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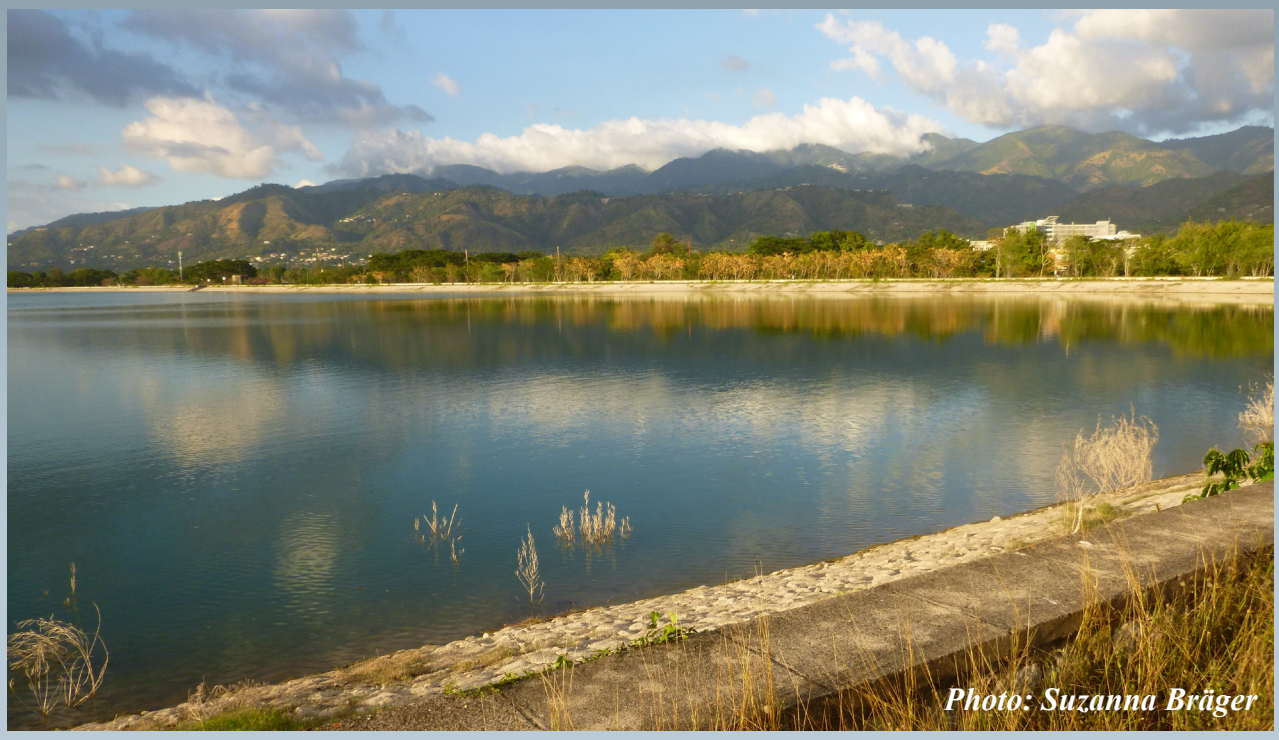

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Short-term fluctuations and long-term changes in the use of a tropical water reservoir by resident and migratory waterbirds in Jamaica

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Abstract The waterbird populations of a man-made drinking water reservoir near Kingston, Jamaica, were monitored closely over a period of 28 months (156 surveys, 2014–2016). A total of 21 species were recorded: 2 breeding birds, 6 year-round residents and partial migrants, 6 winter migrants, 1 summer visitor, and 6 locally rare species. The waterbirds fluctuated in abundance and species composition, with time of day, season, and water level identified as influencing environmental factors. A comparison with published observations spanning four decades (1962–1999) allowed for the identification of long-term trends, including the apparent local loss of another 13 species from the reservoir in the meantime.

Keywords environmental factors, historical records, seasonality, time of day, water level fluctuations

Resumen Cambios a corto y largo plazo en el uso de un embalse tropical por especies de aves acuáticas residentes y migratorias en Jamaica—Las poblaciones de aves acuáticas de un embalse artificial de agua potable cerca de Kingston, Jamaica, se monitorearon de cerca durante un período de 28 meses (156 muestreos, 2014–2016). Se registró un total de 21 especies: 2 reproductoras, 6 residentes todo el año y migrantes parciales, 6 migrantes invernales, 1 visitante de verano y 6 especies raras localmente. Las aves acuáticas fluctuaron en abundancia y composición de especies y se identificaron como factores ambientales influyentes: la hora del día, la estación y el nivel del agua. No obstante, una comparación con observaciones publicadas durante cuatro décadas (1962–1999) permitió identificar tendencias a largo plazo, incluida la pérdida local aparente de 13 otras especies en el reservorio.

Palabras clave archivos históricos, estacionalidad, factores ambientales, fluctuaciones de nivel de agua, hora del día

Résumé Fluctuations à court terme et changements à long terme de l'utilisation d'un réservoir d'eau tropical par des oiseaux d'eau sédentaires et migrateurs en Jamaïque—Les populations d'oiseaux d'eau d'un réservoir artificiel d'eau potable près de Kingston, en Jamaïque, ont été suivies pendant 28 mois (156 relevés, 2014-2016). Au total, 21 espèces ont été recensées : 2 espèces nicheuses, 6 sédentaires et migratrices partielles, 6 visiteuses d'hiver, 1 visiteuse d'été et 6 espèces rares localement. Il a été montré que l'abondance des oiseaux d'eau et la composition en espèces variaient en fonction de l'heure de la journée, de la saison et du niveau de l'eau, trois facteurs environnementaux considérés comme influents. Une comparaison avec les observations publiées sur quatre décennies (1962-1999) a permis d'identifier les tendances à long terme, y compris une apparente disparition de 13 autres espèces sur ce réservoir au cours de la période.

Mots clés facteurs environnementaux, fluctuations du niveau d'eau, heure de la journée, relevés historiques, saisonnalité

Freshwater is frequently collected and stored behind large dams for later use as drinking water, irrigation, or the generation of hydrodynamic power. By making freshwater available where it may not be otherwise, man-made water reservoirs can be very attractive to both waterbirds and bird watchers. Compared to natural water bodies, man-made reservoirs are frequently kept—often with great effort—in a controlled state, sometimes over decades, thus arresting any natural succession. Therefore, man-made reservoirs can provide an experimental setting to study long-term changes in species abundance more readily than at any natural lake or pond, because these tend to experience some measurable levels of habitat changes over time. Furthermore, bird populations on man-made reservoirs are usually easier to observe and to record completely, as reservoirs often provide less vegetation cover and few bays or islands for birds to hide. Waterbird populations of man-made reservoirs have been studied in detail in Europe and North America (e.g., Wagner *et al.* 2014), however, much less so in the tropics (Mwaura *et al.* 2002, Hussien 2015). For example, large bodies of freshwater are

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rare in the Caribbean, and very few studies of waterbird populations on man-made reservoirs have been published. Thirty years ago, a directory of Neotropical wetlands listed only 15 wetlands in Jamaica, most of which were coastal swamps under threat of some development (Fairbairn and Haynes 1986).

Even with natural succession excluded, however, there are numerous environmental factors that may influence naturally occurring waterbird populations. These factors need to be understood in order to interpret long-term trends. They may be natural—season or time of day, for example—or they can be a consequence of human use of the reservoir.

To study environmental factors influencing short-term fluctuations of the local waterbird populations, a tropical water reservoir was visited regularly for 28 months and the observed waterbirds were recorded. In a second step, the current species assemblage was compared to published information collected on the local waterbird populations at the same reservoir during the past 54 yr by multiple ornithological studies (see "Earlier Observations" below).

Methods

Study Site

Mona Reservoir (18°0.32'N, 76°45.29'W) is the largest drinking water reservoir in Jamaica. It is located about 180 m above sea level in the parish of St. Andrew on the northeastern outskirts of Kingston (for a schematic map see Goodbody and Goodbody 1998). It has a circumference of 2,600 m and was designed to hold 3 million m³ of freshwater. Some of its storage capacity, however, has been lost due to siltation. Plans for the construction of the reservoir were initiated in 1939, and in October 1959, the reservoir was finally brought into full service (National Water Commission 2016). For its construction, three of its sides were enclosed by an earthen embankment 11 m high. Leakage was a major problem during construction, which is why the entire bottom of the reservoir was lined in 1955 with a specially prepared, compacted soil blanket (National Water Commission 2016). Currently, the city of Kingston can draw some 57,000 m³ of water from the reservoir per day, which at times leads to rapid water level changes. According to historic photographs, the appearance of Mona Reservoir has not changed much in the past 57 yr.

The dam of Mona Reservoir is open to the public and frequented by dozens of joggers every day, a phenomenon to which the majority of the birds appear to have become accustomed. Any other human use—including swimming, boating, hunting, and fishing—is strictly prohibited. The water body itself is surrounded by a knee-high wall that separates the walking track from the water. Depending on the water level, the water may reach up to the wall or leave ≥ 10 m of space for plants to sprout. Any such cover, however, is usually removed promptly by the employees of the National Water Commission. Over the years the two water inflows have led to siltation, which in turn has created a wider margin of sediment, more or less natural in appearance, in the southwestern corner of the reservoir. Any developing "sandbanks" are removed when possible (for example, in 2015 in front of the eastern intake).

Jamaica has a bimodal rainy season peaking in May and October with 74% of Jamaica's total annual rainfall (1971–2000 annual average for Kingston = 1,034 mm) falling between May and November (Meteorological Service of Jamaica 2018). However, the volume of total precipitation can be highly variable (depending, for example, on El Niño Southern Oscillation events; Chen and Taylor 2002, Jury *et al.* 2007, Klotzbach 2011), at times leading to droughts when drinking water restrictions are also implemented. Vegetation growth is strongest in the reservoir at low water level when large areas are exposed between the wall and the water edge. This is mowed, usually at 6–8 week intervals. Terrestrially breeding birds do not only have to cope with the frequent mowing, but also with the introduced predator small Indian mongoose (*Herpestes auropunctatus*).

Fieldwork

In this study, waterbirds are defined ecologically rather than taxonomically as being either piscivorous or benthivorous, which means they either feed on fish (e.g., grebes, pelicans, herons, or kingfishers) or on the invertebrate fauna of the substrate (e.g., ducks, herons, or shorebirds). Other species such as White-winged Dove (*Zenaida asiatica*), Antillean Nighthawk (*Chordeiles gundlachii*), Antillean Palm-Swift (*Tachornis phoenicobia*), and Gray Kingbird (*Tyrannus dominicensis*) are frequently closely associated with the water surface or the water edge during feeding. However, these species are not classified as waterbirds for this study, as their connection with the reservoir habitat does not appear to be obligatory.

Mona Reservoir was circled on 156 days between March 2014 and June 2016 following the same route at different times of day. On average, it took 45 min to complete the circular walk of 2,600 m on the dam. Favorable weather conditions were selected, although glare was a problem at times. Species, age, sex, and numbers of all waterbirds as well as the water level were recorded in as much detail as possible.

It quickly became apparent that the evening was the most productive time for bird watching (as also noted by Petch 1970), probably because many species frequent the reservoir for roosting overnight. Therefore, most subsequent counts took place just before sunset. Due to the high variance between adjacent counts, and to avoid introducing biases, only the monthly maximum count per species was used for the following analyses.

Earlier Observations

The waterbirds of the reservoir had been studied previously by other ornithologists (Houston 1964, Petch 1970, Goodbody and Goodbody 1994, 1998, among others). Their results as well as chance observations by many others have been published in the *Broadsheet* of the Gosse Bird Club (now BirdLife Jamaica). To evaluate long-term changes in the abundance of waterbird species, the contents of the first 74 volumes of the *Broadsheet* (published between 1963 and 2000) were analyzed. Most of these observations were likely incidental and not due to a systematic monitoring scheme. Therefore, these random observations are likely to record only minimum abundances and are unlikely to provide a complete picture of the bird populations at the time. Nonetheless, a comparison of the recent data with those collected in the 1960s, 1970s, 1980s, and 1990s proved to be useful. Two recent well-known population increases served to validate the method.

Table 1. Composition of waterbird species observed at Mona Reservoir comparing the maxima of this study with counts made in the years 1962–1999 and published in the *Broadsheet* between 1963 and 2000. (The early maximum of 115 individuals for the two grebe species did not differentiate between species.)

Species	1960s *Broadsheet 1–19*	1970s *Broadsheet 15–33*	1980s *Broadsheet 34–54*	1990s *Broadsheet 60–73*	2014–2016 *This Study*	Local Trend
Breeding species						
Pied-billed Grebe (*Podilymbus podiceps*)	10 (to 103?)		11	15	13	stable
Killdeer (*Charadrius vociferus*)	27 (+ 3 nests)	chicks	7	5	15	stable
Year-round residents and partial migrants						
Brown Pelican (*Pelecanus occidentalis*)		1	2	8	14	increasing
Great Egret (*Ardea alba*)				1	26	increasing
Snowy Egret (*Egretta thula*)	1		1	3	15	increasing
Little Blue Heron (*E. caerulea*)	22			2	16	stable
Cattle Egret (*Bubulcus ibis*)		526	hundreds roosting	60 nests	500	stable
Green Heron (*Butorides virescens*)	1–2	2		1	5	stable
Winter migrants						
Blue-winged Teal (*Spatula discors*)		10			16	stable
Ring-necked Duck (*Aythya collaris*)	25		3		19	stable
Lesser Scaup (*A. affinis*)	60		2		32	stable
Spotted Sandpiper (*Actitis macularius*)	25			2	17	stable
Great Blue Heron (*Ardea herodias*)				1	1	stable
Belted Kingfisher (*Megaceryle alcyon*)				1	5	increasing?
Summer visitors						
Black-crowned Night-Heron (*Nycticorax nycticorax*)					8	increasing?
Locally rare species						
Least Grebe (*Tachybaptus dominicus*)	12 (to 105?)		1		1	declining
Black-necked Stilt (*Himantopus mexicanus*)	10			20–30	1	declining?
Willet (*Tringa semipalmata*)					2–3	?
Tricolored Heron (*Egretta tricolor*)	1			1	1	stable
White Ibis (*Eudocimus albus*)					1	?
Glossy Ibis (*Plegadis falcinellus*)					1	?
No longer observed at Mona Reservoir						
Bufflehead (*Bucephala albeola*)	3				0	declining
Ruddy Duck (*Oxyura jamaicensis*)	45–300	≥ 1			0	declining
American Coot (*Fulica americana*)	15				0	declining
Black-bellied Plover (*Pluvialis squatarola*)	7		2		0	declining
Wilson's Plover (*Charadrius wilsonia*)	≥ 1				0	declining
Semipalmated Plover (*C. semipalmatus*)	≥ 1				0	declining
Ruddy Turnstone (*Arenaria interpres*)	≥ 1				0	declining
Stilt Sandpiper (*Calidris himantopus*)	1				0	declining
Least Sandpiper (*C. minutilla*)	several				0	declining
Solitary Sandpiper (*Tringa solitaria*)	1				0	declining
Lesser Yellowlegs (*T. flavipes*)	3				0	declining
Greater Yellowlegs (*T. melanoleuca*)	several monthly				0	declining
Magnificent Frigatebird (*Fregata magnificens*)	1		1	3	0	declining

Results

Between March 2014 and June 2016, a total of 21 waterbird species were observed and recorded at Mona Reservoir: 3 ducks, 2 grebes, 1 pelican, 8 herons and egrets, 2 ibises, 4 shorebirds, and 1 kingfisher. These species utilized the reservoir at different intensities and for different purposes. The maxima for the 21 species recorded during the 28 months are presented in Table 1. The pattern of seasonal abundance allows the subdivision into the following five functional groups: 1) breeding species, 2) year-round residents and partial migrants, 3) winter migrants, 4) summer visitors, and 5) locally rare species.

Breeding Species

Pied-billed Grebes (*Podilymbus podiceps*) were observed attempting to breed throughout the year, and it appeared that this involved one to two pairs around the reservoir. However, all but one nesting attempt failed (usually during incubation) due to changes in water level that either left the nests stranded or submerged (cf. Goodbody and Goodbody 1994, 1998). Only a nest built at the end of January 2016 hatched. On 21 February, the nest contained one chick and two eggs. Six days later, the adult was on the nest with only chicks and no eggs. From 5 March to 30 April, the adults were observed with two rapidly growing chicks, which became increasingly independent in April. In early May, the chicks were observed on other parts of the reservoir before dispersing soon thereafter. The monthly maxima recorded for this species varied from 2 to 13 individuals.

Killdeer (*Charadrius vociferus*) bred in the southwestern corner of the reservoir in 2014 and 2015; this resulted in three chicks in May 2014, of which only one was still present in June, and four chicks in July 2015, of which only one was observed in August. The monthly maxima recorded for this species varied from 1 to 15 individuals with more than 5 individuals only in August and September 2014, June to November 2015, and in February 2016.

Year-Round Residents (Species Observed during Almost Every Survey) with the Following Monthly Maxima

Brown Pelican (*Pelecanus occidentalis*) was normally observed in groups of 2–14 individuals (adults and immatures) with no clear seasonal pattern in abundance.

Great Egret (*Ardea alba*) occurred in groups of 2–26 individuals with more than 10 individuals recorded only in October 2015 (possibly an influx of migrants).

Snowy Egret (*Egretta thula*) occurred as 1–15 individuals with more than 6 individuals recorded only in March 2014 and in September and October 2015.

Little Blue Heron (*E. caerulea*) occurred in groups of 3–16 individuals with immatures and subadults recorded from March to August 2014, February to June 2015, and August 2015 to June 2016.

Cattle Egret (*Bubulcus ibis*) occurred on a daily basis in large numbers of up to 500 individuals. Groups arrived at the reservoir near sunset to roost for the night in tall trees about 30 m from the northwestern water edge. From May to August/September, the roosting numbers declined to less than 150 individuals.

Green Heron (*Butorides virescens*) sightings ranged from one to five individuals with no sightings in January or December 2015 and five individuals in September and October 2015.

Winter Migrants (Observed between August and May) with the Following Monthly Maxima

Blue-winged Teal (*Spatula discors*) sightings ranged from 7 to 16 individuals between September/October and March/April, 2014–2016.

Ring-necked Duck (*Aythya collaris*) sightings ranged from 8 to 19 individuals from December until March, 2014–2016.

Lesser Scaup (*A. affinis*) sightings ranged from 19 to 32 individuals between mid-November and mid-March, 2014–2016. It is unknown whether the Ring-necked Duck and Lesser Scaup, both diving species, leave Mona Reservoir at night to forage elsewhere. According to sediment excavations, however, the reservoir houses a large population of quilted melania (*Tarebia granifera*), a small benthic snail that might also serve as prey.

Spotted Sandpiper (*Actitis macularius*) sightings included up to 17 individuals between August and May, 2014–2016, with more than 10 individuals between September and May (and a single bird already in the second half of July 2015).

Great Blue Heron (*Ardea herodias*) occurred as individuals in December 2014 and between October 2015 and March 2016.

Belted Kingfisher (*Megaceryle alcyon*) sightings included 1–5 individuals between October and April, 2014–2016 (although no individuals were observed in spring 2014).

Summer Visitors (Observed between March and October) with the Following Monthly Maxima

Black-crowned Night-Heron (*Nycticorax nycticorax*) sightings included 1–8 individuals between March and October with the exception of 2 adults already present on 10 February 2016. Night-herons usually only arrived at the reservoir after sunset.

Locally Rare Species

Least Grebe (*Tachybaptus dominicus*): one individual on 10 December 2015.

Black-necked Stilt (*Himantopus mexicanus*): one individual each on 22 March 2014, 12–14 September 2015, and 14 April 2016 (possible transients during migration).

Willet (*Tringa semipalmata*): two or three individuals were observed briefly on 26 August 2015.

Tricolored Heron (*Egretta tricolor*): one individual each on 6 December 2014, 25 October 2015, 17 November 2015 (found dead), and from 22 May to 26 June 2016.

White Ibis (*Eudocimus albus*): one immature on 7 November 2014 and one immature from 17 October to 17 November 2015.

Glossy Ibis (*Plegadis falcinellus*): one individual each on 9 May 2015, and on 30 April and 25 June 2016.

Discussion

Environmental Factors Influencing Abundances

To determine the optimal time to monitor birds at Mona Reservoir, and to understand the variation in occurring abundances, it is important to estimate this variation or at least understand its directionality. Time of day is an obvious factor; the difference in numbers between morning and evening counts was so great that surveys in the morning were quickly abandoned. Moreover, several species such as pelicans, herons, ibises, and egrets (including notable numbers of Cattle Egrets) roost together in the trees at night. This roost apparently has been in existence for

over 47 yr (Petch 1970, Goodbody and Goodbody 1995), but may have changed location from the southwestern end of the reservoir to the northwestern side. Furthermore, the Cattle Egret breeding colony (consisting of 60 nests in February 1995; Goodbody and Goodbody 1995) no longer exists.

Seasonality and water level are also likely factors to impact waterbird presence. The effect of season on winter migrants and summer visitors appears obvious, but several vagrants and year-round residents also appeared to be (in some cases heavily) influenced by the migration season, as outlined above. Migrants frequently arrive from North America and augment the resident bird populations. For example, three months after a juvenile Great Egret was banded in Ontario, Canada, it was identified in Jamaica on 11 October 2011 (Weseloh *et al.* 2014). At Mona Reservoir, October was the only month with more than 10 Great Egrets observed—most likely with migrants among them.

During the two study years from 2014 to 2016, periods with quite different predominant reservoir water levels were recorded and compared with the combined monthly maximum number of Great Egret, Snowy Egret, Little Blue Heron, and Green Heron. These four species were present year-round and were potentially most affected by water level changes. When the water level was low (> 2 m below maximum), the combined monthly maxima of these four herons and egrets was high, whereas when the water level was high (< 1.5 m below maximum), their abundance was 36–44% lower (Table 2). For most other waterbird species (except for nesting grebes), the impact of water level fluctuations appeared negligible or difficult to detect due to interfering factors such as seasonal migration.

Environmental conditions have long been known to influence both local bird populations and migration chronology (see Finger *et al.* 2016). There may be additional factors impacting the habitat quality of either Mona Reservoir (e.g., abundance or quality of available prey due to oxygen levels) or other surrounding wetlands that frequently dry out. These factors were not analyzed here, but most of them (such as the maintenance of water quality at potable levels) appear to support the relative importance of Mona Reservoir for birds and would not explain the apparent decline or loss of almost half of the local waterbird species (15 out of 34; Table 1).

Water level changes also played an important role in the habitat in the past. Petch (1970) noted: "The bird population was also influenced by the depth of water in the reservoir, and it was noticeable that both the number of species and the number of individuals were greater . . . when the water level was low" because natural gravel was exposed in the southwestern corner of the reservoir. The importance of water level changes for waterbird populations has been studied previously in a variety of climates, including in Ghana (Ntiamoa-Baidu *et al.* 1998), Florida (Bancroft *et al.* 2002), British Columbia (Wagner *et al.* 2014), and Kansas (Renken *et al.* 2016). Nonetheless, without published water level measurements, it may be impossible to correct historic sightings for the water level in the reservoir at the time. At Mona Reservoir, however, daily or seasonal water level changes are unlikely to be responsible for long-term changes in waterbird abundance as the reservoir storage volume is always maintained as close to maximum as possible.

Table 2. Combined mean monthly maximum number of four Ardeidae species (Great Egret, Snowy Egret, Little Blue Heron, and Green Heron) in relation to the water level in Mona Reservoir.

Time Period	Water Level Low (> 2 m below Maximum)	Water Level High (< 1.5 m below Maximum)	Change in Mean from Previous Period
March–June 2014	27.3		
December 2014–March 2015		15.3	−44%
April–October 2015	27.7		
November 2015–June 2016		17.8	−36%

Long-Term Changes in Waterbird Species Composition and Abundance

The results of the years 2014 to 2016 were compared to historic observations during past decades. In Table 1, the recent abundances were compared with the maxima of the years 1962–1969, 1970–1979, 1980–1989, and 1990–1999. Two species showed strong increases over decades that were well-studied and documented previously at other locations.

***Brown Pelican.*—**This species increased from no observations in the 1960s to a single individual on 9 September 1972 and another in February 1980. From then on, sightings at Mona Reservoir increased continuously (Table 1), and nowadays the recorded maximum amounts to 14 individuals at the same time. This general increase reflects the slow recovery of the Brown Pelican from a continent-wide population crash attributed to reproductive failure from organochloride pesticide contamination in the 1950s and 1960s (e.g., Jehl 1973, Holm *et al.* 2003, Hurlbert *et al.* 2007, King *et al.* 2013). This population increase also led to its recent removal from the endangered species list in the United States (USFWS 2009).

***Great Egret.*—**This species increased drastically much more recently, with the first observation at Mona Reservoir recorded in the *Broadsheet* for 10 November 1994 when the observer noted that it was "the first time I have seen one here" (P. Golding in Broadsheet 62:19). Its adaptability as a generalist has contributed to the Great Egret's wide-ranging recovery from previous North American population decimation (McCrimmon *et al.* 2011).

The fact that the increases of these two species were clearly discernible can be used as a measure of the reliability of the long-term dataset to detect trends (Table 1). The decline of Least Grebes, Ruddy Ducks, and American Coots may even reflect an island-wide trend for these species that were common in the 1960s (and early 1970s).

Conclusion

This man-made drinking water reservoir is easily accessible, and its waterbird population can be monitored reliably. Published observations since 1962 provided a historical reference to evaluate the results of 28 months of intensive monitoring. The documented increase of two well-studied species, Brown Peli-

can and Great Egret, served as a test for the validity of this study, for example, to serve as a long-term monitoring tool. Although haphazardly collected data or anecdotal observations cannot provide an ideal baseline of bird populations for the past 54 yr, the local decline of breeding bird species depending on bodies of freshwater (such as Least Grebes, Ruddy Ducks, and American Coots) provides a useful indicator for future conservation initiatives.

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