Population Dynamics of Waterbirds in Wastewater Lagoons in Njoro, Kenya

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Abstract

Waterbirds were studied in a series of three wastewater lagoons located at Egerton University, Njoro Division, Kenya, to elucidate their spatio-temporal population dynamics. The sacred ibis and the yellow-billed ducks were most abundant in the lagoon with raw unprocessed sewage (WLI). The population of yellow-billed ducks in WLI differed significantly from the populations in the middle lagoon (WLII) and in the last lagoon (WLIII) before the 'processed water' was discharged into the Njoro River. Post-hoc analysis using Bonferroni multiple range test ($\alpha = 0.05$) indicated that WLI had the highest populations of yellow-billed ducks, sacred ibis and the Egyptian geese. The group sizes of the Egyptian geese in WLI were between 6-10 individuals. The diurnal distribution of the bird populations in the three lagoons did not define distinct patterns although the population of red-billed teals in WLI showed a peak increase at around 1200 h. The observed fluctuations of the populations within very short temporal periods indicated that the birds were not flying far from their habitat. They were returning to the lagoons within 2-4 hours. The highest number of birds was counted between 1200 and 1400 h, 0800 and 1000 h and, 1200 and 1400 h, in WLI, II and III, respectively. *Chironomus gr. plumosus* (Chironomidae) dominated the macroinvertebrate assemblages in the wastewater and could be food for the waterbirds. Total body lengths of the chironomids in all the three lagoons were similar. The size structures portrayed by the invertebrates in the three lagoons raised questions on food selectivity by the birds and/or survival strategies by the invertebrates themselves. The current data indicate that bird populations could be used to determine roughly the health of wastewater lagoons. The value of wastewater lagoons as small-sized bird sites needs full recognition.

Key words: Avidiversity, group sizes, ground counts, invertebrates, wastewater lagoons, Kenya

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Introduction

Stochastic behaviour and spatial heterogeneity have been of great concern in modern ecological theory (Bolker et al., 1997). Furthermore, there has also been a marked resurgence of interest in biological diversity in recent years. Kenya has about 1089 species of avifauna and has set up key bird sites, i.e. Important Bird Areas (IBAs) under the IBA programme in order to conserve her avifauna and biodiversity. Birds are widespread and diverse and are an important focus for conservation attention in their own right (Fanshawe and Bennun, 1991). They play major roles in the functioning of many ecosystems and are also an important source of revenue through birdwatching tourism and sport hunting (Bennun and Njoroge, 1999). Waterbirds can further be used as indicators of the health of hydrosystems (Kingsford, 1999) and also as indicators of the efficiency of sewage treatment plants (personal observation).

Most of the wetlands under the IBA programme are large-sized (e.g. creeks, estuaries, papyrus swamps, etc.) and the small-sized (<1.0 km^2) ones have been largely ignored. Wastewater lagoons are widespread in all major towns and could serve as homes of unique 'sewage' bird communities. Wastewater lagoons cannot fit into the definition and category of the 'congregations' of the IBAs. 'Congregation' is a site known or thought to hold, on a regular basis, equal or greater percentage of a biogeographic population of a congregatory waterbird species (Bennun and Njoroge, 1999). Nevertheless, if the assertion by Bennun and Njoroge (op.cit.) that there are no fixed size maxima or minima for IBAs is acceptable, then the current spatial scale of IBAs from 1 to 10 million ha should be reviewed to include those less than 1 ha. Small-sized wastewater lagoons provide an opportunity to census all the birds within and in their vicinity unlike the survey of waterbirds in floodplains whose survey estimates have been questioned because bias is unknown (Johnson, 1989).

The principal aim of sewage treatment is for the final effluent to attain stipulated standards before being discharged into streams. These standards are largely ignored in the developing countries. Consequently, the effluent discharged into streams is of very poor quality thus questioning the functionality of the lagoons. The quality as well as the efficiency of the wastewater lagoons could be assessed using the diversity of the microfauna and the levels of chemical elements. In addition, the presence of macrofauna such as waterbird communities could also be used in assessing the efficiency of wastewater lagoons in processing the effluent and hence their health. Therefore, one obvious measurable component of the health of wastewater lagoons is the dynamics of the waterbird community, which forms an important part of the biological community.

A wide range of waterbird species feed on aquatic macroinvertebrates, plants, fish and frogs and their distribution in the lagoons may be a useful index to the concentration and availability of the birds' food. Composition of bird species in a particular lagoon could also be a measure of the abundance and preference of a certain food present in the lagoon. Similarly, bird species that are primarily herbivorous, for instance, yellow-billed ducks (*Anas undalata undalata*), could be indicators of the presence of aquatic macrophytes in the lagoons.

The ability to effectively count all the waterbird species simultaneously allows observers the flexibility of detecting changes to the suite of species temporally and spatially. Ground counting is often believed to be accurate and without error (Kingsford, 1999) although its precision is usually unknown (Heusmann, 1990). The Egerton University wastewater lagoons were ideal for ground counts because of their small size and lack of macrophytes that could obstruct the observers. Much imprecision in ground counts could be attributed to daily variability, birds obscuring each other, birds missed while diving, glare of the water and the haze and possibly observer fatigue (Kingsford, 1999). Nevertheless, the results of the ground counts may be applied in the management of the wastewater lagoons and improving their efficiency and also raising awareness locally and nationally on the importance of these small-sized lagoons as bird congregation sites. The objective of this study was therefore to elucidate the temporal and spatial population dynamics of the birds associated with three serial wastewater lagoons located within Egerton University, Kenya. Other secondary objectives were to examine the health status of the lagoons using the counts of birds as indicators and to assess the abundance of wastewater invertebrates that could be possible food for the waterbirds.

Materials and Methods

Characteristics of the Wastewater Lagoons

Three study lagoons in a series (Fig. 1) were chosen for this study and were designated as follows: raw sewage lagoon (WLI), middle lagoon (WLII) and, last lagoon before the 'processed water' is discharged into the Njoro River (WLIII). Their surface length*width dimensions are 150*75, 90*45 and 90*45 metres, respectively, and are bounded by gently sloping concrete embankments. Water quality, the microflora and fauna are expected to change as wastewater progresses through the lagoons. The treatment is entirely natural and is considered environmentally friendly. WLII and III are 6.5 and 13.5 metres from WLI, respectively. WLIII is 450 metres from the Njoro River into which the 'processed water' is discharged. WLI receives fresh effluent from the Egerton University community of not less than 10,000 people. Grasses formed the main growth forms around these lagoons. All trees were cleared to leave the lagoons exposed to direct sunlight.

Submerged and emergent macrophytes were absent in the lagoons and therefore no obstruction of the waterbirds during the censuses. WLIII had a leakage at the bottom and therefore had little wastewater retained in comparison with the other two lagoons. The lagoons were chosen for this study because of their small size, their bird populations which were easily censused without a possibility of double counts and, their proximity to the observers' working laboratories. Their unique bird community distinct from the surrounding environment also provided a further incentive for choosing the lagoons for this study. Efforts were made to minimize disturbance and biased counts during the census occasions.

Determination of Physical and Chemical Variables

Wastewater temperature and pH were recorded using a multimeter (model WFW-pH91) whilst dissolved oxygen was measured with an OX192 oxygen meter. Conductivity was measured with a WFW-LF90 conductivity meter. The total suspended solids (TSS) were determined by filtering 100 ml of the wastewater through a pre-weighed 0.45 µM Ederol BM/C glass fibre filters. The filters together with the attached remains were dried at 105ºC until a constant weight was achieved. The total suspended solids (TSS) in the wastewater was calculated thus: TSS (parts per million) = $((WC - W1)/V)*10^6$, where W1 is the weight of precombusted filters in grams, WC the constant weight of filters plus residue in grams and V volume of wastewater sample filtered in ml. Nitrate-nitrogen, ammonia-nitrogen, total phosphorus and soluble reactive phosphorus (SRP) in the wastewater were analysed using standard methods (APHA, 1995).

Estimation of Invertebrates in the Wastewater

It was speculated that the birds were feeding on invertebrates in the wastewater. In order to estimate the potential food of the birds, the invertebrates were sampled using a sweepnet (mesh-size: 100 µm) and their abundance determined. The samples were sieved through a series of sieves (100 – 1000 µm mesh-size) to separate them into different size spectra. The total body lengths of the Chironomidae, mostly *Chironomus gr. plumosus*, were measured using a stereomicroscope with a scale. This involved measuring the organisms from the farthest anterior tip to the most posterior tip of the body.

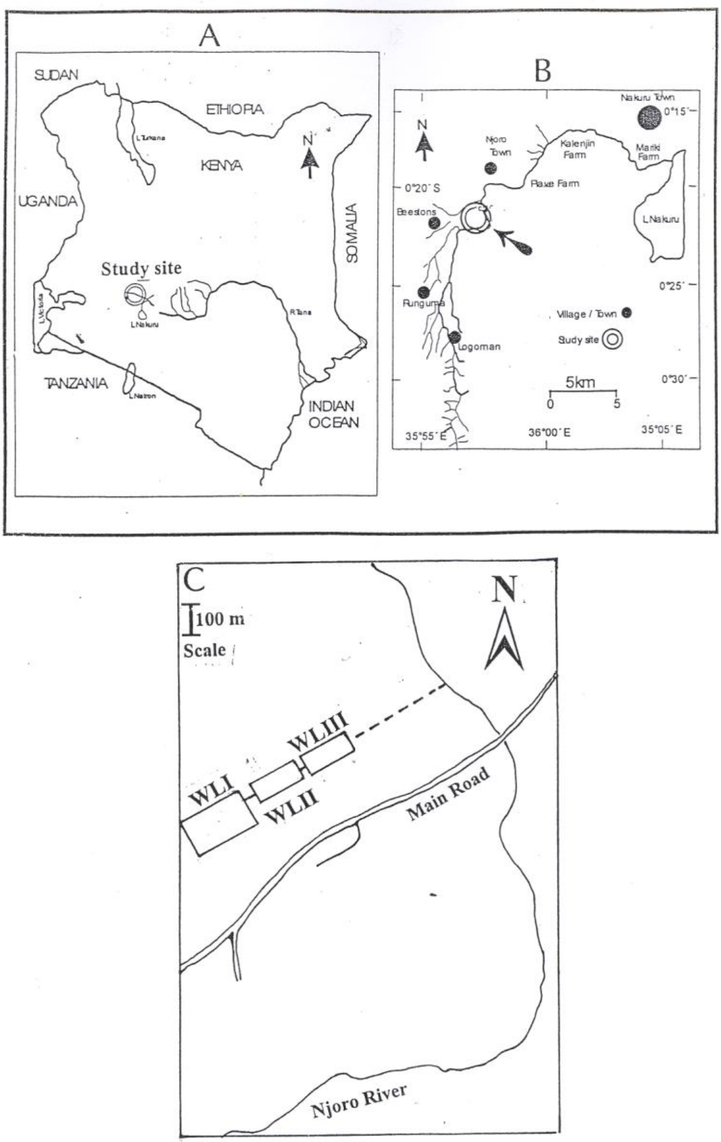

Figure 1: (A) A map of Kenya showing the location of the study sites (B) the location of the site on the river Njoro (arrowed) and (C) the siting of the wastewater lagoons (WI, WII and WIII)

Waterbird Census Protocol

Waterbirds were counted from May to September 2000 in order to elucidate any patterns in the bird populations and their distributions in the three wastewater lagoons. In order to avoid loss of information, all waterbirds within the lagoons and those resting and foraging on the shoreline were counted with minimal disturbance using a pair of binoculars. Total coverage was achieved because the wastewater lagoons are small-sized and the short distance to the opposite shoreline of each lagoon did not make identification and enumeration difficult. Species diversity (H) of the birds was calculated using the Shannon-Weiner Diversity Index (Pielou, 1975) as a measure of bird structural heterogeneity, and equitability (E) as $H/H_{Maximum}$ after computing $H_{Maximum}$ (maximum species diversity) as $\log_2 S$, where S is the number of bird species.

Ground bird counts were carried out at hourly intervals and began as early as 0630 h and ended at around 1915 h in the evening. In some cases, sporadic daytime counting trips were made to the lagoons to determine the waterbird numbers at a particular time. The identification of the birds involved the use of local expertise and where necessary, available published literature (e.g. Van Perlo, 1995; Zimmerman et al., 1999).

Results

Physical and Chemical Characteristics of the Wastewater

The physical and chemical variables for the wastewater in the three lagoons are given in Table 1. During the study period, wastewater temperature ranged from 17.8-20.7, 17.6-21.8 and 17.9-24.5ºC in a similar order. Similarly, pH ranged from 7.1-8.4, 7.2-8.6 and 7.5-8.2 for WLI, II and III, respectively.

Table 1: Summary of physical and chemical data for the three-wastewater lagoons at Egerton University, Kenya. WL = wastewater lagoons. ± standard error. Values for nitrate-nitrogen, orthophosphate and total phosphorus are ranges

	Wastewater lagoons		
Variables	WLI	WLII	WLIII
Temp (ºC)	19.5 ± 0.4	20.1 ± 0.7	21.2 ± 1.0
pH	7.5 ± 0.2	7.6 ± 0.2	7.8 ± 0.2
Conductivity (µScm^{-1})	1147 ± 51	1168 ± 40	1182 ± 53
Dissolved oxygen (mgl^{-1})	4.7 ± 1.3	8.7 ± 2.0	12.5 ± 2.4
Oxygen saturation (%)	66 ± 19	120 ± 29	175 ± 35
Ammonia-nitrogen (mgl^{-1})	28.5± 0.8	28.7 ± 0.6	26.5 ± 1.4
Nitrate-nitrogen (mgl^{-1})	0.05-0.13	0.08-0.17	0.05-0.12
Orthophosphate (mgl^{-1})	1.14-1.32	1.26-1.36	1.23-1.35
Total phosphorus (mgl^{-1})	1.24-1.42	1.35-1.58	1.31-1.56

Dissolved oxygen and oxygen saturation for the three lagoons ranged from 4.7-12.5 mg/l and 63-175%, with the highest concentration and saturation recorded at WLIII. Conductivity ranged from 1147-1181 µScm^{-1} with the highest value also recorded at WLIII. It is worthwhile to note that WLIII had the lowest wastewater volume that might have concentrated the dissolved organic and inorganic substances. The lowest ammonia-nitrogen amount recorded over the study period was 25.0 mgl^{-1} in WLIII. WL1 had the least total phosphorus concentration of 0.19 mgl^{-1} whilst WLIII had the highest, about 1.58 mgl^{-1}. The sum of all the forms of phosphorus content, P_{tot}, is a reasonable measure of the fertility of the wastewater. With each lagoon having more than 1000 µP_{tot} per litre, it shows that all of them were extremely fertile. This should effectively increase the plankton population, which may provide food to some of the vertebrates.

The total suspended solids concentrations ranged from 80–260 mgl^{-1} with the highest recorded in WLIII; this was attributed to the high algal bloom observed in the lagoon. There was a significant difference in TSS concentration among the three-wastewater lagoons (Kruskal-Wallis test, $p<0.05$). Although there was no significant difference in the nutrient concentration among the three lagoons (Kruskal-Wallis test, $p>0.05$), the extremely high values of NH_4-N concentrations recorded were an indication of high levels of pollution and the inability of the system to clean the wastewater.

Abundance of Wastewater Invertebrates

Absence of a wide diversity of invertebrates was evident in the wastewater. Copepods, cladocerans and chironomids were the only macroorganisms retained in the sieves of more than 100 µm mesh-size. Chironomidae, mainly *Chironomus gr. plumosus*, dominated the macroinvertebrates in the three lagoons. Their total body lengths (±standard deviation) in all the three lagoons were similar, i.e. 13.4±2.9, 13.2±2.1 and 14.3±1.8 mm in WLI, II and III, respectively. The size spectra for the dominant invertebrates in the lagoons were narrow as shown by the numbers retained by the sieves of differing mesh-sizes (Table 2). It was only Cladocera, which showed a widened size spectrum, between 100–1000 µm. All the Copepoda individuals were less than 500 µm in size. About 42%, 29.5% and 28.6% of the chironomids were found in WLI, WLII and III, respectively. All the chironomid larvae were greater than 1000 µm in size.

Table 2: Abundance of invertebrates in the three-wastewater lagoons (WLI, II & III)

		Wastewater lagoons		
Taxa	Size fraction (µm)	WLI	WLII	WLIII
Copepoda	100–500	-	$1.0*10^{6}$	$1.0*10^{7}$
	500–1000	-	-	-
	>1000	-	-	-
Cladocera	100–500	$4.7*10^{6}$	-	$1.9*10^{7}$
	500–1000	$1.1*10^{7}$	$2.0*10^{5}$	$8.8*10^{6}$
	>1000	-	-	-
Chironomidae	100–500	-	-	-
	500–1000	-	-	-
	>1000	$1.7*10^{14}$	$1.2*10^{14}$	$1.2*10^{14}$

Dynamics of Bird Populations

Percentage occurrence of the waterbird species encountered over the entire study duration in the three lagoons is given in Table 3.

Table 3: Percent occurrence of birds within and immediately outside the wastewater lagoons (WLI, II & III) at Egerton University, Kenya

		% occurrence		
Common name	Scientific name	WL1	WLII	WLIII
Yellow-billed ducks	*Anas undalata undalata*	45.22	67.85	41.46
Red-billed teal	*Anas erythrorhyncha*	3.12	7.41	28.26
Egyptian goose	*Alopochen aegyptiacus*	20.24	1.81	1.40
Hamerkop	*Scopus umbretta umbretta*	0.40	0.63	4.66
Blackheaded heron	*Ardea melanocephala*	2.17	0.63	0.78
Grey heron	*Ardea cinera cinera*	0.22	0.24	0.62
Sacred ibis	*Threskiornis aethiopicus aethiopicus*	19.54	7.72	6.21
African spoonbill	*Platalea alba*	0.00	0.16	0.00
Hadada ibis	*Bosstrychia hagedash brevirostris*	0.07	0.00	0.00
Great white pelican	*Pelecanus onocratulus*	0.07	0.08	0.00
Cinnamon-chested bee-eater	*Merops oreobates*	0.00	0.00	0.31
Common sandpiper	*Actitis hypoleucos*	2.28	3.31	3.26
Little grebe	*Tachybaptus ruficollis capensis*	0.18	1.58	0.00
African darter	*Anhinga rufa*	0.04	0.16	0.00
Black kite	*Milvus migrans*	0.00	0.00	0.16
Helmeted guineafowl	*Numida meleagris*	0.04	0.00	0.62
Pied avocet	*Recurvirostra avosetta*	0.96	0.71	0.31
Grassland pipits	*Anthus cinnamomeus*	0.22	0.00	0.00
African pied wagtails	*Motacilla aquimp*	4.11	6.07	11.65
White-rumped swift	*Apus cafer*	0.11	0.00	0.00
Ring-necked doves	*Streptopelia capicola*	0.07	0.00	0.00
Common stilt	*Himantopus himantopus*	0.15	1.34	0.31
Cattle egret	*Bubulcus ibis*	0.04	0.32	0.00
Others (e.g. Blue-billed ducks, African black duck, etc)		0.73	0.00	0.00

The sacred ibis (*Threskiornis aethiopicus aethiopicus*), yellow-billed ducks (*Anas undalata undalata*), red-billed teals (*Anas erythrorhyncha*) and Egyptian geese (*Alopochen aegyptiacus*) were the most abundant waterbirds. WLIII had the highest bird species diversity among the three lagoons (Table 4).

Table 4: Bird species diversity values in the three-wastewater lagoons in Egerton University, Njoro

	Wastewater lagoons		
	WLI	WLII	WLIII
Bird species diversity	1.59	1.30	1.62
$H_{maximum}$	3.04	2.77	2.64
Equitability	0.52	0.47	0.61

WLII had the least diversity though it had high species richness compared with WLIII. The yellow-billed ducks and sacred ibis were mostly confined in WLI, with a progressive population decrease in WLII and WLIII (Figure 2). Further, the Egyptian geese were almost confined solely to WLI. A contrasting pattern was, however, depicted by the population of the red-billed teals in which there was a gradual increase from WLI to WLIII. Because there was heterogeneity of variances (Levene statistic = 13.16, $p<0.001$), all bird counts were transformed $\log_{10}(x+1)$ before using one-way ANOVA to test whether the populations of the yellow-billed ducks were significantly different in the three lagoons. The population of yellow-billed ducks in WLI differed significantly from the populations in WLII and WLIII (One-way ANOVA, $F_{(2,279)} = 16.15$, $p<0.001$). Post-hoc analysis indicated that WLI had the highest population of yellow-billed ducks per observation (Bonferroni multiple range test, $\alpha=0.05$). Similarly, the population of the sacred ibis in the three lagoons differed significantly (one-way ANOVA, $F_{(2,276)} = 12.70$, $p<0.001$), with post-hoc Bonferroni multiple range test indicating that WLI had the highest population, about 5 individuals/observation (see Figure 2).

The diurnal distribution of the bird populations in the three-wastewater lagoons did not define distinct patterns (Figure 3), although the red-billed teal population in WLI showed a peak increase at around 1200 h. The fluctuations of the bird populations within very short temporal periods was an indication of populations which were not foraging far from their habitat. They were returning to the lagoons within 2–4 hours.

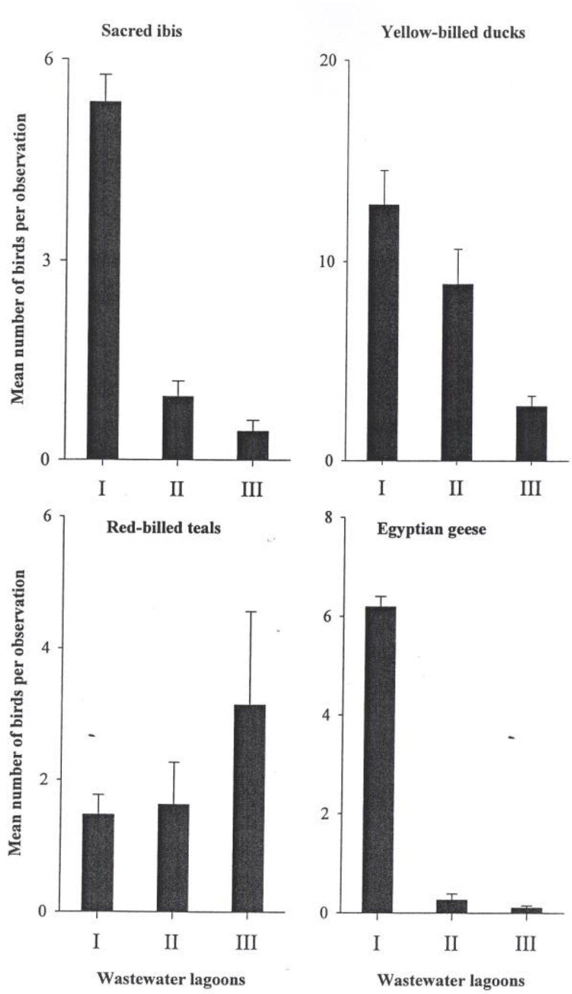

Figure 2: Distribution of bird population over the study duration in the wastewater lagoons I-III at Egerton University, Njoro. Vertical bars: +/- Standard error

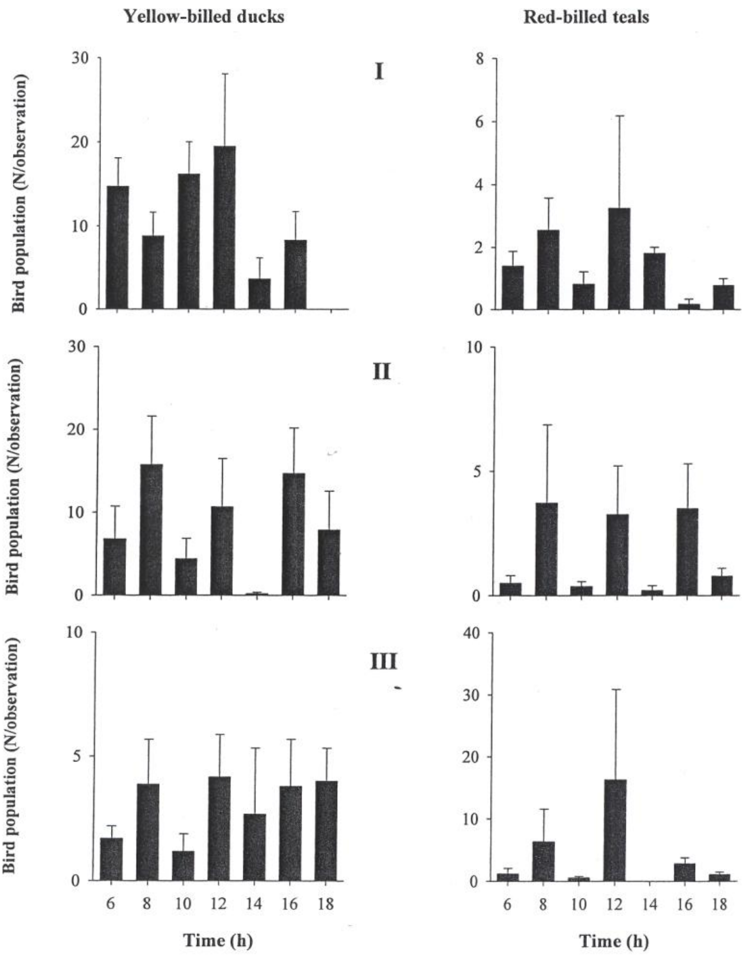

Figure 3: Diurnal distribution of bird populations in the wastewater lagoons I-III at Egerton University, Njoro. Vertical bars: +/- Standard error

The highest number of the birds was counted between 1200 and 1400 h, 0800 and 1000 h and, 1200 and 1400 h, in WLI, II and III, respectively. Estimates of group sizes of the yellow-billed ducks during the observations were sometimes 80 but more frequently observers counted numbers of less than 10, i.e. in WLI, II and III, about 52%, 49% and 84% of the population, respectively, were in group sizes of less than 10 individuals. The majority of group sizes of red-billed teals were less than 10 individuals/observation (Figure 4).

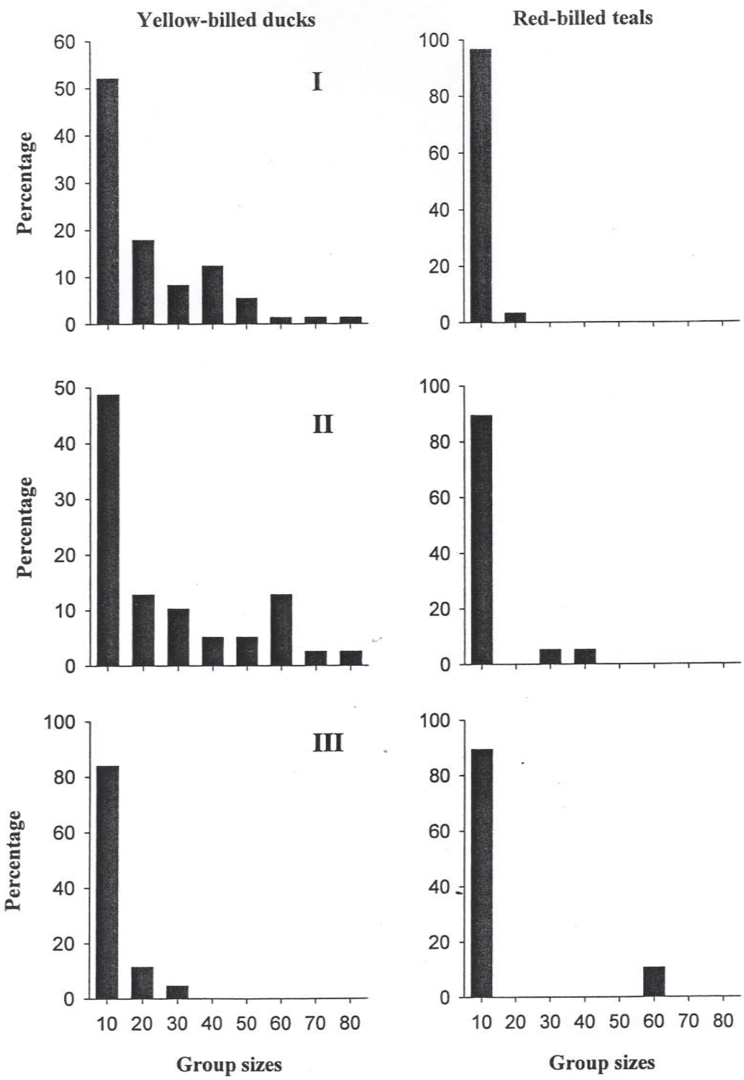

Figure 4: Frequency of group sizes of some of the waterbirds counted in the wastewater lagoons I-III at Egerton University, Njoro

While there was a good distribution of group sizes of yellow-billed ducks in WLI and II, these were limited to less than 30 individuals/observation in WLIII. Group sizes of the Egyptian geese, however, were between 6-10 individuals/observation and were concentrated in WLI. Only a few group sizes of less than 5 individuals were found in the other two lagoons. Hamerkop, *Scopus umbretta umbretta*, group sizes were all less than 5 individuals in all the three lagoons. About 84% of all the birds in the three wastewater lagoons were observed feeding between 0800 and 1000 h and a few were feeding between 1700 and 1800 h. The rest of the time was spent resting either in the wastewater or outside the lagoons. Feeding activities, especially by the ibises and to some extent, the Egyptian geese, were concentrated in WLI wastewater inlet and also in WLII.

Discussion

Many bird species are native of a particular habitat type, which makes possible to distinguish particular morphoecological types of birds. For real stochastic individual-based populations, chance events may cause the number of individuals to hit zero, after which recovery can only come from an external source (Keeling, 2000). It was evident that waterbirds formed an important part of the biological community of the Egerton University lagoons. Bird species composition consisted of both endemic (e.g. the red-billed teals and the yellow-billed ducks) as well as Palaearctic migrants (e.g. the common sandpiper, *Actitis hypoleucos*). The waterbird community in the lagoons was very dynamic in its composition and abundance within a short time. There were cases when bird populations were being interchanged between the lagoons and also when the birds could fly probably short distances away from the lagoons. Presumably, these were the same birds which came back to build up the remnant populations in the lagoons.

There was generally low avidiversity in all the three lagoons. It was evident that some waterbirds were more obvious parts of the biological community on the lagoons than others. For instance, the yellow-billed duck, *Anas undalata undalata*, was dominant throughout the study duration. With a few exceptions, the bird population in these lagoons compared favourably with those recorded in the Dandora Oxygenation Ponds in Nairobi, Kenya (Bennun and Njoroge, 1999). However, the southern pochard (*Netta erythrophthalma*), which was common in the Dandora Ponds was absent in the Njoro lagoons.

Most bird species exhibit high adaptive abilities in relation to both breeding and feeding. Food availability (Newton, 1998) and good quality territories (Stacey and Ligon, 1987) have frequently been considered some of the most important factors limiting bird populations. The different bird populations in the lagoons seemed not to compete for food resource. Chironomids, which act as energy base for the birds in the lagoons, were of similar abundance and sizes. It could therefore be postulated that the high number of chironomids, rather than their sizes, led to the high occurrence of some bird species in WLI. Intuitively, food resource seemed not to be limiting in all the lagoons. When two species compete for resources, one species will always be better than the other in gathering or utilizing the resource that is scarce. Visual observation did not reveal any evidence of such phenomenon and no species disappeared or adopted strategies to avoid competition. Whether there was diet shift as a result of competition or not could not be ascertained within the scope of this study. Our results on the distribution of the waterbirds in the three lagoons implied that common, environmental stochastic factors could also be principal causes of the patterns between populations. There is, however, need for further investigation to ascertain the existence or not of resource partitioning in the lagoons.

Many of the waterbirds either nest or feed in areas that can be described as ecotonal habitats. Some of the birds found in the lagoons were sporadic visitors, e.g. the Great white pelican, *Pelecanus onocratulus*, was an uncommon visitor in the evenings. Ecotonal zones, both river-land and lake-land, provide especially attractive resting grounds and overnight shelters for many bird species (Doborowski, 1994). This could also apply to the lagoon-shrub ecotone in the current study where non-waterbirds were found resting and in association with other birds. Apart from a few bird species, which were permanently observed in the lagoons, e.g. the yellow-billed ducks, *Anas undalata undalata*, and the Egyptian geese, *Alopochen aegyptiacus*, the majority appeared to be just on transit or spending their night near the lagoons. Most waterbirds were observed to rest on the shoreline or forage near the vicinity of the lagoons. The common sandpiper, *Actitis hypoleucos*, was commonly seen walking at the lagoon edges on the concrete slabs while feeding. Kingsford and Porter (1994), when working in an Australian lake, have reported similar observations.

The activities of the waterbirds depended on the time of the day and these activities included swimming and feeding. Feeding was carried out in the morning hours probably because of hunger brought about by the previous night's metabolism. Feeding activities were concentrated in WLI and WLII as a result of not only the presence of live food resources but also the presence of solid organic matter in these lagoons. Sacred ibis preferred to feed at the wastewater inlet in the morning and evening hours. The Egyptian geese and the red-billed teals were observed alternating their activities between swimming, feeding and resting at the grass or concrete slabs at the edges of WLI and WLII. Some feeding activity was also observed in the evening hours. This showed that two feeding peaks occurred in the bird community, with the major peak occurring between 0800 and 1000 h and a minor one between 1700 and 1800 h. The intervening hours were spent on other activities. The structure of the size patterns portrayed by the invertebrates in the three lagoons raises questions on food selectivity by the birds and/or survival strategies by the invertebrates themselves. The presence of chironomids greater than 1000 μm and absence of the smaller sizes could probably explain size selectivity in the live food eaten by the birds, especially the ducks.

Bird populations, i.e. their numbers and diversity, in hydrosystems have been used to assess the health of such systems (Kingsford, 1999). Because of the presence of waterbirds within and on the shores of the Egerton University wastewater lagoons, the health of the lagoons was questionable. This meant that the lagoons were either not efficient functionally, i.e. in wastewater processing, or that they just acted as throughflows of the untreated wastewater to the adjacent Njoro River. The composition of waterbird communities could reflect invertebrates and aquatic macrophytes abundance in hydrosystems (e.g. Kingsford and Porter, 1994). The Egerton University wastewater lagoons lacked nekton and macrophytes (submerged and emergent) and therefore they were not factors influencing the dynamics of bird populations. The decrease of some bird populations from WLI to WLIII suggested that the wastewater quality was improving towards lagoon III, though below international standards. Waterbird counts could therefore serve as important indicators of efficiency and health of small or large wastewater lagoons and give quick results for their management. The ground census of the waterbirds was a fast method to assess whether the lagoons were actually in good health and whether remediation was necessary. The complete census takes a short time and is less expensive unlike the aerial method, which is expensive and extends for long periods (Braithwaite et al., 1986; Kingsford, 1999). Although previous data on the bird population were not available, the current data indicate that birds could be used to determine roughly the health of wastewater lagoons. Wastewater lagoons may not provide suitable habitat for waterbirds as natural wetlands do but they form important feeding sites by virtue of their productivity. The value of the lagoons as small-sized bird sites is, however, not fully recognized.

Acknowledgements

We would like to thank the Aquatic Research Projects Initiative 2000 (ARPI 2000) Group of the Department of Zoology, Egerton University, Kenya, for assisting with fieldwork.

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