Natural versus artificial- wetlands and their waterbirds in Sri Lanka

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ABSTRACT

As natural wetlands have disappeared around the world, artificial wetlands have increased. We found interesting differences in waterbird communities of two natural (Bundala Ramsar site) and seven artificial wetlands (irrigation tanks, salt ponds, rice paddies) in south-east Sri Lanka. Eight species exclusively used natural and one species artificial wetlands. Migratory species (shorebirds 64%, terns 47%) dominated species' richness of natural lagoons, with densities of shorebirds 3–6 times greater than on artificial wetlands. Contrastingly, resident species (dabbling ducks, gallinules) contributed most to the diversity (59%) and density of waterbirds on artificial irrigation tanks. Cattle egrets dominated waterbird density (>70%) of rice paddies. Waterbird communities reflected physical and chemical character of wetlands: natural wetlands were shallow (<2 m) and saline (EC > 1000 mS m⁻¹) compared to deep (>2 m) and freshwater (EC < 110 mS m⁻¹) artificial wetlands. Artificial inputs of water drained into the natural Embilikala lagoon changing its physico-chemical profile and disrupting the natural seasonal drying. Consequently its waterbird community was similar to artificial irrigation tanks, with shorebird species particularly impacted: densities half that of the other natural lagoon. Artificial salt ponds had similar physico-chemical properties to the natural Bundala lagoon and a similar waterbird community. Even though artificial wetlands supported waterbirds, they were not adequate replacements for loss of natural wetlands, favouring some species. Imposed hydrological stability degraded habitat quality for migratory shorebirds on one of our Ramsar site lagoons.

1. Introduction

Natural wetlands continue to decline globally (Dahl, 1990; Hollis, 1992; ANCA, 1996), with increasing human development. As a result, waterbirds are declining around the world (Davidson and Stroud, 2006; Cao et al., 2008; Nebel et al., 2008) because of their dependency on wetlands for survival, reproduction and recruitment (Haig et al., 1998; Guadagnin and Maltchik, 2007).

Agriculture and aquaculture have expanded at the expense of wetlands (Revenga et al., 2000; Galbraith et al., 2005) but have created artificial wetlands (Hoeg, 2000). Natural wetlands occupy only about 6% of the earth's surface, compared to agro-ecosystems covering about 25%, excluding Greenland and Antarctica ( Mitsch and Gosselink, 2000). Many artificial wetlands are created to convey or hold water (e.g. reservoirs, paddy fields, salt evaporation ponds) but are used by waterbirds ( Fasola and Ruiz, 1996; Rehfisch, 1994; Masero, 2003). A key question is whether such artificial wetlands replace natural wetlands ( Tourenq et al., 2001; Ma et al., 2004). Waterbirds can be used to examine this question because different species (e.g. piscivores, herbivores) sample habitat complexity, with diversity and abundance reflecting wetland functional value ( Short and Burnham, 1982).

A matrix of natural (coastal lagoons) and artificial (paddy fields, salt evaporation ponds and irrigation tanks) wetlands exist within a large irrigation and agricultural settlement scheme in the dry zone of southern Sri Lanka, the Kirindi Oya Settlement Project (KOISP) (Fig. 1). The coastal lagoons are part of a Ramsar site, whose hydrology is potentially degraded by agricultural development (Piyankarage et al., 2004; Smakhtin et al., 2004).

We compared species richness, abundance and waterbird community composition between natural and artificial wetlands. Natural wetlands were expected to have a higher ratio of migratory to resident species because their limnological and hydrological characteristics were different to freshwater artificial wetlands. Low densities, particularly shorebirds, were also expected at wetlands with imposed hydrological stability ( Kingsford et al., 2004).

We tested whether waterbird composition differed among different type of wetlands, and if species richness and densities were higher on natural (coastal lagoons) than artificial wetlands.
2. Methods

The Kirindi Oya Irrigation and Settlement Project (KOISP) in the south-east of Sri Lanka began in 1982, expanding the ancient Ella-gala irrigation system (Fig. 1; old paddy fields), comprising five irrigation tanks (Wewawila, Debara, Tissa, Pannagamuwa and Yoda) and providing water to about 4200 ha of irrigation (Matsuno, 1999) (Fig. 1). The tanks supply water for irrigation, domestic use and fisheries (IUCN and CEA, 2006) and are surrounded by densely populated, intensively managed agricultural land (rice cultivation). In 1987, irrigated area increased to 10,450 ha (Matsuno, 1999, Fig. 1; new paddy fields) with the two main canals of the KOISP.
The coastal natural lagoons of Bundala and Embilikala, at the southern end of the Kirindi Oya catchment, are part of Bundala National Park (Fig. 1), and an area of 121 ha of artificial salt evaporation ponds exists on the western side of Bundala lagoon (Fig. 1). Four lagoons, Koholankala (390 ha), Malala (650 ha), Embilikala (430 ha) and Bundala (520 ha), form a wetland system that supports a rich bird life of 197 bird species (46 migratory), including many waterbirds (Bambaradeniya, 2001; IUCN and Ministry of Environment and Natural Resources, 2007). This system is listed as a wetland of international importance under the Ramsar convention. Migratory waterbird species reach the wetlands between the end of July and beginning of August and leave between April and May, using the Central-Asian Flyway (Kotagama et al., 2006). Herons, jacanas, spoonbills, cormorants and storks are always resident and breed (De Silva, 1999).

The climate of the study area is hot and dry (Cooray, 1984), with a mean annual temperature of 27.1°C and an average annual precipitation of 1074 mm. There is one dry season (July–September) and two wet seasons: the north east monsoon (October–March) with the highest rainfall in November (IIIM, 1995) and the south west monsoon (April–June), producing two rice cultivation seasons (Maha and Yala seasons, respectively).

2.1. Waterbird surveys

We surveyed waterbirds each month during the wet (January–May 2006 – February–April 2007) and dry seasons (July–September 2006 – August–September 2007) of two consecutive years (2006–2007), at two of the natural lagoons of Bundala National Park (Bundala and Embilikala), at all five artificial irrigation tanks of the KOISP and at the salt evaporation ponds of Bundala lagoon (Fig. 1). The survey periods were selected according to waterbird phenology (August–September arrival and April departure of migratory waterbirds) and to the rice cultivation seasons. From the end of October until the end of April, agricultural drainage water is regularly released into the natural wetland of Embilikala. Two surveys were done of all wetlands in March each year: at the beginning (BMar) and end of the month (EMar), to cover the transition period between rice cultivation seasons. Two lagoons were not surveyed: elephants made Malala lagoon dangerous to survey, and access to the privately managed Koholankala (salt extraction) was restricted. Paddy fields were surveyed in November 2006 and end of October 2007 when rice cultivation started, and monthly from February–April 2007 and August–September 2007 to cover the entire rice production cycle (from sowing to harvesting).

Waterbirds were identified and counted using binoculars (10 × 50) and a telescope (60×), standardising survey methodology for each wetland. We avoided disturbing birds and usually completed counts before birds flew away, but tracked birds, if disturbed, to avoid double counting. Most counts were of individual birds but flocks larger than hundred individuals were estimated by counting blocks of 10, 20, 50 or 100 birds and estimating similar-sized groups in the flock (Rapold et al., 1985). We performed a complete count of all birds present at each wetland. Pannagamuwa and Debara tanks (Fig. 1) were surveyed from the roof of a car on their bund walls while Yoda and Weerawila tanks (Fig. 1) were surveyed from bordering roads at fixed locations. Total birds on Tissa tank (Fig. 1) were counted by boat, along the marshy fringe and across the centre to the island in the middle. Bundala lagoon was surveyed by walking the perimeter while Embilikala lagoon was surveyed by car, stopping at fixed locations, due to the presence of elephants. The salt evaporation ponds were surveyed from the edge. We only surveyed rice paddies visible and accessible by the main roads, by imposing a sampling grid (2 ha) and identifying 254 sample locations (GPS) from which 60 random locations were selected each month.

Surveys over all wetlands were over two days and started at dawn (5.30–6.00 am) and ended around sunset (6.30–7.00 pm), allowing survey of all artificial irrigation tanks and paddy fields on one day and natural lagoons and the salt evaporation ponds on a second day. Wetland order varied among census periods to reduce possible systematic bias due to potential regular bird movements. Weerawila tank and Yoda tank were, respectively, not surveyed close to sunset and early morning because of sun reflection over water (Appendix A).

2.2. Water level and hydrochemistry

Data on daily water level (cm) were obtained for most irrigation tanks (no data for Pannagamuwa) (Irrigation Department of Tissamaharama) (Table 1). We used an index (height (cm) to water from a road culvert over water) of water levels at Bundala and Embilikala lagoons, with measurements once a week (January–November 2006) and daily January–September 2007. Temperature (°C), pH, electrical conductivity (ms m⁻¹), dissolved oxygen (mg l⁻¹) and turbidity (NTU) were measured monthly for each site, when waterbird counts were done, using a hand-held water quality meter.

2.3. Statistical analyses

We used a dominance species accumulation curve (PRIMER, 6.1.6) to compare relative species evenness and richness between
artificial and natural wetlands. High values on the y axis and low values on the x axis of the cumulative dominance curve's plot (Fig. 2), indicated communities with few species dominating.

Abundance data were first transformed into densities (number of birds ha\(^{-1}\)) to allow comparison among wetlands of different size. Densities were square-root transformed to down weight numerically dominant species that could have given erratic counts over replicates samples (months) within a site (Clarke and Warwick, 2001). Low or high densities for particular guilds (shorebirds) were sometimes primarily related to migratory movements rather than local factors. Data were tested for homogeneity of variance with the Levene test (SPSS, 17.0) but transformation did not stabilise variances. So, differences in waterbird densities among the five type of wetlands (three types of artificial wetlands: irrigation tanks, rice paddies, salt evaporation ponds, and the two natural lagoons: Bundala and Embilikala) were tested with the non parametric test Kruskal Wallis, followed by the post hoc Games–Howell (that does not assume equal variances) multiple comparison test, among ranked means (SPSS, 17.0). Differences were tested for total densities between Embilikala and the irrigation tanks (post hoc: p > 0.05) from the one of salt evaporation ponds (Fig. 3), but there was no significant difference (post hoc: p > 0.05) from the one of Bundala lagoon.

3. Results

Sixty-eight species of waterbird (18 families) were observed during surveys. Eight species (northern pintail, pied avocet, greater sand plover, Asian dowitcher, terek sandpiper, painted snipe, great knot, sanderling) exclusively used natural wetlands while one species (western reef egret) occurred only on artificial wetlands (Appendix A). There were differences between waterbird use of natural and artificial wetlands. Total species richness (\(H_0^{\text{5.4}} = 9.48, H = 60.24, p < 0.001\)) and total waterbird density (\(H_0^{\text{5.4}} = 9.48, H = 36.504, p < 0.001\)) was higher on natural than artificial wetlands (Tables 2 and 3). Few numerically dominant species made up the waterbird assemblages of artificial wetlands, in particular rice paddies, while a more even distribution of individuals among the different species was found in the waterbird assemblages of natural wetlands (Fig. 2). Despite this, there was not as clear a dichotomy natural versus artificial as we expected with diversity (Table 2) and abundance of particular guilds (Table 3), differing within the two natural lagoons and within the three types of artificial wetlands. Rice paddies had the lowest diversity (Table 2) and species evenness (Fig. 2) among artificial wetlands, with migratory and resident species contributing to total diversity (Table 2, Fig. 3). By contrast, migratory species (terns and shorebirds) made up 76% of salt evaporation ponds diversity, while resident species (dabbling ducks and gallinules, herons and storks) made up more than 50% of the diversity of irrigation tanks (Fig. 3, Table 2). The two natural lagoons had, like rice paddies and salt evaporation ponds, a higher ratio of migratory to resident species (\(H_0^{\text{5.4}} = 9.48, H = 66.65, p < 0.001\)) than irrigation tanks (Fig. 3). Migratory shorebirds and migratory terns composed 64% of Bundala and 47% of Embilikala natural lagoons total species richness (Table 2). In contrast, resident species made up only 3% of total diversity of the natural lagoon of Bundala and 15% of Embilikala (Table 2). Bundala lagoon had also a higher ratio of migratory to resident species than Embilikala (post hoc: p = 0.009) (Fig. 3), but not significantly different (post hoc: p > 0.05) from the one of salt evaporation ponds (Fig. 3).

Variation in total densities was similarly found within natural and artificial wetlands. Densities of herons on paddy fields were higher than on natural lagoons or all other artificial wetlands (post hoc: p < 0.05) (Table 3). Migratory terns and shorebirds densities were higher on salt evaporation ponds than other artificial wetlands (post hoc: p < 0.015, Fig. 3, Table 3), similar to Bundala (post hoc: \(p_{\text{waders}} = 0.73; p_{\text{phalangers}} = 0.38\)) but higher (post hoc: \(p_{\text{waders}} < 0.001; p_{\text{phalangers}} = 0.001\)) than Embilikala (Table 3). Densities of terns and shorebirds were also higher on the two natural lagoons than on artificial irrigation tanks (\(H_{\text{waders}} = 73.18, H_{\text{phalangers}} = 49.77, p < 0.001\)). Contrastingly, densities of dabbling ducks and gallinules were significantly higher at irrigation tanks than on Bundala lagoon (post hoc: p = 0.002) or salt evaporation ponds (post hoc: p < 0.001), but there was no significant difference in densities between Embilikala and the irrigation tanks (post hoc: p = 0.38) (Table 3). Densities of dabbling ducks and gallinules

![Fig. 2. Species cumulative dominance curves for natural wetlands and artificial wetlands.](image-url)
Fig. 3. Percentage of resident, resident/migratory and migratory species’ abundances at all wetlands: Bundala (BUN) and Embilikala (EMB) natural lagoons, and at the artificial wetlands Salt evaporation ponds (SAL), Yoda (YOD), Tissa (TIS) and Weerawila (WIR) irrigation tanks, rice paddies (PAD), and salt evaporation ponds (SAL). (January–May 2006, July–September 2006, Nov 2006, February–April 2007, and August–September 2007). (–) taxa not recorded.

Table 2
Species richness (monthly average ± SE), combined (all birds) and each guild, recorded at natural wetlands, Bundala (BUN) and Embilikala (EMB) lagoons, and artificial wetlands, Debara (DEB), Pannagamuwa (PAN), Yoda (YOD), Tissa (TIS) and Weerawila (WIR) irrigation tanks, rice paddies (PAD), and salt evaporation ponds (SAL). (January–May 2006, July–September 2006, November 2006, February–April 2007, and August–September 2007). (–) taxa not recorded.

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<td>EMB</td>
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<td>Terns</td>
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Table 3
Mean densities (birds ha⁻¹) (square-root transformed) ±SE for all birds and each guild, at natural wetlands, Bundala (BUN) and Embilikala (EMB), and artificial wetlands, Debara (DEB), Yoda (YOD), Pannagamuwa (PAN), Tissa (TIS) and Weerawila (WIR) artificial irrigation tanks, salt evaporation ponds (SAL) and rice paddies (PAD). (January–May 2006, July–September 2006, November 2006, February–April 2007, and August–September 2007). (–) taxa not recorded. Guilds for which significant differences exist between waterbird densities among wetland sites **p < 0.01.

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<th>Artificial Wetlands</th>
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<tr>
<td></td>
<td>BUN</td>
<td>EMB</td>
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<tr>
<td>All Birds</td>
<td>11.7(1.4)</td>
<td>8.4(0.5)</td>
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<td>Pelicans</td>
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<td>Cormorants, diving waterbirds</td>
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<td>0.6(0.1)</td>
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<td>Flamingoes, storks, ibises, spoonbills</td>
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<td>Herons</td>
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<td>1.6(0.05)</td>
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<td>Dabbling ducks &amp; gallinules</td>
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<td>Shorebirds</td>
<td>6.1(1.0)</td>
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<td>Pelagic forag. shorebirds</td>
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<td>Visual forag. shorebirds</td>
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<td>Tactile forag.-shorebirds</td>
<td>2.4(0.6)</td>
<td>0.7(0.2)</td>
</tr>
<tr>
<td>Terns</td>
<td>1.7(0.2)</td>
<td>0.9(0.1)</td>
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(post hoc: $p < 0.001$) were also higher at Embilikala than Bundala (Table 3), and several gallinules (pheasant-tailed jacana, purple swamphen, common coot), were exclusively recorded on Embilikala but not on Bundala (Appendix A). Pelican density was higher (post hoc: $p < 0.02$) on the Bundala lagoon than on all artificial wetlands, but not different between Embilikala and the irrigation tanks (post hoc: $p = 0.99$) (Table 3). Densities of visual foraging waders (post hoc: $p = 0.06$), cormorants (post hoc: $p = 0.06$), pelicans (post hoc: $p = 0.035$) and tactile (post hoc: $p = 0.031$) foraging waders were significantly higher on Bundala than on Embilikala (Table 3). Total densities were similar on Bundala and Embilikala for herons (post hoc: $p = 0.23$), terns (post hoc: $p = 0.18$), flamingoes, storks and ibis (post hoc: $p = 0.992$), and pelagic foraging waders (post hoc: $p = 0.996$) (Table 3).

These differences within natural and artificial wetlands were accentuated in community composition (Fig. 4a and b). Wetlands clearly separated out in two dimensional space (MDS stress 0.02, $p < 0.01$) (Fig. 4b). Bundala lagoon clustered (group 4) with the salt evaporation ponds while Embilikala clustered (group 2) with the large irrigation tanks (Fig. 4a and b). The small irrigation tanks (Debara and Pannagamuwa) had a waterbird community with fewer highly dominant species (cattle egret, little egret, little cormorant, white winged tern, pheasant-tailed jacana, purple swamphen, Asian open-bill stork) than on large irrigation tanks (Yoda, Tissa and Weerawila) (Table 2, Table 3). Paddy fields (group 3) had distinct waterbird assemblage (Fig. 4a), dominated by cattle egrets (>70% similarity). Resident waterbird species (dabbling ducks and gallinules, herons and cormorants) drove similarity among waterbird communities on large and small irrigation tanks while migratory species (lesser sand plover, little stint, curlew sandpiper, redshank, Kentish plover) were drivers on salt evaporation ponds and Bundala. Embilikala lagoon had a waterbird

![Fig. 4. Analysis of similarities (Bray–Curtis) of waterbird communities (mean species’ densities, square-root transformed) among wetland types: (a) there were four clusters of similarities among: (1) small irrigation tanks: Debara (DEB) and Pannagamuwa (PAN); (2) large irrigation tanks: Weerawila (WIR), Yoda (YOD), Tissa (TIS) and Embilikala natural lagoon; (3) rice paddies; (4) Bundala (BUN) natural lagoon and salt evaporation ponds. (b) Multidimensional scale (MDS) ordination of wetland sites with superimposed groups from the cluster analysis.](image-url)
community similar to irrigation tanks, predominantly composed of resident species (little cormorant, lesser-whistling duck, great egret, grey heron, Indian pond heron, pheasant-tailed jacana, little egret, intermediate egret, purple swamphen, spoonbill).

This dichotomy between resident and migratory species identified interesting functional differences among wetlands, reflecting previous species richness and density patterns (Fig. 3, Tables 2 and 3), and physico-chemical characteristics (Table 1, Fig. 5a). Electrical conductivity explained 60% (first axis) (Fig. 5a, Table 4) while turbidity explained 24% of the variance (second axis) in waterbird communities (Fig. 5b, Table 4). Electrical conductivity (EC) of artificial wetlands was lower than in the natural lagoon of Bundala and salt evaporation ponds (Table 1, Fig. 5a) than irrigation tanks (Table 1, Fig. 5a). Electrical conductivity was as well lower in Embilikala than Bundala lagoon suggesting that this natural wetland was changing its chemical characteristics of coastal brackish lagoon and becoming more similar to freshwater artificial wetlands. Turbidity (NTU) was higher at artificial wetlands and Embilikala than at Bundala lagoon and the salt evaporation ponds (Table 1, Fig. 5b).

Among large irrigation tanks, turbidity was highest at Yoda and lowest at Weerawila (Table 1, Fig. 5b) and higher on Debara than Pannagamuwa tank for small irrigation tanks (Table 1, Fig. 5b).

Hydrological variability also separated wetlands and the feeding groups of waterbirds in relation to depth. Small irrigation tanks had higher hydrological stability than large irrigation tanks and seasonal water level fluctuation was much lower at Embilikala than Bundala (Table 1). Species that dived and fed in deep water (e.g., cormorants, grebes), or fed in medium to deep water (e.g., great egret, intermediate egret) or utilised floating vegetation (e.g., gallinules, jacanas) dominated waterbird communities on small and large irrigation tanks (Fig. 6). This contrasted the communities using the other artificial wetlands, rice paddies and the salt evaporation ponds, species that fed in shallow water (e.g. small shorebirds, small egrets) to medium depth (e.g. medium shorebirds, medium egrets) (Fig. 6).

Finally, the different waterbird communities on the two natural lagoons reflected their hydrological regime (Table 1). Small and medium shorebirds that fed in water <30 cm (Appendix A) dominated the waterbird community on Bundala with its seasonal, wet and dry, water level fluctuations (Table 1), while Embilikala had a waterbird community dominated by species feeding in medium to deep water (61–90 cm), large egrets and herons, dabbling ducks, gallinules and spoonbills (Fig. 6), favoured by stable water levels kept artificially high by drainage from irrigation.

4. Discussion

Rather than a dichotomy natural versus artificial wetlands, we found specific waterbird assemblages that reflected clear
functional difference among the wetland types of the study area. Waterfowl species clearly preferred irrigation tanks over the other types of wetlands, whereas migratory species, particularly shorebirds, were more abundant on Bundala lagoon and salt evaporation ponds. The distinct feeding requirements of these two waterbird guilds strike to the distinct physical–chemical characteristics and hydrology of these wetlands. Shorebirds feed almost exclusively on invertebrates (Skagen and Oman, 1996; van de Kam et al., 2004) while gallinules and waterfowl species are omnivorous, feeding on a variety of aquatic plant seeds and material and invertebrates (Thompson et al., 1992).

Wetlands as well are more productive for many shorebird species when shallow (<20 cm) (Isola et al., 2000) with more foraging habitat (Collazo et al., 2002) where prey concentrate, contributing to high productivity (Kingsford and Porter, 1994). This contrasts deep artificial wetlands whose prime purpose is to store water and keep water levels artificially high (Kingsford et al., 2004). Shorebird densities were low on deep irrigation tanks with minimal water level fluctuation (Tables 1 and 3). Only Weerawila and Yoda tanks supported roosting and feeding of several species of shorebirds during the dry season when large areas of mud and grass (200–300 m from margin) were exposed, but densities were lower than on both natural wetlands. Embilikala and Bundala lagoons had large expanses of shallow water and exposed mud in the dry season, during their drawn down phases, available to several species of migratory shorebirds, in densities, respectively, six times higher and three times higher than on artificial irrigation tanks (Table 3). High numbers of shorebirds and few waterfowl used as well the artificial salt ponds (Table 3, Fig. 4a and b). Low water levels maintained in the ponds evaporated sea-water for salt harvest. This environment favoured extremely high densities of mosquito larvae and brine shrimps that formed a rich food source for shorebirds (van de Kam et al., 2004). On artificial wetlands, numbers of dabbling ducks and gallinules were instead more than double those on the natural lagoon of Bundala (Table 3). The small irrigation tanks, Pannagamuwa and Debara, were covered by emergent lotus plants (Nelumbo spp.) and water hyacinth (Eichhornia spp.) while the large irrigation tanks, Tissa, Yoda and Weerawila, supported floating clusters of Pistia spp., other submerged aquatic plants (Hydrollo spp., Najas spp., Chara spp.) and water lilies. We observed several species (common coot, little grebes, jacanas) feeding on these macrophytes and their invertebrates. Variation of waterbird densities among irrigation tanks probably reflected turbidity differences because biomass of macrophytes and associated invertebrate fauna decrease with increased turbidity reducing numbers (Moreno-Ostos et al., 2007) and feeding efficiency (Gregg and Rose, 1985) of herbivorous waterbirds (e.g. coot). Edges of Yoda tank were trampled and grazed by livestock (CEA, 1994), producing higher turbidity levels and lower densities of common coots and little grebes than Weerawila tank (Table 1, Fig. 5b).

Differences in densities of these two waterbird guilds were also found between the two natural lagoons and clearly related to their functionality. Embilikala had densities of dabbling duck and gallinules intermediate between the natural Bundala and the artificial wetlands (Table 3, Fig. 4a and b). Embilikala’s flooding and drying regime was changed by regular (at least once a week) inflows of drainage water from rice paddies (November–April). Bundala started drying at the end of January until September but drying on Embilikala was constantly interrupted by freshwater inputs, producing stable high water levels (February–April) (Table 1). Freshwater lowered electrical conductivity in Embilikala, compared to Bundala (Table 1, Fig. 5), maintained after KOISP development (Piyankarage et al., 2004). This probably favoured development of aquatic vegetation, cattail rush (Thyra angustifolia) and submerged macrophytes (Pistia stratiotes, Salvinia molesta, Ottelia spp.) on Embilikala which were almost absent on Bundala. Increased sediment loads and nutrient levels from agricultural runoff may have also contributed to higher turbidity on Embilikala than Bundala, and detrimentally affect aquatic benthic invertebrates (Cordone and Kelley, 1961; Batzer and Wissinger, 1996; Keddy, 2000). This probably resulted in lower densities of visual foraging shorebirds and tactile foraging shorebirds, that feed almost exclusively on aquatic benthic invertebrates (van de Kam et al., 2004), on Embilikala than Bundala lagoon (Table 3). Contrarily, densities of pelagic foraging shorebirds on the two natural lagoons were similar, probably because sieving of prey (zooplankton) are not highly influenced by turbidity (Table 3).

Egrets, herons, storks and ibis were found in similar densities on artificial and natural wetlands. We did not investigate breeding, but great egret, intermediate egret and little cormorant, nested and roosted on trees on Pannagamuwa, Debara and Tissa irrigation tanks in hundreds but nested in their thousands on the natural coastal lagoons (De Silva, 1999). Although we did not assess reproductive success of artificial wetlands, disturbance could be a problem as water lilies are harvested on these tanks. On the island in Tissa irrigation tank, house crows (Corvus splendens) preyed on nests of egrets, cormorants and ibis, when tourist’s boats disturbed (<1 min) incubating adults. Human disturbance did not occur around breeding areas on natural wetlands so reproductive success as well as breeding numbers could be higher on natural than artificial wetlands (Layne, 1983; Toland, 1999).

Rice paddies had almost a monotypic waterbird community (Table 3), dominated by egrets and herons (Fasola and Ruiz, 1996; Bambaradenuya and Amarasinghe, 2003). In Asia, herons may now be reliant on such artificial habitat (Kushlan and Hafner, 2000; Czech and Parsons, 2002). Shorebirds and waterfowl also used paddies but in lower densities than natural wetlands (Table 3), similar to other parts of the world (Tourenq et al., 2001; Taylor and Schultz, 2008).

In conclusion we showed that artificial wetlands, favouring some waterbird species over others, may perform some but not all the functions of natural wetlands (Novitzki et al., 2002; Ma et al., 2004). This is a world wide key conservation issue. In the United States, a compensatory wetland policy was introduced in 1987 (Kettlewell et al., 2008), potentially allowing draining of natural wetlands as long as replaced by similar sized artificial wetlands. Water depth, water level fluctuations, salinity and turbidity reflected whether a wetland was natural or primarily used for water storage. These influenced macrophytes and invertebrates, prey for waterbirds, their distribution and availability ultimately determining waterbird communities. Artificial wetlands could not replace the conservation value of the natural Bundala lagoon in supporting a rich biodiversity of waterbirds, particularly migratory shorebirds, and possibly breeding colonies. Salt evaporation ponds, known to be important for shorebirds (Velasquez, 1992; Masero, 2003) elsewhere in the world, may partly replace degraded natural wetlands (Embilikala) but they certainly did not have the rich biodiversity of Bundala lagoon and they were very small (121 ha) so not an adequate replacement in terms of area. The hydrology and physical chemical characteristics of Embilikala natural lagoon, and consequently the waterbird community, were more similar to freshwater irrigation tanks than to the coastal brackish lagoon of Bundala. As with alteration of flow regimes around the world (Lemly et al., 2000), the irrigation development (KOISP) changed the functional role of Embilikala lagoon. Alternative agricultural management could minimise this impact by diverting drainage water into surrounding rice paddies instead of the lagoon and flooding straw from harvested rice instead of burning to improve waterbird biodiversity in rice paddies (Day and Colwell, 1998; Bird et al., 2000).

Waterbird use of artificial agricultural wetlands has increased as natural wetlands have been lost (Czech and Parsons, 2002) but...
the quality of artificial wetlands depends on their structure and management (Day and Colwell, 1998; Bird et al., 2000). Functions of artificial wetlands could improve with management (Rehisch, 1994; Day and Colwell, 1998), mitigating impacts of some loss of natural wetlands on waterbirds but artificial wetlands were not adequate replacements for natural wetlands in this area of south-east Sri Lanka, favouring some waterbird species (fowl) more than others (shorebirds). The ecological character of the Embilika lagoon of the Ramsar site has clearly been degraded. Migratory shorebirds are particularly threatened and do not have many alternatives if the loss and degradation of the unique functional role of these natural coastal brackish lagoons in Sri Lanka will continue.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2009.08.007.

References


