decomposing carcasses which may carry potential pathogens of deadly diseases (Prakash *et al.*, 2003)^[92].

Pest regulation

To increase the yields of crops, use of agrochemicals is increasing day by day on the cultivated land. These pesticides have some advantages in crop production but they have disadvantages as well. They degrade the soil fertility, kill non-target animals and increase the erosion of soil, which affects the environment. Food produced by using pesticides is not good for human health. We can regulate pest population by their natural enemies such as birds instead of using chemicals (Benayas *et al.*, 2017)^[9]. In agro ecosystem, insectivorous birds play vital role in controlling pest in fields. It was found that there was 20 to 70% reduction in biomass of invertebrates due to predation of birds in vineyards and other agroecosystem (Sekercioglu, 2006; Barbaro & Battisti, 2011; Jedlicka *et al.*, 2014)^[105, 5, 49]. They also reduce the number of herbivores which helps in decreasing the damage of leaf and mortality of plants and as a result there was 60% increase in

production of fruit and crop yield (Mols & Visser, 2002; Mantyla *et al.*, 2011; Whelan *et al.*, 2015) [74, 69, 116]. Food consumption and ingestion of bird's species basically depends on their size which defines the role of species as a controlling agent of pest (Kirk & Mineau, 1996) [56].

Insectivorous birds

Insectivorous birds consume around 500 million metric tons of prey biomass per year all over the world. As per scientific studies there are about 50% species of birds which are insectivorous and 2/3rd of them eat invertebrates (Sekercioglu, 2006; Barbaro *et al.*, 2017) [105, 6]. They mostly eat arthropods. Arthropods belong to seven orders Coleoptera, Diptera, Araneae, Orthoptera, Lepidoptera, Hymenoptera and Hemiptera are consumed frequently (Sam *et al.*, 2017) [102]. Insectivorous birds mostly consume caterpillars and beetles in forest and farming lands (Pagani-Nunez *et al.*, 2017) [85] whereas grassland bird's essential diet nutrients are grasshoppers (Joern, 1986; Bock *et al.*, 1992; Kobal *et al.*, 1998) [50, 13, 59]. In tropical areas termites are the main food source of these birds but in desert areas they mostly feed on termites, beetles and ant (Nyffeler *et al.*, 2018) [78].

Case studies

Codling moth (caterpillar) caused most of the damaged in apple orchards in Netherlands and to control them biologically Great Tit performed crucial role to eradicate them. The nest boxes were kept in orchards where Great Tit increased their population and during breeding seasons the bird start consuming caterpillars for themselves as well as for their nestlings (Mols & Visser 2007) [72]. This way these birds decreased the damage of apple fruit by consuming caterpillars of codling moth (Mols *et al.*, 2005; Simon *et al.*, 2010) [73, 107]. Birds contribute positively or negatively in apple orchards. The damage by birds in apples orchard were less than average of 1.9% whereas positive role played by birds by eating most of the insects damaging the fruits and, on an average, the damaged caused by insects was 12.8%. So, over all damaged reduced by birds to orchard growers was 10.9% (Peisley *et al.*, 2016) [89].

The role played by birds is very important in fruit production by regulating the insect pest in apple orchard. There are some pests like (*Cydia pomonella*) feed on fruit instead of leaf, they can damage the fruit crops by 90% and are very dangerous for these crops. Birds play beneficial role by limiting the population of (*Cydia pomonella*) codling moth (Mangan *et al.*, 2017) [67].

Hypothenemus hampei (Coffee berry borer) is also one of the main pests which damage the coffee crops throughout the world. Female berry borer lays egg (around 100) inside the coffee seeds, where they feed and get mature. The adults start mating with their own kind and before death they move on to next seed (Damon, 2000; Johnson *et al.*, 2010) [26, 51]. The coffee berry borer resides in seed coat so use of pesticides is ineffective and they also develop resistance rapidly against pesticides (Brun *et al.*, 1995) [14]. The birds were excluded from coffee shrubs on a coffee farm in Costa Rica during an experiment and that resulted in almost double damage due to coffee borer (Karp *et al.*, 2013) [54].

Raptors

Raptors are very unique kind of predators as they are very sensitive and easily affected by disturbances in environment. Raptors are on the top in hierarchy of predators, they play an

important role in controlling the population of rodents which are very harmful for agricultural crops and products as well as lethal for human health (Hanski *et al.*, 2001; Gilg *et al.*, 2003; Palvi *et al.*, 2010) [44, 41, 87]. Worldwide rodent plays very significant role as agricultural pest. They destroy the crop and can be the carrier of several zoonotic diseases which can affect the human health (Luna *et al.*, 2020) [63]. The presence of raptor can decrease the population of prey by creating fear on landscapes. These predators have more indirect effect on prey instead of direct as they can change the behavior of prey and stabilize the dynamics between predator and prey which led to species richness because of competition. Their fear can influence the population of species of prey by reducing the foraging activity and protection of the nest of other birds by raptors were also reported in many cases (Sekercioglu, 2006) [105].

Case studies

The nest boxes and perches placed in soyabean fields for raptors increase the population of raptors and decrease the population of house mouse. The introduction of falcons in vineyard decreased the loses in fruits approx. \$275 per hectare by pest birds in Newzealand (Wenny *et al.*, 2011; Kross *et al.*, 2012; Lindell *et al.*, 2018) [114, 61, 62].

During summer and autumn season there was more damage caused by Passeriformes in vineyards due to ripening of grapes (Somers & Morris, 2002; Tracey & Saunders, 2003; Saxton *et al.*, 2004) [109, 113, 104]. Starling, Song thrush, Blackbird and Silver eye caused excessive damage in absence of falcon but by introducing falcon to vineyards decreased the damage by birds (Kross *et al.*, 2012) [61].

Vultures contributes economically, spiritually and environmentally role in very significant manner. The decline in vulture population in Indian Sub-Continent due to various reasons has resulted increase in number of feral dogs and rats (Pain *et al.*, 2003; Markandya *et al.*, 2008) [86, 70] which act as reservoir of pathogenic diseases such as rabies and bubonic plague. As a result, chances of infection in humans and domestic animal species are very high (Markandya *et al.*, 2008; Ogada *et al.*, 2012; Donazar *et al.*, 2016) [70, 81, 29].

Scavengers

The transfer of energy between the trophic levels is the necessary process in ecosystem and energy transfer takes place when prey animals are eaten by predators. Latter provide different services like scavenging to maintain the stability of food web, they help in transfer of nutrient from one trophic level to another, carrion removal from the ecosystem because the unscavenged carrion may be the reservoirs of many pathogenic and zoonotic diseases which are harmful for humans and other organism (Inger *et al.*, 2016; Peisley *et al.*, 2017) [48, 89]. Foraging activity of scavenging birds helps in removal of waste and nutrient cycling. Scavengers stop the accumulation of toxins by removing the carcasses from the environment. Scavenger such as vulture decrease the risk of disease spread as they outcompete the host which are reservoir of diseases. Several researchers observed the out competition of stray dogs by vultures. A steep decline in population of vulture (approx. 90%) from the year 1999-2000, has been recorded in India because of diclofenac a non-steroidal anti-inflammatory drug given to cattle in inflammation and pain. It was found toxic to vulture and cause renal failure as a result the population of stray dogs increased and the cases of rabies increased

therefore (O'Bryan *et al.*, 2018)^[80].

Non-trophic process linker

Non-trophic process linker changes the physiochemical state of the environment, provide nest cavities to another organism.

Ecosystem engineer

Birds play a role as ecosystem engineer by providing habitat directly or indirectly to other organism through changing the state of resources in ecosystem (Jone *et al.*, 1994)^[52].

Nest construction

Birds construct the nest for egg laying later on these nests may be used by other organism in the ecosystem in other words bird modify the ecosystem through various activities like foraging, breeding etc. Mainly three types of nests are built by birds for breeding purposes: Burrows or excavated nest, domed and cup shaped nests. Birds construct domed shape nest which are generally made above the ground (Whelan *et al.*, 2008)^[117]. There are many other species of animal's kingdom such as insect lizards, frog, snake, wasp and beetle etc. which uses domed shape ovenbird nest for various purposes (Remsen, 2003)^[96]. In pine ecosystem cavities were created by Red cockaded Woodpeckers which are used by another organism. There are many species such as frogs, Hymenoptera, spider, moth, squirrel, skinks who uses the cavities created by Red cockaded Woodpeckers (Conner *et al.*, 1997)^[21]. In arid ecosystem bird made burrow type nest such as European bee-eater. Other bird species like sparrow uses nest of bee-eater for the living by adding some material to burrow nest. Sometimes bee eaters nest become enlarge either due to erosion or digging by other species and because of enlargement, the nests are used by large species (little owl, European roller). Reptiles, rodents, mammals, amphibian also take benefits from nest made by bee-eater (Criville & Valera, 2005)^[19]. In southern islands Albatrosses make elevated nests where they lay eggs and nurture their chicks. Many invertebrates and flightless moth lives in these nests, it provides the advantage to moth by decreasing the exposure to cold in winter and Albatrosses act as thermal engineer in these areas (Sinclair & Chown, 2006)^[108].

Resource linker

Resource linkers transport energy, organic and inorganic material, e.g., nutrients or minerals. Resource linker has role to play in replenishing nutrients in water and land. Piscivorous are one of best example of the resources linkers. They transport nutrient in their droppings and plays significant role to island ecosystem (Sekercioglu, 2006)^[105].

Nutrient cycling

Birds provide many services to our ecosystem such as transfer of nutrient and formation of the soil. But birds play very essential role in ecosystems for the movement of nutrients. They maintain the flow of nutrient in and between the surroundings of environment (Whelan *et al.*, 2008; Bauer & Hoyer, 2014)^[117, 7]. They also help in farther movement of nutrients than any other animal taxa. There is directly proportional relationship between diversity of birds and deposition of nutrients. Aquatic birds perform very important role as nutrient loader because their faeces contain nitrogen and phosphorus in large quantity. There are some activities like breeding, roosting and flocking in which they deposit nutrient on the aquatic habitats. Piscivorous birds act as an

internal loader role such as cormorant and grebes because they feed and excrete faeces at same place so the fixed nutrient will be accessible for primary production where as gulls act as external loader where they feed on terrestrial ecosystem and excrete in wetland sites at the time of breeding and resting (Hahn *et al.*, 2007)^[43]. They change the environmental conditions of the area where they breed and roost by depositing nutrients such as phosphorus and nitrogen (Otero *et al.*, 2018)^[84]. The upper layer of water column is fertilized by the droppings of birds and inorganic nutrient present in faeces which are soluble in water speed up the growth of phytoplankton whereas the organic nutrient in faeces stimulate the growth of microbes. Shallow ecosystem may be affected by aquatic birds because of excreta rich in nutrient (Petkuvienė *et al.*, 2019)^[90]. First of all, primary producers start flourishing due to flow of nutrients thereafter primary consumer will emerge and then the colonization of top predator, which will help to maintain and balance the biodiversity. The observations of an experiment performed in Gulf of California on guano birds resulted in that these birds' deposits nutrients on island where they roost and growth of vegetation in those areas was fast and very productive in nature (Deng & Yimam, 2020)^[28]. In tropical areas nutrient levels may be very low due to heavy rain, soil erosion but these aquatic birds deposit nutrients to these areas and play very crucial role in ecosystem by promoting the growth of plant communities (Rowe *et al.*, 2017)^[100].

Case studies

Experiment performed in laboratory shows that addition of the faeces of aquatic birds in sea water enhances the growth of phytoplankton. The faeces of sea birds contain mineral salt (17%) and remaining is organic material both are soluble in water which increase the photosynthetic activity and growth of phytoplankton (Bedard *et al.*, 1980)^[8].

Terrestrial habitat affected by piscivorous birds e.g., as in case of Marion Island, the main source of nitrogen is excreta of penguin. On coral islands aquatic bird's deposits around 0.6 kg of dry weight to maintain the forest ecosystem by promoting the growth of plants. In Florida bay piscivorous birds feed far away from their nest and bring food for their young ones and excrete near their nest, due to this activity sea grass near the nest increase up to 200m as compared to the grass in those regions where sea bird colonies are absent (Powell *et al.*, 1991)^[91].

Barnacle goose excretes around 100g day^{-1} faecal matter in grazing areas they deposit 0.3 droppings m^{-2} per day, soluble nitrogen is very less in wet areas so growth of plant is less but the goose excreta rich in soluble nitrogen enhance the plant productivity so goose play crucial role in plant growth in those areas where nitrogen is limited (Buij *et al.*, 2017)^[15].

Cultural services

There are many cultural services provided by birds. Among them few are most significant like bird watching, photography, identification, observation of their behavior etc. these activities are used for ecotourism worldwide. As per United States budget, 40.9 billion dollars were spent in 2011 on equipments to observe birds related activities (Carver, 2013)^[18]. Bird watching maintains the connection between living beings and nature where urbanization is increasing and positive results for conservation of many bird's species can be achieved if this connection is maintained properly (Cox & Gaston, 2016)^[23]. Interaction with nature and its beautiful

creations like birds can provide several benefits to mankind like mental, social and physical (Keniger *et al.*, 2013; Hartig *et al.*, 2014) ^[55, 45]. Most important component of nature which provides benefits to human is not understood. However, birds' interaction is always highlighted as a contributor (Kaplan, 2001; Keniger *et al.*, 2013) ^[53, 55] because they are nature's best vocalist and unique colored on earth where some people interact with them for food or to experience the closer look of nature (Cox & Gaston, 2016; Gaston *et al.*, 2018) ^[23, 38].

Environmental bioindicator

Bioindicators are the organisms which are sensitive to change in environment and also detect the contamination. Environment health is monitored by bioindicators (Saulovic *et al.*, 2016) ^[103]. Birds play important role as bioindicators because they sense the changes in ecological system by indicating the increase or decrease in number of other organism and status of nutrient (Amat & Green, 2012) ^[2]. Their population responds to the change in environment by changing in physiological and behavioural characteristics because they are subjected to fluctuations in environment where they live. Basic population rates such as birth or death rates and dispersal rate are affected by these changes. Change in primary population parameter leads to changes in secondary population parameters like population size, age structure, density, sex ratio etc. (Temple & Wiens, 1989) ^[112].

Why birds are used as bioindicators?

They are easily detectable and easy to observe by their colour, calls and diurnal activities of numerous species. By their classification, it becomes easy to identify in the fields. Their abundance, distribution, life history, ecology, biology is widely known. Birds occupy close to top of the food chain

that's why they are sensitive to disturbances at lower trophic level of food chain and contamination in the environment.

Exposure to heavy metals

Heavy metals are the necessary for organisms but they are toxic with high concentration affecting behavioral and reproductive function of an organism. Avian species accumulate high concentration of heavy metals and biomagnified via food web or chain. Birds absorb heavy metal by dermal contact, enters by inhalation or ingestion as a result creating a risk for wildlife. Bird's feces can accumulate high concentration of heavy metals then transfer of pollutants takes place through feces from one place to another because of migration (Egwumah *et al.*, 2017) ^[32]. Exposure of heavy metals to birds in ecosystem is well known international issue (Salamat *et al.*, 2014) ^[101]. Some heavy metals like lead can affect the immune and nervous system; cadmium can reduce the reproductive potential of birds. Chromium concentration can affect the mallard duck in excessive manner by decreasing growth, viability and hatching of embryo (Kler *et al.*, 2014) ^[58]. According to WHO maximum 50mg/kg of chromium is required for wild bird and above the threshold level it can be harmful for birds (Abduljaleel *et al.*, 2012) ^[1]. There are many adverse effects of mercury on birds such as decrease in fertility and weight of egg, increase in brain and kidney lesions, inadequate coordination etc. (Rezaee *et al.*, 2005) ^[97]. The death rate of birds increases with increase in pesticides. Decrease in population of birds due to use of pesticides is a sign of warning. Home range made by birds compared with the data of soil concentration and the result patterns shows the uptake and exposure of heavy metals (Colestock, 2007) ^[20].

Table 1: Bird's contributions to ecological system

Functional group	Ecological process	Ecosystem service	References
Frugivorous	Dispersal of seed	<ul style="list-style-type: none"> ▪ Maintain plant diversity. ▪ Increase flow of gene. ▪ Increase viability of seed and germination power. 	(Sekercioglu, 2006) ^[105] (Mahendiran & Azeez, 2018) ^[66] (Calvino-Cancela, 2004) ^[16]
Nectarivorous	Helps in pollination of several plants	<ul style="list-style-type: none"> ▪ Increase seed output and regeneration capacity of plant. ▪ Enhance reproductive efficiency of plant. 	(Wenny <i>et al.</i> , 2011) ^[114] (Ramirez & Ornelas, 2010) ^[93]
Insectivorous	Regulate population of invertebrates	<ul style="list-style-type: none"> ▪ Reduce the biomass of invertebrates. ▪ Reduce damage on plants and decrease the rate of mortality of plants, increase crop and fruit yield. ▪ Substitute to agrochemicals. 	(Sekercioglu, 2006; Barbaro & Battisti, 2011) ^[105, 5] (Mols & Visser, 2002; Whelan <i>et al.</i> , 2015) ^[74, 116] (Benayas <i>et al.</i> , 2017) ^[9]
Raptors	Regulate population of mammals	<ul style="list-style-type: none"> ▪ Keep potent check on population of rodents and feral dogs. ▪ Stabilize predator prey dynamics. 	(Wenny <i>et al.</i> , 2011; Pain <i>et al.</i> 2003) ^[114, 86] (Sekercioglu, 2006) ^[105]
Scavengers	Helps in waste removal	<ul style="list-style-type: none"> ▪ Maintain stability in food web by consumption of carcasses. 	(Inger <i>et al.</i> , 2016; Peisley <i>et al.</i> , 2017) ^[48, 89]
Piscivorous	Feeds on fish also on invertebrates	<ul style="list-style-type: none"> ▪ Maintenance of biodiversity, deposition of guano. ▪ Movement of nutrient between aquatic to terrestrial habitat. ▪ Enhance plant productivity and increase the growth of microbes. 	(Deng & Yimam, 2020) ^[28] (Hahn <i>et al.</i> , 2007) ^[43] (Petkuvienne <i>et al.</i> , 2019) ^[90]
Ecosystem engineer	Provide habitat to another organism	<ul style="list-style-type: none"> ▪ Environment modulator and act as thermal engineer. 	(Jone <i>et al.</i> , 1994; Sinclair & Chown, 2005) ^[52, 108]
Other species	Provide cultural services	<ul style="list-style-type: none"> ▪ Bird watching, Photography. 	(Gaston <i>et al.</i> , 2018) ^[38]
	Environmental indicator	<ul style="list-style-type: none"> ▪ Sensitive to disturbances in Environment. ▪ Indicator of abundance of an organism and nutrient status. 	(Amat & Green, 2012) ^[2]

Conclusion

Birds are essential to maintain balance in our ecosystem they play diverse role in different habitats. Dispersal of seed helps to increase diversity of plants and species richness in ecosystem. Scavenging activities by birds help to stop the spreading of various deadly diseases. Role of birds in transportation of nutrient maintain the integrity of food web by increasing the growth of primary producer which in turn attract the top predator and establish cascading effect on food web. Other services like pollination by birds increase the genetic diversity among plant and pest control service stabilize the predator prey dynamics. Cultural services increase awareness among humans and may be source of income for some people. Extinction of vulnerable bird species may imbalance the ecosystem because their ecological functions are irreplaceable. That is why long-term investigations are necessary on ecological functions performed by birds. It helps us to predict the impact of declining birds on our ecological and economical resources worldwide. Quantification of ecosystem services helps us to make better policies for the conservation birds and their habitat.

Future perspective

Birds are amazing creature of the nature that connects the world. They are truly ecological linkers of the food webs. The economic values of the birds in natural system are very prestigious and many aspects of these values also unexplored till date, requires scientific based approach to address them. So, this review paper highlights these ecological and economically parameters and values of birds which they perform to stable natural eco balance and left behind many eco approaches which need to address in future time and space.

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