The Role of Building a Community Wastewater Treatment System of The King's Royal Initiated Laem Phak Bia Environmental Research and Development Project for Species Diversity and Abundance of Birds at Ban Laem District, Phetchaburi Province, Thailand

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Abstract

The wastewater treatment system of The King's Royal Initiated Laem Phak Bia Environmental Research and Development Project (LERD Project) consists of 4 main systems: oxidation ponds, grass filtration, constructed wetland and mangrove forest filtration, before releasing treated wastewater into mangrove forest. For this reason, LERD Project has differences in conditions of area which has resulted in diversity of food sources and habitats for birds. This research aims to study role of building a wastewater treatment system of LERD Project and food factor of birds including benthic fauna and insect that effected to species diversity and density of birds by dividing study area into 4 sub-study areas including (1) oxidation ponds (2) constructed wetland (3) mudflat and (4) mangrove forest during October 2019 - February 2020. The result found that a total of 99 species belonging to 14 orders 42 families 77 genera, 53 species (53.54% of total) were resident birds and 46 species (46.46% of total) were migrant birds. The highest species diversity index (H') were found in oxidation ponds followed by mangrove forest, constructed wetland and mudflat 3.41, 3.14, 2.92 and 2.17, respectively. The highest densities were found in constructed wetland followed by mudflat, oxidation ponds and mangrove forest 0.081, 0.058, 0.011 and 0.007 birds/sq.m., respectively. In addition, different areas showed different proportions of the most bird populations, family Ardeidae for constructed wetland and mangrove forest (38.72% and 22.82% of total, respectively), family Laridae for oxidation pond and family Recurvirostridae for mudflat (49.03% of total), which related to food factor, corresponding to benthic density in mudflat 115.73±38.97 no./sq.m. and insects density in constructed wetland, oxidation ponds and mangrove forest 144.67±49.9, 111.20±22.35 and 5.73±3.22 no./sq.m., respectively. Moreover, bird population in each study area are also related to habitat and refuge needs, this is the reason why species diversity and density of birds differ in each study area.

The research shows that by-products of anthropogenic territorial changes can create man-made habitats for birds and support the birds to be able to take advantage of being both habitat, refuge and food source. Furthermore, it can also serve as a supporting area for migratory bird population during migration season and represents one of the sustainable approaches to conservation bird resources in LERD Project.

Keywords: Birds, Diversity, Density, Wastewater Treatment

1. Introduction

The King's Royal Initiated Laem Phak Bia Environmental Research and Development Project (LERD Project) is located on the coastal estuary that delineates the ecotone between the mudflats and mangrove-dominated coastline of the Inner Gulf of Thailand at the estuary bay of Phetchaburi province and the exposed sand beaches extending southwards to the peninsula. (14˚42.240'N, 06˚17.780'E) It has a total area of approximately 500 acres (Sathienpong and Kasem, 2016), north and east adjacent to the coast and natural mangrove forest, west is the salt pans and community areas and the south is located of the Phetchaburi Coastal Aquaculture Research and Development Center, Phetchaburi Province. LERD Project in the past, was a natural mangrove forest and unexploited wasteland thus become a habitat for just 3 groups of birds including forest birds, waterfowl birds and shorebirds (Prayoth,1996). After 1991, LERD Project was established due to the demands of King Bhumibol Adulyadej The Great (King Rama IX) in 1991 transforming this site to a major environmental problem the treatment of wastewater especially from Muang Phetchaburi district and solid waste through environmentally and ecologically sustainable methods (Philip and Kongthong, 2008). This area is allocated to use in the construction of a community wastewater treatment system. by creating a wastewater treatment approach that consists of 4 main systems namely (1) oxidation ponds (2) grass filtration (3) constructed wetland and (4) mangrove forest filtration (The Chaipattana Foundation, 2016). The difference about area conditions in this area arise from the establishment of LERD Project resulted in an increase in the diversity of bird habitats, including paddy fields, grasslands, freshwater ponds, mudflats, mangrove forests and saltwater ponds. These are excellent habitats, food sources and refuges for a wide variety of birds, resulting in the diversity of bird species that come to live in the project area. According to Prayoth Kanchan (1996), LERD Project found bird diversity total 57 species belonging to 11 orders 24 families 41 genera in 1995 and after 2008, found that bird diversity increase to 59 families, 142 genus and 234 species consist terrestrial birds, seabirds, shorebirds, wandering birds, waterfowls and raptors (Philip and Kongthong, 2008) wherewith bird species occurrence differs in each habitat because each bird species and bird group decide various and differ habitats depend on suitability of the environment in each habitat. (Teerapol, 2007; Nekwa et al., 2008) The structure of each habitat is not only an important factor in differentiating habitat but also affects the bird habitat selecting (Spallholz and Hoffman, 2002). Such structures include type of vegetation, community relationship, soil, temperature, humidity, rainfall and landscape change, ect. (Nekwa et al., 2008; Caprio et al., 2011; Morelli, 2013; Basnet et al., 2016) However, some birds are generalist that have low environmental specificity so they are easily adaptable. Therefore, such birds can be found in diverse habitats (Katuwal et al., 2016)

LERD Project building has the main objective for making this area primarily responsible for treating community wastewater with 4 main systems resulting in a variety of areas within the project. It consequently creates a by-product of being the habitat for various birds in more diverse area forms. Although the habitats within the project are Man-made habitats for birds, this has continued to positively affect the diversity and density of birds. So, the aim of this study was to study role of building a wastewater treatment system of LERD Project and food factor of birds including benthic fauna and insect that effected to species diversity and density of birds during October 2019 - February 2020 in 4 areas where related with types of wastewater treatment including (1) oxidation ponds (2) constructed wetland (3) mudflat and (4) mangrove forest.

2. Material and methods

2.1 Study area

The study area is located in the Laem Phak Bia Environmental Research and Development Project, Phetchaburi Province, Thailand. It has total area of approximately 450 acres and located at 14˚42.240'North to 14˚43.480'North 06˚17.780'East to 06˚19.271' East. (Sathienpong and Kasem, 2016) (Figure 1) It has a total study area of approximately 95 acres, consists of the following 4 sub-study areas including Oxidation ponds, Constructed wetland, Mangrove forest and Mudflat in front of the mangrove forest. (Figure 2)

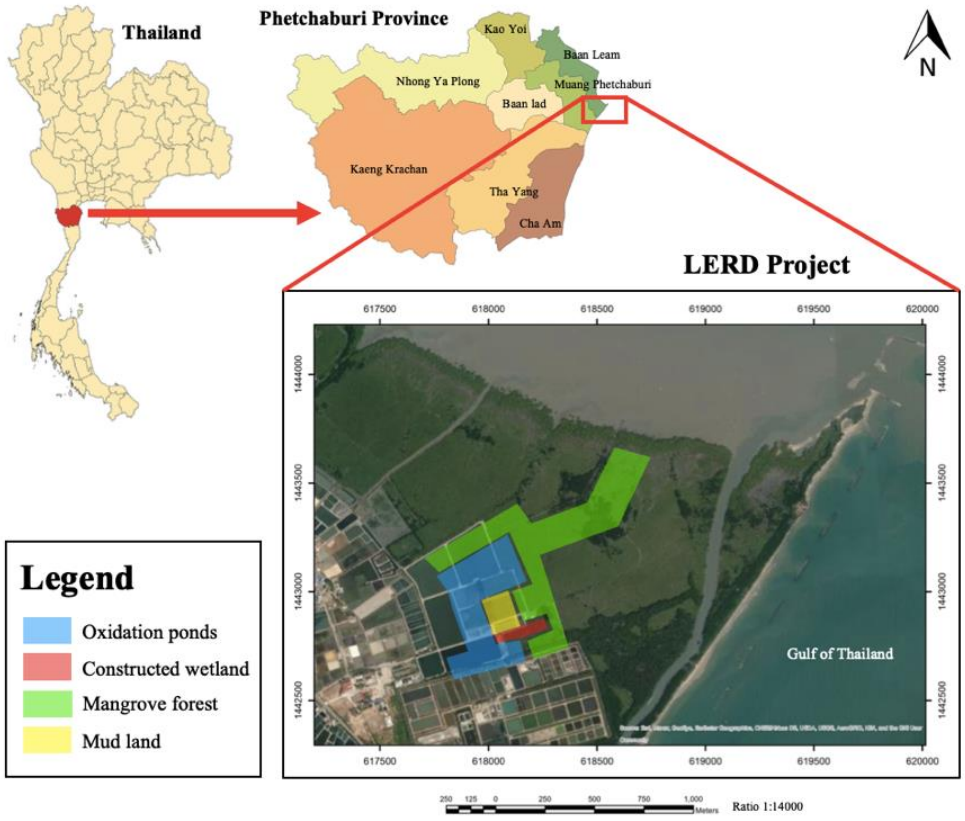

Figure 1. The Location of study area at LERD project, Phetchaburi Province, Thailand

2.2 Species diversity and density of birds

Birds were identified in the field with 3 bird guide books, Bird guide in Thailand (Jarujin et al., 2012), Birds of Laem Phak Bia (Philip and Kongthong, 2008) and A Field Guide to the Birds of the South-East Asia (Robson, 2000). We identified and counted the species richness of birds by following line transects and point counts around the study area and using direct method including visual detection, song identification and other signs identification. 10x42mm Binoculars and 20-60x80mm Spotting scope were used for surveys once a month during October 2019 - February 2020. Bird diversity surveys were conducted at two times at a time, morning 06.00-09.30 A.M. and afternoon 03.30-06.00 P.M. (Barraclough, 2000; Gregory, Gibbons and Donald., 2004).

Figure 2. The conditions of the study area were Oxidation ponds (A) Constructed wetland (B) Mudflat (C) and Mangrove forest (D)

2.3 Benthic fauna and Insect

We collected benthic fauna samples at mudflat and insect samples at oxidation ponds, constructed wetlands and mangrove forest to study the diversity and density of these organism that is food factors of birds found in each study area and see how exuberant they are.

(1) Benthic fauna: Representative benthic fauna samples were randomly chosen three points at the mudflat. After systematic random sampling, the samples were collected in depth of 30-40 cm as a composite sample by using soil core samplers with a diameter of 8 inches. Firstly, stones and other foreign materials were removed from the soil samples then sieved to pass through 2.00, 1.00 and 0.45 mm sieve, respectively before use as the experiment. After sieving, labelled and taken to laboratory for analysis by fixed with 7.0% formaldehyde solution. (APPHA, AWWA and WEF, 2005)

(2) Insect: For soil and leaf litter insect, pitfall trap is used to collect insect samples at the oxidation ponds and constructed wetlands by bringing a plastic cup with a diameter of 40 mm. and height of 50 mm. filled with 5% unscented liquid soap and buried in the soil so that the top edge of the cup is equal to soil surface. Pitfall traps were placed 3 random traps in each study area for 24 hr. from 6:00 AM to 6:00 AM the next day. Then the trapped insects were washed 1-2 times and stored in 95% ethyl alcohol for identification (Sanit, 2004). For flying insect, sweep net is used to collect insects in oxidation ponds, constructed wetlands and mangrove forest. Samples were collected at 3 study area at random, each for 5-10 minutes. After that the insects were euthanized in killing jar by ethyl acetate and stored in 95% ethyl alcohol pending identification in a biological laboratory (Sanit, 2004; 2nd Forest Entomology Research Center, n.d.). Insect samples identification key written by Charles et al (2005) was used to identify the collected specimens to the family level.

2.4 Data analysis

In this study, all bird data collected were subjected to summary statistics including mean and standard deviations (S.D.) of the encountered species and also calculated species richness as the summed individual species presence. Species diversity analysis using Shannon diversity index (H'), have been defined as (1) (Magurran, 1991). Benthic species and insects were identified and grouped and densities per area were calculated to determine the relationship between species diversity and density of bird with food factors.

$$H' = -\sum_{i=1}^{n} Pi \ln Pi \quad (1)$$

when n = total number of all birds irrespective of species (specie richness)
Pi = proportion of number of birds of species *i* to total number of all birds

3. Results and discussions

3.1 Bird Habitats in LERD Project

(1) Oxidation ponds: This area consisting of 5 ponds including (1) sedimentation ponds (2) 1st oxidation pond (3) 2nd oxidation pond (4) 3rd oxidation pond and (5) pre-treatment pond with 42 acres. Each treatment pond has an overflow drainage facility or spillway (Figure 2A) to pass wastewater to next treatment pond before being released to LERD Project's mangrove forest. In addition, there is wood wave barriers around each pond, which serve as resting points, sunbathing spots and ambush point for wandering birds, waterfowls and terrestrial birds etc. Moreover, Presently, community wastewater from Phetchaburi municipality is pumped to treat an average of 6,167 cubic m./day with a flow rate of 303.15 cubic m./hr. and flows into the treatment pond 268.55 cubic m./hr. (Satreethai et al, 2013; Chunkao, et al, 2014; Sathienpong and Kasem, 2016).

The oxidation ponds use the concepts of organic matter that is dissolved by the oxygen-degrading organic process of microorganisms living in wastewater. These organic matters in wastewater is then converted into inorganic or nutrient as small green seaweed or phytoplankton absorbs the nutrients, thus releasing more oxygen through the process of photosynthesis, while the other oxygen addition process is achieved by the natural-based mechanism of atmospheric winds that infiltrate oxygen in surface into the wastewater within the pond. (Jinjaruk, 2014; Sateinpong and Kasem, 2017) Wastewater treatment ponds must control the number of phytoplankton by raising herbivorous fish at a ratio of 4 fish/sq.m. of water surface area (Supim and Jarawee, 2000; Narouchit and Kasem, 2003; Wit et al, 2002), fish that raised in the treated ponds such as Nile tilapia (*Oreochromis niloticus*), Rohu (*Labeo rohita*) and Java barb (*Barbodes gonionotus*) and fish be caught out from the system every 6 months (Office of Royal Development Projects Board, 2009).

(2) Constructed wetland: The area has 2.0 acres comprising 5 plots of grass filtering wastewater and 6 plots of artificial wetlands, each plot size 6.0 x 100.0 and 6.0 x 25.0 sq.m., respectively. Herbaceous plants such as Priprioca (*Cyperus corymbosus* Rottb.), Narrow-leaf Cat Tail (*Typha angustifolia* Linn.), Stargrass (*Cynodon plectostachyus*) and Indian shot (*Canna indica*) are planted here to treat wastewater (Chantana et al, 2000) (Figure 2B). It is a system that uses the principle of allowing wastewater to remain in the water plant plot at a height of 30 cm. from the plot floor. The wastewater has a detention period of at least 1 day. The new wastewater is added to the system to a level of 30 cm., which is equal to the amount of wastewater lost by the evaporation process each day. After about 90 and 45 days of Narrow-leaf Cat Tail and other

growth, respectively, the plant will be cut off to maintain efficiency. These plants are often used for pulp and green fuel but basketry as well. (Office of Royal Development Projects Board, 2009). Besides, this area present compelling evidence of the continued existence of the Large-billed reed warbler (*Acrocephalus orinus*), hitherto known only from the unique type specimen collected in North-Western, India 139 years ago (Bensch and Pearson, 2002). An unusual *Acrocephalus* warbler were caught by mist-nets in Constructed wetland on 27 March 2006 and it is a first time in Thailand and second time in the world after 139 years without any other records (Philip et al, 2007; Philip and Kongthong, 2008).

(3) Mangrove forest: The mangrove forest in front of the LERD project has a long line of mangrove forest adjacent to the sea for approximately 45.0 acres, with a forest width of approximately 920 meters (Oratai, 2012; Rekha et al., 2018), which is an area for accommodating effluents from the wastewater treatment system at an average volume of 6,000 cubic m/day (Jinjaruk, 2014; Satienpong, 2020). It is densely populated with Grey mangrove (*Avicennia marina*) as a dominant species (Oratai, 2012) and also with Loop-root mangrove (*Rhizophora mucronata*), Tall-stilt mangrove (*R. apiculata*), Indian mangrove (*A. marina*) and Api api putih (*A. alba*) (Prathan, 2005; Jinjaruk, 2014; Pussadee et al, 2015). The average tree density was 3,225.97 trees/ha. with the average height was 5.08 m. (Pussadee et al, 2015) It is an area to support treated wastewater from a pre-treatment pond before discharging into the sea. In addition, there are mangrove forest natural trails stretching for more than 860 meters to the coastal beach (Figure 2D) and there is a natural pathway pavilion as a viewpoint located at the end of trail.

(4) Mudflat: It has an area of 2.5 acre and bordered by 1st, 2nd, 3rd oxidation ponds and mangrove forest. It is an open area that is influenced by the rise and fall of sea water during the day. It is an area to support the treated wastewater to flow through before going to the mangrove forest. and continue to flow out into the sea. Therefore, this area has both flooding and low tide times and muddy (Figure 2C) thus wandering bird and shore bird populations that choose to feed on benthic fauna are regularly found here in dense for being food sources and roosting site.

3.2 Insects and Benthic fauna diversity

(1) Benthic fauna: The diversity of benthic fauna was found a total of 21 Species belonging to 18 Families 9 Orders 3 Phylum. Mudflats had mean benthic densities of 115.73±38.98 no./sq.m. The month with the highest density of benthic species was December (Narouchit, 2019; Somthawin et al.,1990). However, the amount and density of benthic fauna varies widely throughout the year depending on the tides, topography and environmental factors in each area (Manop, 1985). The study found that the dominant benthic species was *Cerithidea* sp. (32.32% of total) that classified in family Potamididae, phylum Mollusca followed by *Ablabesmyia* sp., (25.96 % of total) classified in family Chironomidae, phylum Arthropoda (Narouchit, 2019) because these are often found abundantly in areas with high organic matter and it is tolerant of low oxygen condition and also found in a wide variety of areas both in mudflat, sandy beach, seafloor zone and can be found in both brackish and sea water (Phumin, 2014; Rouse and Pleijel, 2001).
(2) Insect: Collecting a variety of insect specimens found both Insect class, Spider class and Millipede class as well. Soil and leaf litter insects were found by using sweeping nets a total 20 families from 7 orders 2 classes, the family that found the highest proportion was Familly Cicadellidae (Leafhoppers) (31.32% of total) while Flying insects by using pitfall traps were found a total 17 families from 7 orders 6 classes, which Family Formicidae (Ants) is the most

proportion (72.26% of total). Constructed wetlands found the most average insect population at 144.67±90.95 no./sq.m., while the number of oxidation ponds was 111.20±72.35 no./sq.m and the lowest average insect population was 5.73±3.22 no./sq.m. in mangrove forest. Most of the insects found in each area were different in term of family, Cicadellidae (31.56% of total) for constructed wetlands, Culicidae (Mosquitoes) (21.82% of total) for oxidation ponds and Formicidae (56.98% of total) for mangrove forests. It is the result of the structure and internal composition of each area are different so the environment and abundance of food sources are different as well, together with the temperature and humidity (Natawut, 2014), all affected to the species diversity and species richness that found because these factors affect to the behaviour and ecology such as reproduction, metamorphosis and foraging of insects (Ponphan, 2011).

3.3 Species diversity and density of birds

A survey of bird diversity in 4 different habitats which include (1) Oxidation ponds (2) Constructed wetland (3) Mudflat and (4) Mangrove forest at LERD Project, Phetchaburi Province between October 2019 and February 2020 found a total of 99 species belonging to 14 orders 42 families 77 genera, 53 species were resident birds (53.54% of total) and 46 species were migrant birds (46.46% of total). We found the highest species in Family Scolopacidae (Sandpipers, Curlews, and Snipes) 12 species followed by Family Ardeidae (Herons and Egrets) 11 species that the dominant species is Javan Pond Heron (*Ardeola speciosa*) (12.43% of total) (Prayoth, 1996) followed by Black-winged Stilt (*Himantopus himantopus*) (11.30% of total) and Whiskered Tern (*Chlidonias hybrida*) (6.98% of total). This study found more bird diversity than Prayoth (1996) that study the bird diversity study between June 1994 to May 1995 around LERD Project, which found a total 57 species belonging to 11 orders 24 families 41 genera and four bird groups: Waterfowls, Wandering birds, Seabirds and Shorebirds, while this study found an additional 42 species and more Terrestrial birds and Raptors in LERD Project.

In terms of species richness, the oxidation ponds showed the highest level at 72 species followed by constructed wetlands and mangrove forests 65 and 46 species, respectively, while the lowest level was Mudflat at 37 species (Figure 3). Meanwhile the highest species diversity index (H') were found in oxidation ponds followed by mangrove forest, constructed wetland and mudflat 3.41, 3.14, 2.92 and 2.17, respectively (Figure 3). The highest densities were found in constructed wetland followed by mudflat, oxidation ponds and mangrove forest 0.081, 0.058, 0.011 and 0.007 birds/sq.m., respectively. The result showed that different species diversity and densities of birds in each study area. In addition, different areas showed different proportions of the most bird populations, family Ardeidae (Herons, Egrets, and Bitterns) for constructed wetland and mangrove forest (38.72% and 22.82% of total, respectively), family Laridae (Gulls and Terns) for oxidation pond and family Recurvirostridae (Stilts and Avocets) for mudflat (49.03% of total), which related to food factor, corresponding to benthic fauna density in mudflat 115.73±38.97 no./sq.m. and insects density in constructed wetland, oxidation ponds and mangrove forest 144.67±49.9, 111.20±22.35 and 5.73±3.22 no./sq.m., respectively.

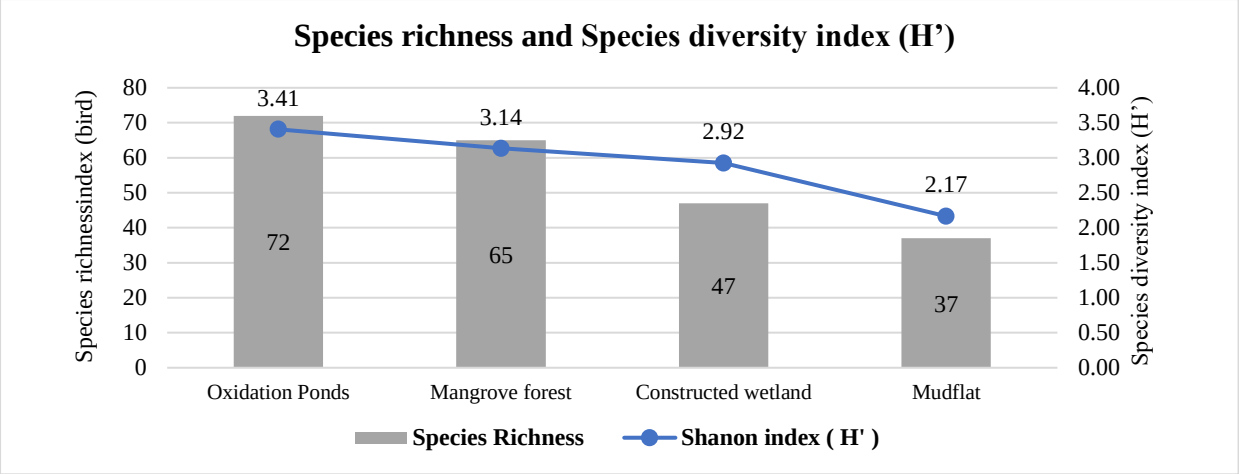

Figure 3. Species richness and Species diversity index (H') of birds in each study area

Being the large five freshwater sources of oxidation ponds provide habitats for all bird group. Birds were found at Oxidation ponds a total 72 species belonging to 35 families 13 orders both Waterfowls, Wandering birds, Seabirds, Shorebirds and Raptors. Dominant species is Whiskered Tern (*Chlidonias hybrida*) (17.09 % of total) followed by Javan Pond Heron (*A. speciosa*) (9.65% of total). Spot-billed Pelican (*Pelecanus philippensis*) and Oriental Darter (*Anhinga melanogaster*) which is classified as Near Threatened (NT) (IUCN, 2020) were found only in this study area. Inclusive of these birds and waterfowls comprise Little Grebe (*Tachybaptus ruficollis*), Little Cormorant (*Microcarbo niger*) and Indian Cormorant (Phalacrocorax fuscicollis) were found here not only because they get most of their total feed requirements from the pond in form of fish, aquatic weeds, insects, earthworms, etc. but these waterfowls also used the water to clean out their body and they need to keep their mucous membranes moist so having clean water available at all times is really important (British Waterfowl Association Constitution, 2020). In addition, Oxidation pond are fed herbivorous fish consist Nile tilapia (*O. niloticus*), Rohu (*L. rohita*) and Java barb (*B. gonionotus*) at a ratio of 4 fish/sq.m. of water surface area (Supim and Jarawee, 2000; Wit et al, 2002; Narouchit and Kasem, 2003) which were a food source for Raptor such as Brahminy Kite (*Haliastur indus*), Sea birds such as Brown-headed Gull (*Chroicocephalus brunnicephalus*), Common Tern (*Sterna hirundo*) and Whiskered Tern (*C. hybrida*) and Wandering birds such as Javan Pond Heron (*A. speciosa*) and Little Egret (Egretta garzetta). These include Common Kingfisher (*Alcedo atthis*) and Collared Kingfisher (*Todiramphus chloris*). Most of all these birds perch on spillway and wood wave barriers around each pond, which serve as resting points, sunbathing spots and ambush point.

Constructed wetland, birds were found at constructed wetland a total 47 species belonging to 25 families 8 orders. Dominant species is Javan Pond Heron (*A. speciosa*) (25.52% of total) followed by Black-winged Stilt (*H. himantopus*) (10.24% of total). Herbaceous plants such as Priprioca (*C. corymbosus* Rottb.), Narrow-leaf Cat Tail (*T. angustifolia* Linn.) and Indian shot (*C. indica*) are planted here. Therefore, besides wandering birds, also found insectivorous and granivorous birds such as Oriental Reed Warbler (*Acrocephalus orientalis*), Scaly-breasted Munia (*Lonchura punctulata*) and Plain Prinia (*Prinia inornata*). Wherewith to insectivorous birds are likely to be influenced by habitat characteristics also indirectly via arthropods living and feeding on the foliage, and representing food resources for these birds (Ghosh-Harir and Price, 2014; Tvardikova, 2013) especially warbler (Ghosh-Harir and Price, 2014). We also

found that there are two species of birds that can only be found in this area is Greater Painted-snipe (*Rostratula benghalensis*) and Black-browed Reed Warbler (*A. bistrigiceps*). More precisely, Nectarivorous birds such as Olive-backed sunbird (*Cinnyris jugularis*) and Brown-throated sunbird (*Anthreptes malacensis*) were also found here because Indian shot (*Canna indica*) are planted here to treat wastewater (Chantana et al, 2000). The result showed that forest and habitat structure significantly influence habitat selection of many bird species, and tree basal area are usually among the significantly important variables (Boves et al., 2013; Tvardikova, 2013). Moreover, the area adjacent to mangrove forests and oxidation ponds, Golden-bellied Gerygone (*Gerygone sulphurea*), Eurasian Tree Sparrow (*Passer montanus*), Javan Pond Heron (*A. speciosa*) and Little Egret (*E. garzetta*) were found in this area as well as in the two study areas mentioned.

Mangrove forest where is densely populated with Loop-root mangrove (*R. mucronata*) and Tall-stilt mangrove (*R. apiculata*) found a total 65 species belonging to 33 families 12 orders. Dominant species is Golden-bellied Gerygone (*Gerygone sulphurea*) (17.71% of total) followed by Malaysian Pied Fantail (*Rhipidura javanica*) (10.44% of total). Meanwhile, Mangrove Whistler (*Pachycephala cinerea*) and Eastern Crowned Leaf Warbler (*Phylloscopus coronatus*) were specially found only in this area. Due to the fact that this area is bordered by oxidation ponds. As a result, wandering birds are found in this area as well, such as Javan Pond Heron (*A. speciosa*), Little Egret (*E. garzetta*) and Black-crowned Night Heron (*Nycticorax nycticorax*). Also, Painted Stork (*Mycteria leucocephala*), which is classified as Near Threatened (NT), also perched on and inhabited in the mangrove forest. While mudflat where is muddy and rich in benthic fauna thus wandering and shore bird populations choose to feed here and regularly found here in dense. Birds were found at mudflat a total 37 species belonging to 15 families 5 orders. Dominant species is Black-winged Stilt (*H. himantopus*) (49.02% of total) followed by Marsh Sandpiper (*Tringa stagnatilis*) (5.42% of total). Also found Red-wattled Lapwing (*Vanellus indicus*) and Long-toed Stint (*Calidris subminuta*). During the same time, Lesser Sand Plover (*Charadrius mongolus*), Ruff (*C. pugnax*), Temminck's Stint (*C. temminckii*) and Common Greenshank (*T. nebularia*) as well as Curlew Sandpiper (*C. ferruginea*) and Red-necked Stint (*C. ruficollis*) which is classified as Near Threatened (NT) (IUCN, 2020) were found only in this study area. This shows that the area is important for the existence of many shore bird populations. However, the species diversity and species richness of shore bird vary accordingly and depends on internal habitat characteristics that benefit those shore birds as well. (Sripanomyom et al., 2011; Thanaphat et al., 2018)

The internal structures in each area that facilitate the use of different bird groups. Oxidation ponds have 5 large freshwater ponds with wave barriers and spillway in each pond along with fish, insect in soil/leaf litter, flying insect as a food source therefore support the waterfowls, wandering birds, seabirds and raptors. Constructed wetland is waterlogging at a level that supports wandering birds and there are grasses and herbaceous plants that are tall and overgrown so terrestrial and wandering birds generally found here while Mangrove forest found terrestrial and wandering birds as same as Constructed wetland but internal structures different, there are dense mangrove trees so the branches and leaves are densely covered to support terrestrial and Wandering birds for perching on and inhabit. Finally, there is muddy soil that has been influenced by the rise and fall of sea water and abound with benthic fauna in Mudflat so shore birds and wandering birds are mostly found in this area.

Table 1. The internal structures involved to promotion the area utilization of each group of birds
in 4 study area.

Study area	The internal structures	Bird group
1) Oxidation ponds	Habitat structure: There are 5 large freshwater ponds with wave barriers and spillway in each pond. Food source: Fish, Insect in soil/leaf litter, Flying insect	Wandering birds, Waterfowls, Seabirds, Raptors
2) Constructed wetland	Habitat structure: There is waterlogging at a level that supports wandering birds and there are grasses and herbaceous plants that are tall and overgrown. Food source: Insect in soil/leaf litter, Flying insect	Terrestrial birds, Wandering birds
3) Mangrove forest	Habitat structure: There are dense mangrove trees. Therefore, the branches and leaves are densely covered. Food source: Flying insect, Benthic fauna, Small aquatic animals	Terrestrial birds, Wandering birds
4) Mudflat	Habitat structure: There is muddy soil that has been influenced by the rise and fall of sea water. Food source: Benthic fauna, Small aquatic animals	Shore birds, Wandering birds

All result show that the species richness, feeding guild and species composition of bird communities differed in 4 different study areas because changes in land use and land cover have affected and will continue to affect biological diversity worldwide (Sala 2000; Jetz et al. 2007) and the major reason for this is the association of specific types and group of birds with particular types of habitats due to the availability of food and shelter (Basnet et al., 2016). Species such as Mangrove Whistler (*P. cinerea*) and Eastern Crowned Leaf Warbler (*P. coronatus*) restricted to the Mangrove forest while Curlew Sandpiper (*C. ferruginea*) and Red-necked Stint (*C. ruficollis*) restricted to the Mudflat. According to Donald et al., (2001) found that different areas result in different types of food so the area has different plant species and characteristic resulting in different species diversity, density and abundance of birds (Morelli, 2013; Ding et al., 2019). Furthermore, the community composition of birds varies with the habitat types and their feeding specialization is one of the major determinants (Pandey et al.,2021). Thus, the habitat specificity and bird feeding are the major reason for association of the bird communities in LERD Project with different environmental variables.

4. Conclusion

The result during October 2019 - February 2020 in 4 areas where related with types of wastewater treatment including (1) oxidation ponds (2) constructed wetland (3) mudflat and (4) mangrove forest found that a total of 14 orders, 43 families and 99 species, 53 species (53.54% of total) were resident birds and 46 species (46.46% of total) were migrant birds. The highest species diversity index (*H'*) were found in oxidation ponds followed by mangrove forest, constructed wetland and mudflat 3.41, 3.19, 2.92 and 2.17, respectively. The highest densities were found in constructed wetland followed by mudflat, oxidation ponds and mangrove forest 0.081, 0.058, 0.011 and 0.007 birds/sq.m., respectively. In addition, different areas showed different proportions of the most bird populations which related to the food factor, corresponding to benthic density in mudflat and insect density in constructed wetland, oxidation ponds and mangrove forest. Moreover, bird population in each study area are also related to habitat and refuge needs, this is the reason why species diversity and density of birds differ in each study area. This research also shows that man-made structures has a relationship with a group of birds found in each area because the structure affects bird accessibility of the

area for many purposes, such as habitat, resting point, nest building and a food source, etc. The different bird needs make the data available in population surveys differ in species, diversity and population, it shows that by-products of anthropogenic territorial changes can create man-made habitats for birds and support habitat for various birds. Moreover, it can serve as a supporting area for migratory bird population during migration season and represents one of the sustainable approaches to conservation bird resources in LERD Project.

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