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Waterbird community changes in the Wilderness Lakes, South Africa (Part 1 of 3): Herbivores and omnivores

Author:
Ian A. Russell[1]

Affiliation:
[1]Department Conservation Services, South African National Parks, Sedgefield, South Africa

Corresponding author:
Ian Russell,
ian.russell@sanparks.org

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Global and regional degradation and loss of aquatic systems can negatively affect wetland-dependent waterbirds. The Wilderness Lakes Complex in South Africa, which incorporates the Wilderness Ramsar site, supports populations of 68 waterbird species including eight which periodically occur in globally significant (>1% population) numbers. The study aimed to document long-term spatial and temporal (including seasonal) patterns of abundance of herbivorous waterbirds in the Wilderness Lakes Complex, and where possible identify potential causes for observed trends. The abundance of waterbirds on these wetlands was determined biannually from 1992 to 2019, with counts conducted from a boat following a standardised route. Historical abundance data from the 1980s was also used to describe long-term abundance changes. Observed seasonality of four herbivorous waterbirds differed from published accounts. Long-term abundance trends indicated a combination of declining, increasing and stable populations which, in several instances, differed from regional (southern African) assessments. Significant long-term decreases have occurred in five herbivorous species in the lakes complex (Common Moorhen *Gallinula chloropus*, Red-knobbed Coot *Fulica cristata*, Yellow-billed Duck *Anas undulata*, Cape Shoveler *Anas smithii*, Cape Teal *Anas capensis*), whereas increases have occurred in two species (Spur-winged Goose *Plectropterus gambensis*, Egyptian Goose *Alopochen aegyptiaca*). Similar types of change occurred across multiple waterbodies, and in different seasons. The similarity of trends in spatially separated wetlands suggested either high interconnectivity of populations between wetland systems and/or some drivers of change of mobile species being broad scaled and regional, rather than system specific. Local reasons for changes potentially include increasing extent of cultivated fields, a proliferation of emergent macrophytes and loss of open sandbanks, changing food availability, increasing disturbance, and disease.

Conservation implications: The fundamental character of the Wilderness Ramsar site has changed, with reduced abundance of several previously abundant herbivorous waterbirds. Drivers of change in species abundances are multifaceted, complex, and frequently poorly understood. Recommended local corrective actions include the management of emergent macrophytes, avian diseases, disturbance, and water quality.

Keywords: Touw system; Swartvlei system; waterbird community change; species abundance; causes of change; wetlands; Ramsar.

Introduction

The degradation and loss of wetlands because of human activities is a global issue (Moser, Prentice & Frazier 1996). It has been estimated that 35% to 60% of wetlands in South Africa have been lost or severely degraded (Department of Water Affairs 2013:42), though global averages may be as high as 87% (Davidson 2014:940), with most of the remaining wetlands affected to some extent by human activities. The degradation or loss of natural wetlands could be expected to negatively affect waterbirds that depend on wetland habitats. By contrast, the number and area of artificial wetlands, such as farm dams and sewage ponds, has increased over the past century, and in many areas may provide alternative habitat for waterbirds (Froneman et al. 2001:267; Harebottle et al. 2008:161; Raeside, Petrie & Nudds 2007:89), though are not necessarily a like-for-like substitute for many species (Ma et al. 2004:343). The global populations of many waterbirds are in decline (Wetlands International 2012) and notably, in Africa (Dodman 2007; Nagy, Flink & Langendoen 2014). However, the role that habitat transformation and loss plays in the decline of waterbird populations frequently remains unclear (Ma et al. 2004), with few long-term studies occurring where transformation and loss has been monitored and documented.

The Wilderness Lakes Complex (WLC) in South Africa, which incorporates the Wilderness Ramsar site, is a nationally and globally important mosaic of wetlands, regularly supporting populations of up to 68 waterbird species (Randall, Randall & Kiely 2007), of which eight periodically occur, or have occurred, in globally significant (>1% global populations) numbers. Assessments of waterbird abundances have been undertaken intermittently over four decades since 1980 in both this and previous (Boshoff, Palmer & Piper 1991) studies. During this period, several directional physical and biological changes have occurred in the wetland environment, including reduced water level variability because of regular artificial breaching of the Touw and Swartvlei estuaries in the WLC; increases of in the abundance and distribution of reeds and dry-land plant species in wetland areas, and associated loss of some exposed shorelines (Russell 2003); changes in water chemistry (Russell 2013, 2015); and the proliferation of new and established alien fishes (Olds et al. 2011). Shorter-term variability has also occurred in the abundance of submerged aquatic plants (Russell et al. 2019:8).

The objectives of this study were to: (1) identify the long term trends and seasonal patterns for frequently occurring and abundant herbivorous (feeding predominantly on terrestrial or aquatic plants) and omnivorous (feeding predominantly on aquatic plants and/or associated aquatic invertebrates) waterbird species (hereafter referred to as herbivorous waterbirds) in the WLC; (2) where possible identify potential causes for the observed trends, and (3) consider the conservation implications of observed spatial and temporal changes. This entailed examining seasonal differences in the abundance of species; assessing changes in the abundance of species between surveys conducted in the periods 1980–1983 (see Boshoff et al. 1991) and 1992–2019; and examining the occurrence of trends in species abundances in summer and winter surveys for a 28-year survey period (1992–2019).

Research methods and design

Study site

The WLC (33°59′S to 34°02′S and 22°35′E to 22°46′E), situated on the south coast of the Western Cape in South Africa, forms a component of the Garden Route National Park. It comprises two estuarine systems (Figure 1). The Touw system consists of three estuarine lakes, namely Rondevlei (~138 ha), Langvlei (~283 ha) and Eilandvlei (~178 ha), and the Touw Estuary (~45 ha), all of which are interconnected by shallow channels. The Touw system, excluding Touw Estuary, is a designated Ramsar site (Randall 1990). The Swartvlei system consists of Swartvlei Lake (~1100 ha) and the connected Swartvlei Estuary (~212 ha). Lakes in the Touw system are relatively shallow, with maximum depths ranging between 4.0 m and 6.5 m, whereas Swartvlei Lake, with a maximum depth of ~17 m, is relatively deep. Both estuaries are shallow, with maximum depths generally not exceeding 4.0 m. Both Touw and Swartvlei estuaries are naturally temporarily open/closed waterbodies, with Touw Estuary being artificially breached when water levels are between 2.2 m and 2.4 m above mean sea level (amsl), and Swartvlei Estuary when water levels are approximately 2.0 m amsl, which in both instances are substantially below that which would

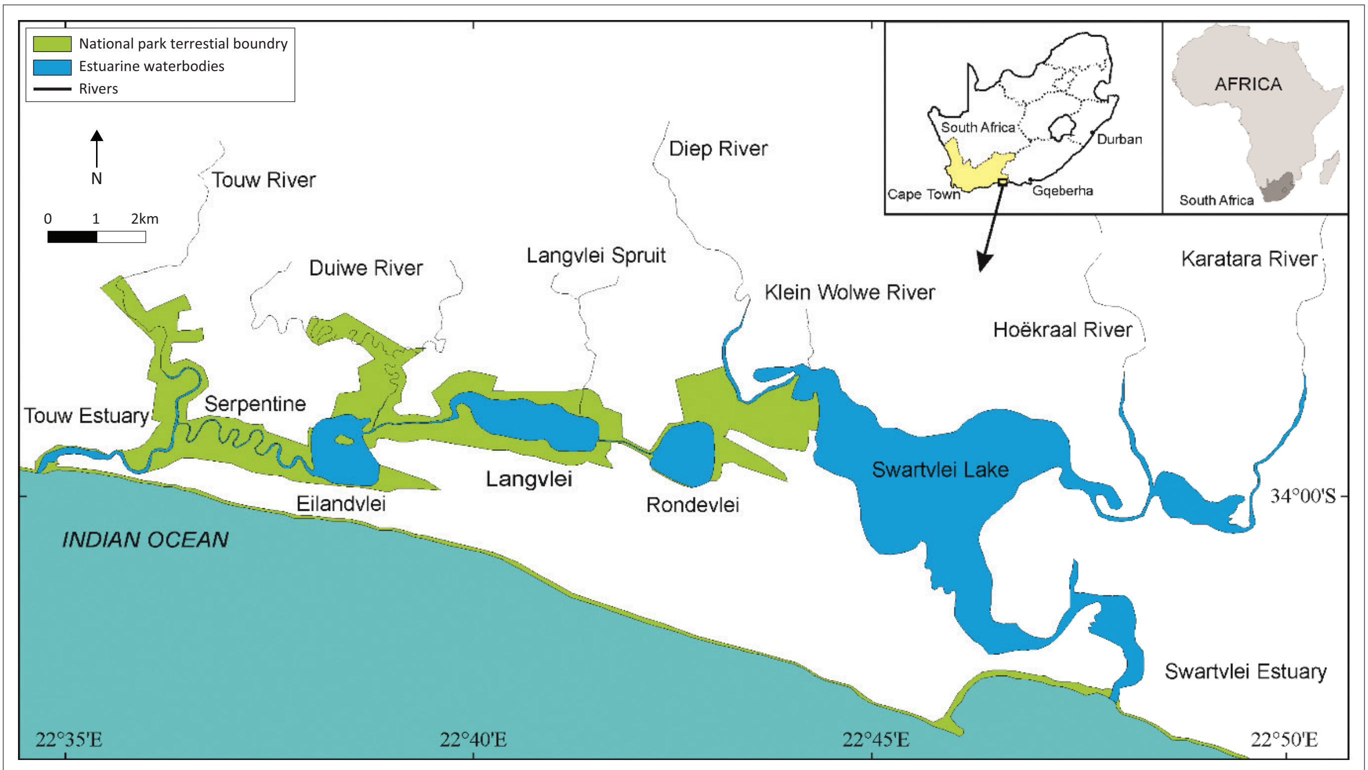


FIGURE 1: Map of study area showing relative position of estuaries and estuarine lakes within the Wilderness Lakes Complex.

potentially be achieved if breaching were to occur naturally (± 3.5m amsl). Reduced freshwater inputs and artificial breaching have resulted in reductions in the percentage of time both estuaries are open, with Touw Estuary now (1991–2019) being open 28% of the time, and Swartvlei Estuary 55% of the time (South African National Parks [SANParks] unpublished data).

Annual rainfall is between 600 mm and 700 mm (Schafer 1992), with little seasonal variation (Whitfield, Allanson & Heinecken 1983). South-west winds predominate throughout the year (Howard-Williams & Allanson 1978), though warm north and north-east winds are fairly common during winter months. Strong winds are uncommon with 97% below 30 km h^{-1} (Whitfield et al. 1983). Mean daily minimum and maximum air temperatures are between 15 °C – 25 °C (summer) and 7 °C – 19 °C (winter) (Whitfield et al. 1983).

Six rivers flow into the lake system (Figure 1). The lower catchments of the larger perennial rivers (Touw, Hoëkraal, Karatara), and majority of the catchments of the smaller intermittently flowing rivers (Duiwe, Langvlei Spruit, Klein Wolwe) are intensively utilised for agriculture, plantations, and urban development (Filmalter & O'Keeffe 1997). Dissolved inorganic nutrients (NOx-N, NH4-N and PO4-P) in the Touw system are variable though typically low, with external catchment fluxes likely not the dominant drivers of long-term nutrient patterns in the lakes (Taljaard, Van Niekerk & Lemley 2018:65).

Submerged macrophytes occur in all of the estuarine waterbodies, though they are generally confined to waters less than 3.0 m deep (Whitfield 1984). Lake communities are dominated by fennel-leaved pondweed *Stucenia pectinate*, water hornwart *Ceratophylum demersum,* stoneworts (Charophyta) and filamentous algae (Howard-Williams & Liptrot 1980). Eelgrass *Zostera capensis* is abundant in Swartvlei Estuary, although it occurs only sporadically in Touw Estuary. Emergent aquatic plants occur on the margins of the lakes, of which the common reed, *Phragmites australis*, bulrush, *Typha capensis*, and clubrush, *Schoenoplectus scirpoides*, and clubrush *Schoenoplectus scirpoides* are widespread and abundant (Russell 2003). The fish fauna consists of a combination of estuarine (Russell 1996 ; Whitfield 1984) and alien freshwater species (Olds et al. 2011).

Recreational fishing and boating are permitted on all estuaries and lakes except Langvlei and Rondevlei. Walking is possible and permitted along portions of the shorelines of the Touw and Swartvlei estuaries.

Waterbird counts

Assessments of changes in waterbird abundances were based on waterbird counts undertaken in two separate surveys periods.

Firstly, monthly waterbird counts in all waterbodies in the WLC, with the exception of Touw Estuary, were undertaken monthly for 4 years (January 1980 to December 1983) by staff of the then named Chief Directorate: Nature and Environmental Conservation. These counts were undertaken either by using binoculars from a boat following a fixed route (Swartvlei Lake), using a zoom telescope from fixed shore sites (Eilandvlei, Rondevlei, Swartvlei Estuary) or a combination of these methods (Langvlei), as described in Boshoff et al. (1991). The lead of these surveys, Dr Andre Boshoff, made all of the original waterbird abundance data from these counts available to SANParks in the mid-1990s, for unrestricted use in future assessments of changes in waterbird abundances.

Secondly, total abundances of all waterbird species on each waterbody in the WLC were determined biannually, during summer (January–February) and winter (July–August) from January 1992 to July 2019 by the author and co-workers. During the 28-year study period, 56 surveys on each of six waterbodies were undertaken. Counts of all waterbirds were conducted separately on each waterbody by four observers using binoculars, from a boat following a fixed and repeated route parallel to the shoreline of each waterbody. The routes allowed for observation of all open water areas in each waterbody, as well as sparsely vegetated areas on the waterbody floodplain. Boat speeds were low and stands of dense emergent vegetation supporting high abundances waterbirds were avoided to minimise disturbance of waterbirds on the water surface. Variability in observer error was minimised by the use of the same observers wherever possible throughout the study period, with observers specialising in different taxa. One observer participated in all 56 surveys, and a second one in 55 (98%) of surveys. Accurate counts could only be undertaken on days with little or no wind. Online long-term weather forecasts (https://www.yr.no; https://www.windguru.cz) were used to select the likely suitable sample days with little or no wind and a low probability of precipitation on four consecutive days within a 3-week window. Counts were undertaken in the morning when wind speeds are typically low, commencing at 08:00, and usually ending at approximately 13:00, with counts undertaken on either one or two waterbodies in a day. In a few instances when wind speeds unexpectedly increased substantially during surveys, thus reducing the accuracy of counts, the survey was abandoned for the day and restarted on the next day. All counts for the entire WLC were conducted over a maximum of four consecutive days in each survey. The scientific and common names of waterbird species are based on those used by Hockey, Dean and Ryan (eds. 2005).

Analysis

The non-parametric Mann-Whitney test was used to assess differences in the abundance of individual bird species in different seasons (summer and winter) using pooled data from all waterbodies collected in the 1992 to 2019 surveys. The data were tested for normality using the Shapiro-Wilk test.

The mean abundances of waterbirds in four different decades from the years 1980 to 2019, thus spanning all available waterbird abundance records, were used to assess long-term changes in abundance in the Touw and Swartvlei estuarine systems. Defined decades, and years in which data were collected were the 1980s (data 1980 to 1983), 1990s (data 1990 to 1999), 2000s (data 2000 to 2009), and the 2010s (data 2010 to 2019). To achieve consistency in the calculation of mean abundances across the entire 1980 to 2019 study period, only data collected in January and July surveys in the 1980s period were used in analyses. Comparisons of species abundances in different decades excluded all data collected on the Touw Estuary as surveys were not undertaken on this waterbody during the 1980s (Boshoff et al. 1991).

The Mann-Kendall trend analysis test was used to determine the significance (*p*) and direction (increasing or decreasing) of long-term non-seasonal trends in the abundances of waterbirds on both individual waterbodies in the WLC as well as pooled abundance data for the WLC as a whole, with analyses performed separately for summer and winter count data collected in the 1992–2019 surveys.

The selection of reliable estimators of population change is essential in monitoring programmes generating trend data (Ortiz-Velez & Kelley 2023). Zero-inflation resulting from the inclusion of rare species in datasets can bias statistical estimates and trend detection (Cunningham & Lindenmayer 2005), and data screening prior to analysis can typically include exclusion of species with few observations (Thomas & Martin 1996) by setting arbitrary thresholds of percent presence among samples (Ortiz-Velez & Kelley 2023). Count data of only abundant and regularly occurring waterbirds were used in analyses, defined here as species that in the 1992 to 2019 surveys had an average abundance of five or more individuals on at least one waterbody as well as on all waterbodies combined, and were recorded in 50% or more of surveys on at least one waterbody. Data were analysed using Systat Version 13 (Systat 2009).

Ethical considerations

This article followed all ethical standards for research without direct contact with human or animal subjects.

Results

A total of 17 indigenous herbivorous waterbird species were recorded in the WLC. The abundance data of 12 of these species were used in analyses (Table 1), whereas the data of five species (White-faced Duck *Dendrocygna viduata*, Fulvous Duck *Dendrocygna bicolor*, South African Shellduck *Tadorna cana*, African Black Duck *Anas sparsa*, and Blue-billed Teal *Spatula hottentota*) were excluded because of the rarity of these species within the WLC.

Seasonal differences in waterbird abundances

Of the 12 species assessed, five were significantly more abundant during surveys undertaken in the winter months (Red-knobbed Coot *Fulica cristata*, Common Moorhen *Gallinula chloropus*, Red-billed Teal *Anas erythrorhyncha*, White-backed Duck *Thalassornis leuconotus* Maccoa Duck *Oxyura maccoa*), and four were significantly more abundant during surveys undertaken in the summer months (Egyptian Goose *Alopochen aegyptiaca*, Yellow-billed Duck *Anas undulata*, Spur-winged Goose *Plectropterus gambensis*, Cape Shoveler *Anas smithii*) (Table 1). The abundance of Southern Pochard *Netta erythropthalma*, African Purple Swamphen *Porphyrio madagascariensis* and Cape Teal *Anas capensis* within the WLC did not differ significantly between summer and winter surveys.

TABLE 1: Seasonality of herbivorous waterbirds on waterbodies in the Wilderness Lakes Complex, with species grouped according to season of higher abundance. Average abundances are given of waterbirds on lakes and estuaries in both summer and winter surveys undertaken from 1992 to 2019.

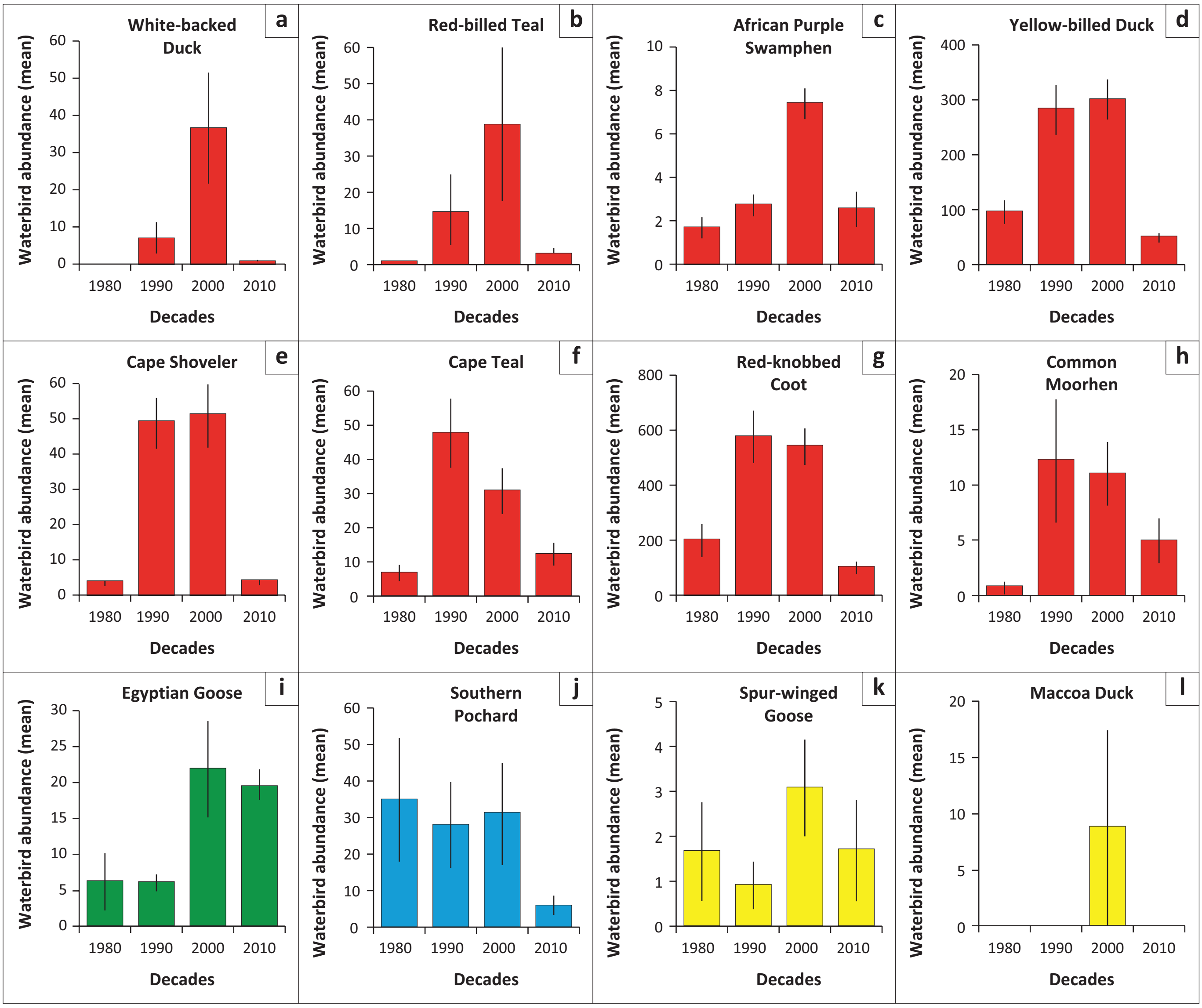
Seasonality	Species	Average abundance - Summer							Average abundance - Winter							Test statistics for WLC	
		RV	LV	EV	TE	SL	SE	WLC	RV	LV	EV	TE	SL	SE	WLC	Mann-Whitney (*U*)	*P* <
Winter	White-backed Duck	5	10	0	0	7	0	21	30	87	8	0	23	0	148	23.0	0.000
	Red-billed Teal	6	10	1	0	3	1	21	16	36	5	0	29	4	90	168.0	0.000
	Maccoa Duck	3	5	0	0	0	0	8	17	50	0	0	0	0	67	85.0	0.000
	Common Moorhen	5	23	16	1	4	0	50	17	74	34	3	11	2	141	89.5	0.000
	Red-knobbed Coot	948	1729	610	6	2390	538	6220	1151	2359	638	11	3955	842	8956	231.0	0.013
Summer	Egyptian Goose	104	106	32	4	11	7	265	24	64	20	6	11	4	128	581.5	0.001
	Yellow-billed Duck	239	336	70	18	122	76	861	112	152	50	19	118	90	541	517.5	0.001
	Cape Shoveler	175	284	58	0	220	136	873	29	82	18	0	96	102	327	572.0	0.005
	Spur-winged Goose	1	18	2	0	1	1	24	0	2	1	0	2	0	4	564.0	0.002
Non-seasonal	Cape Teal	3	3	0	0	2	4	12	5	6	0	0	3	6	21	282.0	0.106
	Southern Pochard	68	87	4	0	4	0	161	64	97	18	0	3	2	183	305.5	0.222
	African Purple Swamphen	2	5	3	0	4	1	15	2	5	3	0	4	0	15	379.0	0.987

Note: RV, Rondevlei; LV, Langvlei; EV, Eilandvlei; TE, Touw Estuary; SL, Swartvlei Lake; SE, Swartvlei Estuary; WLC, Wilderness lakes complex comprising all before mentioned waterbodies. Test statistics are given for the seasonal difference in the abundance of waterbirds within the entire Wilderness Lakes Complex for the Mann-Whitney *U* test where *p*, probability value.

Variation in waterbird abundances between survey periods

Herbivorous waterbirds could be categorised into one of four groups depending on the pattern of change in abundance across the four decades in the study period. These included: (1) species increasing significantly in most or all decades; (2) species decreasing significantly over time and particularly relative to abundances in the 1980s; (3) species with a low-high-low pattern, with significant increases in the decades after the 1980s, a high in either the 1990s or 2000s, followed by a decline in the following decade or decades; and (4) species with consistently low abundance, and for whom no substantial change in average abundance between decades was apparent.

Most abundant herbivorous waterbirds on the Swartvlei system (8 out of 10) underwent similar changes, namely relatively low abundance in the 1980s, higher abundance in the 1990s (Cape Teal, Red-knobbed Coot, Common Moorhen) (Figure 2f–h) and/or 2000s (Cape Shoveler, Yellow-billed Duck, Red-billed Teal, White-backed Duck, African Purple Swamphen), followed by a decline in the 2010s (Figure 2a–e). The low-high-low trend exhibited by Maccoa Duck (Figure 2l) is probably not biologically significant, as the species is mostly absent on the Swartvlei system, and was recorded only once (seven individuals on Swartvlei Lake in July 2008) out of 126 surveys conducted on waterbodies in this system. The abundance of Egyptian Goose on the Swartvlei system remained stable between the 1980s and 1990s, increased substantially in the 2000s, followed by a relatively small decline in 2010s (Figure 2i). By contrast, Southern Pochard, although relatively uncommon on the Swartvlei system, exhibited an overall decrease in abundance, with average abundances showing little change from the 1980s through to the 2000s and decreasing in the 2010s.



Note: Vertical whiskers show 95% confidence limits of means in each decadal period. Colouring of bars is used to categorise species into one of four groups depending on the pattern of change in abundance across the study period, where red = species with a low-high-low pattern, with significant increases in the decades after 1980s, a high in either the 1990s or 2000s, followed by a decline in the following decade or decades, green = species increasing significantly in one or more decades, blue = species decreasing significantly over time and particularly relative to abundances in the 1980s, and yellow = species with consistently low abundance, and/or for whom no substantial change in average abundance between decades was apparent.

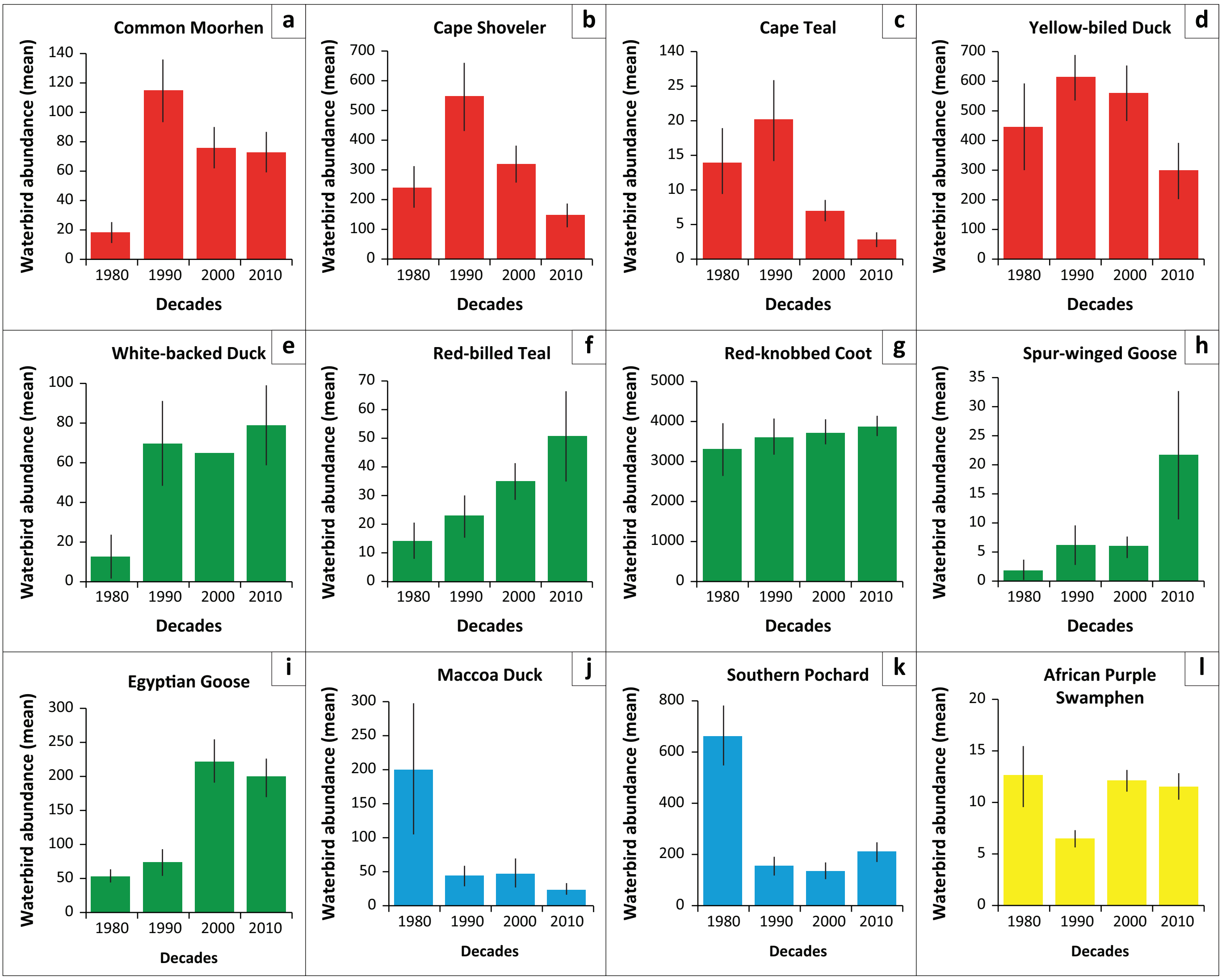
FIGURE 2a-l: Average abundances of herbivorous waterbirds on the Swartvlei system over four decades, where 1980 = period 1980–1989, 1990 = period 1990–1999, 2000 = period 2000–2009 and 2010 = period 2010=2019.

All species on the Swartvlei system underwent a decrease in abundance in the 2010s compared to the 2000s, and in most cases also the 1990s (Figure 2). For some species, notably Egyptian Goose, the decrease was relatively small (Figure 2i), whereas for other species such as White-backed Duck, Red-billed Teal, Cape Shoveler, Yellow-billed Duck and Red-knobbed Coot, the decreases in average abundance in the 2010s were substantial (Figure 2a, Figure 2b, Figure 2d, Figure 2e and Figure 2g).

Out of 12 herbivorous waterbirds on the Touw system, four (Common Moorhen, Cape Shoveler, Cape Teal, Yellow-billed Duck) showed the same low-high-low trend as exhibited by most herbivorous waterbirds, including these species, on the Swartvlei system (Figure 3a, Figure 3b, Figure 3c, Figure 3d). Decreases in the abundance of Common Moorhen, Cape Shoveler and Cape Teal were already substantial in the 2000s, whereas decreases in the abundance of Yellow-billed Duck were more prominent in the 2010s. Four species (White-backed Duck, Red-billed Teal, Red-knobbed Coot, Spur-winged Goose) increased in abundance on the Touw system (Figure 3e, Figure 3f, Figure 3g, Figure 3h), and a fifth species, Egyptian Goose, despite decreases in the 2010s, also exhibited an overall increase in abundance on this system (Figure 3i). By contrast, an overall decrease in the abundance of the Near Threatened Maccoa Duck, and Southern Pochard, occurred on the Touw system (Figure 3j and Figure 3k), with the most substantial changes in or by the 1900s. The average abundance of the relatively uncommon African Purple Swamphen on the Touw system remained largely unchanged over time (Figure 3l).

Abundance trends: 1992 onwards

Decreases have occurred in the abundance of five herbivorous waterbirds in the WLC as a whole from 1992 onwards during either one season (Common Moorhen)



Note: Vertical whiskers show 95% confidence limits of means in each decadal period. Colouring of bars is used to categorise species into one of four groups depending on the pattern of change in abundance across the study period, where red = species with a low-high-low pattern, with significant increases in the decades after 1980s, a high in either the 1990s or 2000s, followed by a decline in the following decade or decades, green = species increasing significantly in one or more decades, blue = species decreasing significantly over time and particularly relative to abundances in the 1980s, and yellow = species with consistently low abundance, and/or for whom no substantial change in average abundance between decades was apparent

FIGURE 3a-l: Average abundances of herbivorous waterbirds on the Touw system over four decades where 1980 = period 1980–1989, 1990 = period 1990–1999, 2000 = period 2000–2009 and 2010 = period 2010–2019.

(Figure 4g) or both seasons (Yellow-billed Duck, Cape Shoveler, Cape Teal, Red-knobbed Coot) (Figure 4a, Figure 4b, Figure 4c and Figure 4f), whereas increases have occurred in the abundance of Spur-winged Goose during one season (Figure 4f) and Egyptian Goose during both seasons (Figure 4d).

Decline in the overall abundance of Common Moorhen has been significant in winter (Z = -2.114, p < 0.05) and most prominent on Rondevlei (Z = -2.642, p < 0.01) and Swartvlei Lake (Z = -1.990, p < 0.05). Significant decreases in the abundance of Yellow-billed Duck, Cape Shoveler and Cape Teal in the WLC occurred during both summer (Yellow-billed Duck Z = -2.231, p <0.013; Cape Shoveler Z = -5.087, p < 0.000; Cape Teal Z = -3.600, p < 0.000) and winter (Yellow-billed Duck Z = -4.366, p <0.000; Cape Shoveler Z = -3.971, p < 0.000; Cape Teal Z = -2.876, p < 0.000) survey periods. Declines in the abundances of these three ducks have been widespread, occurring on most WLC waterbodies, and in both seasons (Figure 5), with the exception of Touw Estuary, where Cape Shoveler occurred very infrequently (average <0.2 individuals/survey) and Cape Teal was never recorded during biannual waterbird surveys. Declines in the abundance of Yellow-billed Duck, Cape Shoveler and Cape Teal have occurred across the study period (Figure 4a, Figure 4b and Figure 4d), although they have been particularly prominent from 2015 onwards.

Decreases in abundance of Red-knobbed Coot occurred during both summer (Z = -2.251, p < 0.05) and winter (Z = -2.746, p < 0.01) periods in the WLC, though they displayed contrasting abundance changes on different waterbodies (Figure 5). The overall decline in the abundance of this species was driven largely by substantial decreases on Swartvlei Lake during both seasons (summer Z = -3.502, p < 0.01; winter Z = -3.102, p < 0.01). By contrast, significant increases occurred on Rondevlei during both summer (Z = 2.944, p < 0.01) and winter (Z = 2.746, p < 0.01) periods (Figure 5).

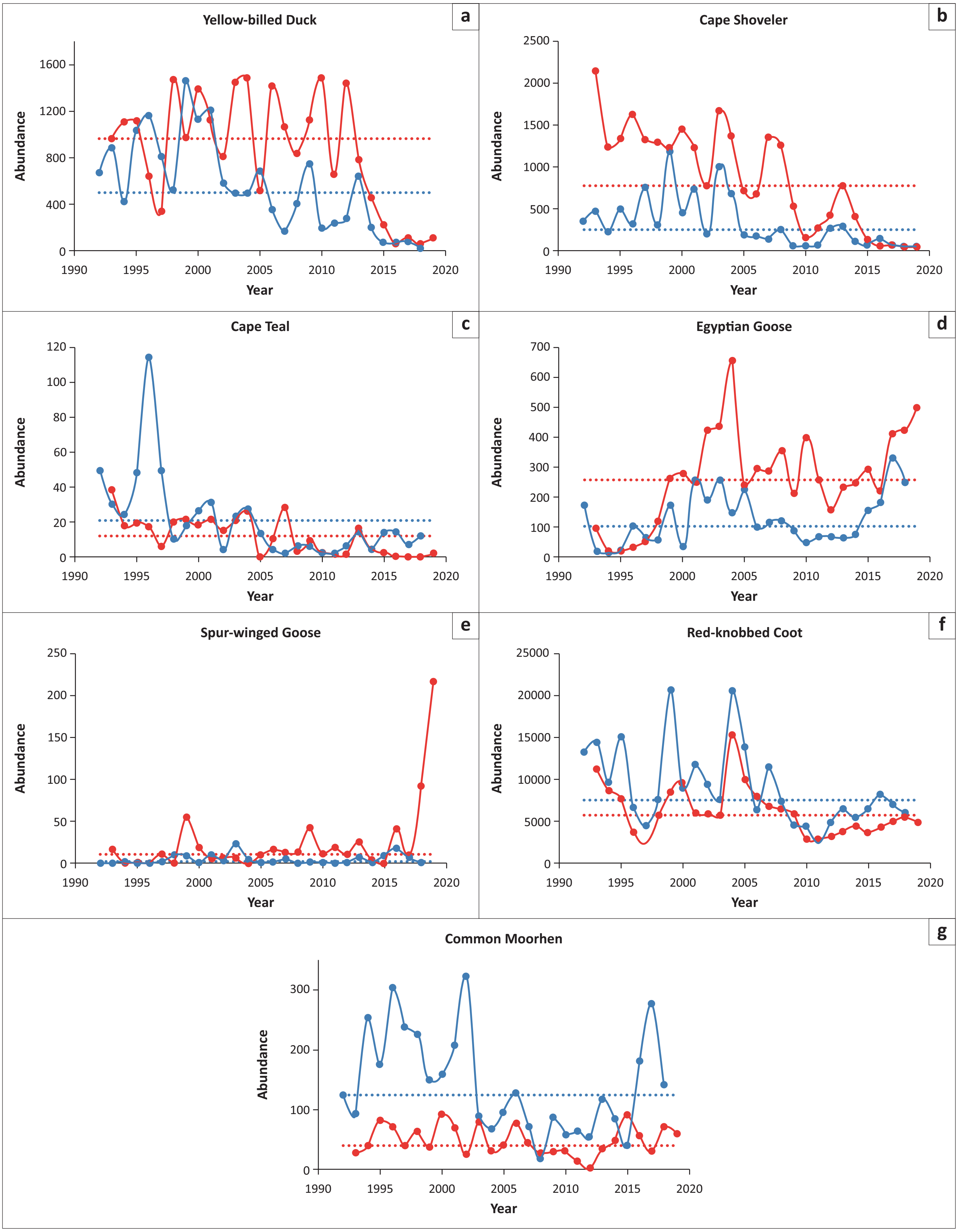
Significant increases in abundance of Egyptian Goose occurred in the WLC during both summer (Z = 2.835, p < 0.01) and winter (Z = 1.917, p < 0.05) periods, though they displayed contrasting abundance changes in different waterbodies (Figure 5). Increases in Egyptian Goose have occurred on most waterbodies, notably during both seasons on Langvlei, Eilandvlei, Touw Estuary and Swartvlei Lake, as well as during winter on Swartvlei Estuary (Figure 5). Contrary to this broad pattern of widespread increases, Egyptian Goose numbers on Rondevlei declined during both summer (Z = -2.095, p < 0.05) and winter (Z = -2.931, p < 0.01) survey periods.

An increase in the abundance of Spur-winged Goose occurred during summer periods in the WLC (Z = 2.325, p < 0.05), driven largely by substantial increases during summer surveys on Langvlei at the end of the survey period (2018–2019) where 216 individuals were recorded in 2019 compared to an average of 10 individuals (max = 49, min = 0) in earlier surveys. By comparison, increases in the abundance of Spur-winged Goose on Eilandvlei were relatively small, with the species not being recorded up until 2014, and being relatively uncommon (average = 2, maximum = 8) in surveys spanning 2015 to 2019.

Five herbivorous waterbirds have undergone changes in abundance on one or more waterbody, though this has not translated into a significant change in overall abundance in the WLC. Red-billed Teal has significantly increased on Rondevlei (Z = 1.722, p < 0.05) and African Purple Swamphen on Langvlei (Z = 2.049, p < 0.05), both during summer survey periods (Figure 5). By contrast, White-backed Duck has significantly decreased in abundance on Swartvlei Lake (Z = -2.312, p < 0.05) during winter survey periods. Both Maccoa Duck and Southern Pochard have undergone differing changes on different waterbodies (Figure 5). Maccoa Duck increased in abundance during both survey periods on Rondevlei (summer Z = 1.939, p < 0.05; winter Z = 2.919, p < 0.01), though over the same period, their abundance significantly decreased on the adjacent Langvlei (summer Z = -2.271, p < 0.05; winter Z = -1.879, p < 0.05). Significant increases in the abundance of Southern Pochard occurred on Rondevlei during summer survey periods (Z = 1.927, p < 0.05), whereas decreases were evident on both Swartvlei Lake (Z = -2.449, p < 0.01) and Eilandvlei (Z = -1.727, p < 0.05).

Of the species that have undergone significant changes in abundance, the dominant pattern in the WLC has been a similar direction of change across multiple waterbodies, and in different seasons, rather than the type of change differing either spatially or temporarily (Figure 5). Exceptions to this pattern have, however, occurred on Rondevlei, where trend directions (increasing or decreasing) for Maccoa Duck, Red-knobbed Coot, Egyptian Goose, and Southern Pochard differ from other waterbodies in the WLC (Figure 5).

The direction of change has differed between species within a waterbody despite similarity in trophic guild, with increases, decreases and stable population sizes recorded on all waterbodies (Figure 5). If a differentiation is made between species that feed predominantly on emergent or land-based plants (Egyptian Goose, African Purple Swamphen) and the remainder that feed predominantly either on submerged macrophytes or associated epibenthic invertebrates, the dominant trends are increases in land-based feeders, and declines in submerged plant feeders on virtually all waterbodies in the WLC. The exceptions are on Rondevlei where, along with species declines, concurrent increases have occurred in four species which feed predominantly on submerged plants or associated invertebrates (Red-knobbed Coot, Red-billed Teal, Maccoa Duck, Southern Pochard), as well as on the Touw Estuary where, because of the persistent low abundance of most herbivorous species, few significant changes have occurred.



Note: Blue solid lines and markers depict average annual abundances in winter surveys, and red solid lines and markers depict average annual abundances in summer surveys. Stippled lines show average abundances across the study period.

FIGURE 4a-g: Abundances of herbivorous waterbirds in the Wilderness Lakes Complex showing significant changes in abundance from 1992 onwards in at least one season.

Seasonality	Species	WLC		RV		LV		EV		TE		SVL		SVE	
		Slope		Slope		Slope		Slope		Slope		Slope		Slope	
		S	W	S	W	S	W	S	W	S	W	S	W	S	W
Winter	White-backed Duck	-	-	-	-	-	-	-	-	-	-	-	↓	-	-
	Red-billed Teal	-	-	↑	-	-	-	-	-	-	-	-	-	-	-
	Maccoa Duck	-	-	↑	↑	↓	↓	-	-	-	-	-	-	-	-
	Common Moorhen	-	↓	↓	↓	-	-	-	-	-	-	-	↓	-	-
	Red-knobbed Coot	↓	↓	↑	↑	-	-	-	-	-	-	↓	↓	-	-
Summer	Egyptian Goose	↑	↑	↓	↓	↑	↑	↑	↑	↑	↑	↑	↑	-	↑
	Yellow-billed Duck	↓	↓	-	↓	↓	↓	↓	↓	-	↓	↓	↓	↓	↓
	Cape Shoveler	↓	↓	↓	-	↓	↓	↓	↓	-	-	↓	↓	↓	↓
	Spur-winged Goose	↑	-	-	-	↑	-	-	↑	-	-	-	-	-	-
Non-seasonal	Cape Teal	↓	↓	-	↓	↓	-	-	↓	-	-	↓	-	↓	-
	Southern Pochard	-	-	↑	-	-	-	↓	-	-	-	↓	-	-	-
	African Purple Swamphen	-	-	-	-	↑	-	-	-	-	-	-	-	-	-

Note: In the table body, Red down arrow, significant decline in abundance within the study period; Green up arrow, significant increase in abundance within the study period; dash, no significant trend within the study period. Test statistics provided in Appendix 1.

WLC, Wilderness lakes complex comprising all the hereafter mentioned waterbodies; RV, Rondevlei; LV, Langvlei; EV, Eilandvlei; TE, Touw Estuary; SL, Swartvlei Lake; SE, Swartvlei Estuary; S, summer counts; W, winter counts.

FIGURE 5: Graphic depiction of the test results of the Mann-Kendall tests performed on selected herbivorous waterbird abundance data collected on each waterbody between 1992 and 2019, and combined data for all waterbodies, per season, to test for the significance and direction of non-seasonal trends.

Discussion

Seasonal differences in herbivorous waterbird abundances

Most southern African Anatidae are thought to be largely non-migratory or sedentary (Scott & Rose 1996), though some can be dispersive and nomadic in their ranges (cf. Red-billed Teal) (Oatley & Prys-Jones 1986), or can undertake local migrations for moulting (cf. Southern Pochard) (Hockey et al. 1989). However, the movement patterns of most southern African herbivorous waterbirds are poorly understood, with observed seasonal differences in the WLC potentially contributing to this understanding.

The absence of significant seasonal differences in the abundance of Cape Teal and African Purple Swamphen is similar to that recorded by Boshoff et al. (1991) in the WLC, as well as regionally in the Western Cape (Maclean 1997a; Taylor 1997). Assessments of the movements of waterbirds on a regional scale found White-backed Duck, Red-billed Teal, Yellow-billed Duck, and Cape Shoveler to be largely resident and sedentary in the Western Cape (Maclean 1997b, 1997c, 1997d, 1997e), or at times nomadic (cf. White-backed Duck) (Irwin 1981), but with no clear patterns of movement. By contrast, distinct seasonality, and seasonally similar changes in the abundances of these four waterbirds were observed in both this study and an earlier assessment (Boshoff et al. 1991) within the WLC. Differing conclusions on the seasonality of other species are also apparent, with Maclean (1997f) describing an influx of Maccoa Duck into the south-western Cape during spring and early summer, whereas both Boshoff et al. (1991) and this study found Maccoa Duck to be significantly more abundant in the winter months. Similarly, recorded increases in the abundances of Egyptian Goose (Hockey et al. 1989; Tree 1987) and Southern Pochard (Maclean & Harrison 1997) in the Western Cape in winter differ from the findings of this study where Egyptian Goose in the WLC were significantly more abundant in summer, and Southern Pochard were non-seasonal. Different waterbird surveys in the WLC have also led to differing conclusions of the seasonality of four abundant herbivorous waterbirds, with Boshoff et al. (1991) in the 1980s, and this study from the 1990s onwards showing different seasonality for Red-knobbed Coot and African Moorhen (non-seasonal vs. winter) as well as Egyptian Goose (winter vs summer) and Southern Pochard (winter vs non-seasonal). Differences in observed seasonal movements of several herbivorous waterbirds between studies indicate possible spatial differences in habitat usage across regions, and the observed differences in seasonal usage of waterbodies suggest that preferential habitat usage among some herbivorous waterbirds may be inconsistent and varies over time, presumably driven by temporal changes in the suitability of wetlands across their ranges for various life processes.

Regular breeding of four Anitidate species (Egyptian Goose, Yellow-billed Duck, Cape Shoveler, Cape Teal) occurs in the WLC (Randall, Randall & Kiely 2007), though only Egyptian Goose breed in significant numbers. Use of the WLC waterbodies by most Anitidae is likely to be predominantly for feeding and moulting. Seasonal differences are thus likely to be driven more by local wetland conditions, including feeding opportunities and disturbance, rather than breeding.

Changes in herbivorous waterbird abundances

The abundances of several waterbirds, including ducks, crakes and allies are thought to be in decline globally (Wetlands International 2012) and notably in Africa (Nagy et al. 2014). However, the quality of existing trend data is generally poor. The trends indicated in this study show a combination of declining, increasing and stable herbivorous waterbird populations which, in several instances, at the species level, differ from regional (southern Africa) assessments. For instance, Wetlands International (2012) describes the populations of Yellow-billed Duck, Cape Shoveler and Cape Teal as increasing, and the population of Red-billed Teal as stable, yet by contrast all four of these species have undergone significant declines on multiple waterbodies in the WLC, and particularly in the 2000s or 2010s. Alternatively, the southern African trend of Egyptian Goose is listed as stable in 2012 (Wetlands International 2012); yet assessments in this study, and elsewhere within South Africa (Harebottle 2011; Hockey & Midgley 2009; Hockey et al. 2011; Ryan 2013; Taylor et al. 1999), show this species to be mostly increasing in abundance across this range. The abundance of African Purple Swamphen within southern Africa was listed in 2012 as decreasing (Wetlands International 2012), though local populations remain relatively stable, and on some waterbodies, such as Langvlei, their abundance is increasing.

Of the species discussed in this study, only the Maccoa Duck is included in the global and regional Red Lists, where it is globally classified as Endangered (IUCN 2022), and regionally (southern Africa) as Near Threatened (eds. Taylor, Peacock & Wanless 2015:296) largely because of declines in its northern populations. The national assessment of waterbird status in freshwater systems, though typically more ecosystem rather than species orientated, stresses that freshwater wetlands are the most threatened of all South Africa's ecosystems, with 48% of wetland types classified as Critically Endangered, yet concludes that the majority of freshwater associated taxa, including 83% of birds, are well protected (eds. Van Deventer et al. 2019:339). The situation is somewhat different in South African estuaries, with ~99% of the total estuarine area classified as Threatened (eds. Van Niekerk et al. 2019:152), and with bird numbers, including herbivorous waterbirds, on a 'significant negative trajectory' in the majority of large systems (eds. Van Niekerk et al. 2019:196), as also observed in the lake systems in this study. Van Niekerk et al. (eds. 2019:198) also highlight notable declines across multiple systems of Southern Pochard (~95%) and Maccoa Duck (~94%), which are the two species on the Touw system that have undergone substantial declines in or by the 1990s, whereas for all other assessed species changes have been more complex, and declines more recent. Increases in the abundance of Egyptian Goose are also highlighted as a wide-scale trend occurring in multiple systems (eds. Van Niekerk et al. 2019:198).

Changes in herbivorous waterbird communities have been observed on several coastal wetlands within the Western Cape. Changes are specific to wetlands, with past studies in Rocher Pan (1979–2004) failing to demonstrate an overall decline in duck numbers (Harebottle 2011), whereas the more common trend, as in the Bot Estuary and De Hoop Vlei, and similar to the WLC, appears to be long-term declines in several species of herbivorous waterbirds, including Red-knobbed Coot, Yellow-billed Duck, Southern Pochard and Cape Shoveler, and increases in Egyptian Goose (Harebottle 2011; Shaw 1998). Of the Anitidae undergoing declines in the WLC, Maclean (1997a, 1997c, 1997d) states that populations of Cape Shoveler, Yellow-billed Duck and Cape Teal are either stable or likely increasing across their ranges, including the Western Cape, after having benefitted from the provision of dams and sewage ponds. This would suggest that local declines would be driven primarily by changes in local conditions. However, the similarity of trends in the spatially separated Touw, Swartvlei and the Knysna systems (unpublished Coordinated Waterbird Counts [CWAC] data), suggests either high interconnectivity of populations between wetland systems and/or some drivers of change of some mobile species may be broad scaled and regional rather than just system specific.

Possible reasons for changes in herbivorous waterbird abundances

Population changes may occur because of multiple reasons, including variation in the suitability of count sites, as well as other non-surveyed sites (Bennun & Nasirwa 2000:224). Linking changes in waterbird abundance to causal factors is generally difficult, and requires detailed knowledge of the environmental requirements of species, movement patterns, environmental changes across their range, and changes in recruitment and survivorship. These are, for the most part, poorly understood and particularly at larger scales, though exploring correlations between known local conditions and bird abundances can provide some insights into these linkages.

Intensifying agricultural activities and land-use changes throughout waterbird ranges can affect their abundance and movement patterns, particularly of open–water species including ducks and geese (Davidson & Delany 1999:14). Changes in conditions outside of the WLC are the likely cause of increase in the abundance of Egyptian Goose, which utilises waterbodies in the WLC extensively as a moulting site (pers obs). The Egyptian Goose has benefitted in many parts of its range from the increasing numbers of pastures, grain crops and trees for breeding, and reduced hunting pressure (Hockey & Midgley 2009; Hockey et al. 2011; Mangnall & Crowe 2001; Taylor et al. 1999). Spur-winged Goose also feeds extensively on croplands (Maclean 1997g) and the species is also likely to have benefitted from the expansion of cultivated fields (Raeside et al. 2007:84). Increase in geese numbers in the WLC, and Egyptian Goose on the adjacent Knysna Estuary (unpublished CWAC data) within the survey period, is consistent with increases reported throughout the Western Cape over the past few decades (Harebottle 2011; Ryan 2013; Taylor et al. 1999).

Several authors have commented on the likelihood of increases in habitat for waterbirds through the creation of artificial wetlands, notably farm dams (eds. Hockey et al. 2005; Kalejta-Summers, Allan & Longrigg 2001a) and waste water treatment works (Harebottle et al. 2008; Kalejta-Summers, McCarthy & Underhill 2001b). Dabbling species in particular, such as Yellow-billed Duck, have benefitted from shallow artificial wetlands (Vernon & Dean 2005), unlike diving species, such as Maccoa Duck, which favour deeper waters with ample vegetation generally not characteristic of artificial wetlands (Froneman et al. 2001; Raeside et al. 2007:83; Russell, Randall & Hanekom 2014:12). Davidson and Delany (1999:14) suggested that the creation of year-round habitat can lead to changed seasonal patterns of movement, particularly for open–water species including ducks and geese, which in some cases may now remain at their breeding sites to moult (Kalejta-Summers et al. 2001b). The possibility exists that decreases in the abundances of several herbivorous waterbird species in the WLC may, in part, result from favourable habitat increasingly occurring elsewhere, rather than just a decline in local conditions, or regional population declines.

Internal environmental processes in wetlands and long-term changes in these processes, as occurring in the WLC (Russell 2003), also likely influence habitat usage by waterbirds and temporal variability in their abundance. Significant long-term (~40 year; from mid-1970s onwards) changes have occurred in emergent aquatic vegetation in the WLC, including increases of tall reeds (*P. australis*) and rushes (*T. capensis*), and the loss of many open shorelines and sandbanks because of invasion and establishment of emergent aquatic plants (Russell 2003). These changes in environmental conditions are likely to affect habitat suitability for several herbivorous waterbirds. All of the ducks, with the exception of the stiff-tail species (Maccoa Duck, White-backed Duck), use open shorelines and sandbanks for resting, maintenance and roosting, and loss of such areas is likely to have reduced the suitability of some waterbodies for these activities, and particularly the lake-like water bodies in both the Touw and Swartvlei systems. Alternatively increases in sheltered sites resulting from the proliferation of emergent vegetation are likely to favour rallids, who utilise emergent macrophytes for cover and as a nesting platform (Common Moorhen, Red-knobbed Coot) and feeding (African Purple Swamphen).

Local changes in environmental conditions, and particularly the accessibility of food, have been demonstrated to have substantial effect on waterbird numbers (Heÿl & Currie 1985; Terörde & Turpie 2013). Most herbivorous waterbirds use waterbodies in the WLC predominantly as feeding and moulting areas rather than breeding sites (Randall et al. 2007). The diet of many of the waterbirds discussed here consists largely of aquatic plants or invertebrates commonly associated with submerged plants (Brickell 1988; eds. Hockey et al. 2005). Russell et al. (2009:38) demonstrated the relationship between herbivorous waterbird abundance and submerged macrophyte density in the Touw system, with declines in plant biomass in the adjacent Swartvlei system also correlating with significant declines in herbivorous waterbirds (Russell & Randall 2017:669). Changes in the availability of local food sources would be expected to significantly influence herbivorous bird abundances (Russell et al. 2009:39). Several bird abundance changes that have occurred between surveys can potentially be explained, in part, by altered environmental conditions in the lakes, and particularly the abundance of aquatic plants. Conditions in the 1980–1983 surveys were in some senses atypical, with high rainfall events recorded in 1980 leading to elevated turbidity levels, prolonged opening of estuary mouths and associated elevations of salinity in the Swartvlei system, and resultant reductions in plant biomass (Weisser, Whitfield & Hall 1992; Whitfield 1984). The biomass of pondweed *S. pectinata* in Swartvlei Lake in 1979 was 1035 g/m^2 but declined to 24 g/m^2 in 1980, and 0 g/m^2 in mid-surveys in 1982 (Whitfield 1984) following substantial floods in 1980. Although the biomass of aquatic plants in Swartvlei Estuary was not determined during bird surveys in the early 1980s, the biomass of the dominant specie spiral tasselweed *Rupia chirrosa* was likely low as significant declines in the biomass of this species typically occur in Swartvlei Estuary after flood events (Hanekom & Russell 2015). Although sampling of plant biomass in Rondevlei did not occur between 1980 and 1983, prior assessments indicated low biomass (1975 g/m^2– 0 g/m^2; 1978 g/m^2 – 25 g/m^2) (Hall 1985) compared to that recorded in surveys from 1992 onwards (average 702 g/m^2) (Russell et al. 2019) suggesting that low plant biomass was likely during the 1980–1983 waterbird surveys. By contrast, the plant biomass in both Langvlei (1982 g/m^2 – 799 g/m^2, 1983 g/m^2 – 1100 g/m^2) and Eilandvlei (1982 g/m^2 – 748 g/m^2, 1983 g/m^2 – 1100 g/m^2) was high (Hall 1985), and comparable to the biomass in the 1992–2019 survey period (Russell et al. 2019). Thus, the expectation would be, and as observed for most duck and particularly dabbling ducks, substantially lower abundance of herbivorous waterbirds on the Swartvlei system in the 1980s when plant biomass was low compared to later decades, and with this trend being less pronounced on the Touw system.

A significant reduction in submerged aquatic plants in the Swartvlei system from 2007 onwards following elevations in salinity (Russell & Randall 2017), is likely to have contributed to the decline in the abundance of several herbivorous waterbirds species, and particularly the previously abundant, Yellow-billed Duck, Cape Shoveler and Red-knobbed Coot. Declines in plant biomass in the WLC, although significant, are possibly not the sole causal factor for the observed changes in herbivorous waterbirds, as attested by declines in particularly Yellow-billed Duck and Cape Shoveler on Knysna Estuary over the same time period (unpublished CWAC data), and where there is no evidence of changes in plant biomass.

The Garden Route National Park is, in essence, an urban conservation area, with multiple adjacent and embedded urban, settlement and agricultural areas, particularly adjacent to the lakes and larger estuaries along the coast. The majority of the waterbodies in the WLC are open access, and actively used for a range of dynamic recreational activities, including sailing, powerboating, canoeing, swimming, fishing and walking, by an ever-increasing population of permanent residents and seasonal holiday makers. Only on Rondevlei and Langvlei is access restricted and recreation is limited to bird-watching from two bird hides. Disturbance and displacement of waterbirds as a result of recreational activities can be significant, with on De Hoop Vlei in the Western Cape, the Cape Shoveler found to be the most severely affected of the herbivorous waterbirds, with disturbed individuals abandoning their initial position for up to an hour (De Blocq van Scheltinga 2017). Even the so called eco-friendly, nature based recreational activities (for example non-motorised boating) can have a range of negative effects on birds, with Steven, Pickering and Castley (2011), in a review of 69 studies addressing the topic, finding that 88% of them demonstrated negative impacts, including changes in bird physiology, behaviour, abundance, and breeding success. While disturbance and temporary displacement of herbivorous waterbirds from a site without special importance to them may seem inconsequential, this will not necessarily be true for birds that are flushed from important feeding or resting sites (Bélanger & Bédard 1990:39). The effects of disturbance on waterbird abundance and behaviour have never been studied on the waterbodies in the WLC. Habituation and tolerance of human disturbance has been reported in several waterbird species (Nisbet 2000:325). However, the weight of international evidence on the negative impacts of recreation and ecotourism activities (Steven et al. 2011), combined with a perceived progressive increases in recreational usage of the WLC (per obs), including potentially highly disruptive practices such as powerboating, skiing and dog walking on many waterbodies, suggests that the impacts of disturbance on waterbirds in open access portions of the WLC could be significant.

Annual outbreaks of avian botulism have occurred on the upper lakes on the Touw system since 2015 with the most severely affected species being Red-knobbed Coot, Cape Shoveler and Yellow-billed Duck (Russell et al. 2019). Declines in these species, and particularly the two dabbling ducks, preceded these outbreaks, thus avian botulism cannot realistically be identified as the primary cause of long-term changes in waterbird abundances. However, the large number of deaths because of the disease (Russell et al. 2019), particularly of Cape Shoveler, has potentially contributed to the continuation of the decline in the last 5 years of the 1992–2019 surveys.

Reasons for significant declines in the abundance of some diving ducks (Maccoa Duck and Southern Pochard) on the Touw system since 1992, as well as contrasting changes on Rondevlei and Langvlei in this system are unclear. These species favour secluded deep water with plentiful vegetation (Irwin 1981; Maclean 1997f; Maclean & Harrison 1997; Raeside et al. 2007:83) as occurring on Rondevlei and Langvlei where they are most abundant (Russell et al. 2014). Water levels do fluctuate in these high use waterbodies but this is substantially reduced from what would occur naturally because of periodic artificial breaching of the linked Touw Estuary (Russell et al. 2019:8), and is unlikely to have an effect on diving ducks, because of their ability to access deeper submerged plants and invertebrates. Diving ducks would likely locate underwater food sources visually. There is no evidence of water clarity having declined in the WLC between surveys, with long term increases in water clarity having been recorded in several waterbodies (Russell 2013). Maccoa Duck rarely leaves the water (Brickell 1988), thus the loss of sandbanks because of water-level stabilisation and the resulting proliferation of emergent vegetation (Russell 2003) is less likely to reduce habitat suitability, and may even maintain or increase the suitability of habitat in the lakes for this specie. Human disturbance is also unlikely to have played a significant role in abundance changes of diving ducks on the Touw system as human access to both Rondevlei and Langvlei has been restricted throughout both study periods, and has been strictly enforced since the proclamation of the lakes as a national park in 1983 at the end of the first survey period. Perceived threats to Maccoa Duck that have the potential to be applicable in the WLC include drowning in illegally used gill nets, the concentration of pollutants in benthic invertebrates which form part of their diet, and competition with alien benthic feeding species such as common carp (eds. Berruti et al. 2007), and could be the focus of future studies.

Conclusions

Changes in the abundances of several herbivorous waterbird species in the WLC over the four decade study period (1980s to 2010s) are substantial, and for most species directional and ongoing. From a conservation perspective, most of the observed trends, and particularly declines in abundance, are concerning. One of the primary reasons for the declaration of the Touw system as a Ramsar site in 1991 was the regular high abundance of both Yellow-billed Duck and Cape Shoveler, particularly on Rondevlei and Langvlei (Randall 1990). The Ramsar criteria of regularly supporting globally significant (>1% global populations) numbers has not been achieved for the Yellow-billed Duck (1% = 1000 individuals) during summer counts on the Touw system since 2012, with this target achieved in 38% of summer surveys in earlier (1992–2012) years. Similarly, for the Cape Shoveler during summer counts of the Touw system, the 1% criteria (320 individuals) has not been achieved since 2014, whereas in earlier years (1992–2014) this level of abundance was exceeded in 83% of the surveys. Although the upper lakes in the Touw system continue to intermittently support Maccoa Duck in numbers in excess of the 1% criteria (75 individuals), the abundance of this species has declined substantially since the 1980s.

The fundamental character of the Wilderness Ramsar site with regard to the support of several abundant herbivorous waterbirds has changed. Drivers of change in waterbird community composition, species abundances and wetland usage are undoubtedly multifaceted, complex and in many instances poorly understood, functioning on multiple spatial and temporal scales, and affect different species in different ways. It is noteworthy that the majority of the species changes in the WLC occur in both seasons, irrespective of species specific seasonal variability in abundance, suggesting that changes occur with both resident and migratory sectors of populations. This is potentially indicative of either changes in total population sizes or changes in the suitability of the count sites, or both. The conservation of vagile species such as waterbirds is a national concern, extending beyond the boundaries of individual waterbodies. The drivers of such change likely included the wide-scale loss of natural wetlands (Department of Water Affairs 2013:42), the environmental degradation of the remaining wetlands (eds. Van Deventer et al. 2019), and possibly factors such as hunting pressures and increasing recreational use and disturbances in the remaining wetlands and breeding sites. Restorative actions are urgently required at a regional and national scale to address regional and national degradation of wetland ecosystem and loss of associated fauna. On a local scale, there are several management actions that could be implemented to potentially reduce anthropogenic impacts on waterbodies in the WLC and restore and reinstate their suitability for several declining waterbird species. These could include:

- Arresting the encroachment of emergent macrophytes into the lakes and reinstatement of open sand banks away from high intensity recreational areas, which can be used by waterbirds for feeding and resting.
- Continuation of disease management through the early and regular location and removal of bird carcasses during avian botulism outbreak periods (typically November to June).
- Reducing the adverse effects of disturbance through active management of recreational pursuits and resource use activities. In many respects, the waterbodies in the WLC are increasingly viewed and used as recreational playgrounds and areas for extractive resource use rather than for sustainable environmental conservation. The desirability of several potentially high disturbance activities, such as powerboating, kitesurfing, sailing and uncontrolled dog walking, on individual waterbodies, both spatially and temporally, needs to be reconsidered in light of their potential detrimental environmental impacts. Zonation within national park and estuary management plans could be used to restrict high disturbance activities to areas and times of low importance to waterbirds. The area of low or no usage or impact within the lakes as a whole should be increased.
- Maintenance of clear water conditions within the lakes through engagement with catchment management agencies and individual landowners regarding wise catchment management practices to minimise the inflow of sediments, as well as plant nutrients that can result in algae and cyanobacteria blooms.
- Research on the changing abundances of waterbirds in the WLC should continue, and should include assessments of the causes of outbreaks of avian botulism, and the occurrence and effects of interspecies competition for resources.

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Data availability

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Appendix starts on the next page→

Appendix 1

TABLE 1-A1: Test results of the Mann-Kendall tests performed on selected herbivorous waterbird abundance data on each waterbody collected between 1992 and 2019, and combined data for waterbodies, per season, to test for the significance and direction of non-seasonal trends.

Species	Season	Rondevlei		Langvlei		Eilandvlei		Touw Estuary		Swartvlei Lake		Swartvlei Estuary		All waterbodies	
		Z	*p*	*Z*	*p*	*Z*	*p*	*Z*	*p*	*Z*	*p*	*Z*	*p*	*Z*	*p*
White-backed Duck	Summer	1.151	0.125	0.932	0.176	-1.504	0.066	-	-	-1.402	0.080	-	-	0.376	0.354
White-backed Duck	Winter	1.471	0.071	0.692	0.245	-1.237	0.108	-	-	-2.312	0.010	-	-	0.553	0.290
Egyptian Goose	Summer	-2.095	0.018	4.742	0.000	5.258	0.000	4.013	0.000	3.406	0.000	-0.417	0.338	2.835	0.002
Egyptian Goose	Winter	-2.931	0.002	1.938	0.026	3.901	0.000	5.380	0.000	2.561	0.005	2.322	0.010	1.917	0.028
Yellow-billed Duck	Summer	-1.285	0.099	-2.549	0.005	-3.125	0.001	0.218	0.414	-1.857	0.032	-3.379	0.000	-2.231	0.013
Yellow-billed Duck	Winter	-4.053	0.000	-2.709	0.003	-3.201	0.001	-2.198	0.014	-3.735	0.000	-4.308	0.000	-4.366	0.000
Cape Teal	Summer	-1.386	0.083	-2.932	0.002	-1.308	0.095	-	-	-2.195	0.014	-2.377	0.009	-3.600	0.000
Cape Teal	Winter	-3.301	0.000	-1.193	0.068	-2.334	0.010	-	-	-1.555	0.060	-1.545	0.061	-2.876	0.002
Red-billed Teal	Summer	1.722	0.042	0.419	0.338	-0.079	0.469	1.609	0.054	-0.775	0.219	0.605	0.272	0.773	0.220
Red-billed Teal	Winter	0.178	0.429	0.890	0.187	1.492	0.068	-	-	-0.743	0.229	-1.549	0.061	0.553	0.290
Cape Shoveler	Summer	-2.095	0.018	-4.603	0.000	-3.599	0.000	0.495	0.310	-3.546	0.000	-2.295	0.011	-5.087	0.000
Cape Shoveler	Winter	-1.562	0.059	-2.904	0.002	-3.127	0.001	-0.558	0.288	-3.541	0.000	-3.952	0.000	-3.971	0.000
Southern Pochard	Summer	1.927	0.027	0.395	0.346	-1.727	0.042	-	-	-2.449	0.007	-1.387	0.083	0.250	0.401
Southern Pochard	Winter	1.562	0.059	0.751	0.226	0.552	0.291	-	-	-0.549	0.292	0.745	0.772	1.304	0.096
Spur-winged Goose	Summer	-0.415	0.339	2.535	0.006	1.274	0.101	1.362	0.087	0.000	0.500	0.602	0.274	2.325	0.010
Spur-winged Goose	Winter	-	-	0.068	0.473	2.681	0.004	-	-	-0.623	0.733	-0.178	0.429	0.549	0.292
Maccoa Duck	Summer	1.939	0.026	-2.271	0.012	-	-	-	-	-	-	-	-	-0.608	0.272
Maccoa Duck	Winter	2.919	0.002	-1.879	0.030	-1.112	0.867	-	-	0.248	0.402	-	-	-0.494	0.311
African Purple Swamphen	Summer	1.470	0.071	2.049	0.020	0.840	0.200	-1.040	0.149	0.148	0.441	-0.109	0.457	1.630	0.052
African Purple Swamphen	Winter	-1.071	0.142	0.883	0.189	0.570	0.284	-0.124	0.451	-0.120	0.452	-0.478	0.316	0.079	0.468
Common Moorhen	Summer	-1.890	0.029	0.237	0.406	0.000	0.500	-0.536	0.296	0.740	0.230	0.917	0.180	-0.375	0.354
Common Moorhen	Winter	-2.642	0.004	0.040	0.484	-0.989	0.161	-1.432	0.076	-1.990	0.023	-	-	-2.114	0.017
Red-knobbed Coot	Summer	2.944	0.002	0.000	0.500	1.166	0.122	0.101	0.460	-3.502	0.000	-0.417	0.338	-2.251	0.012
Red-knobbed Coot	Winter	2.746	0.003	-0.217	0.414	0.000	0.500	0.596	0.276	-3.102	0.001	-0.296	0.383	-2.746	0.003