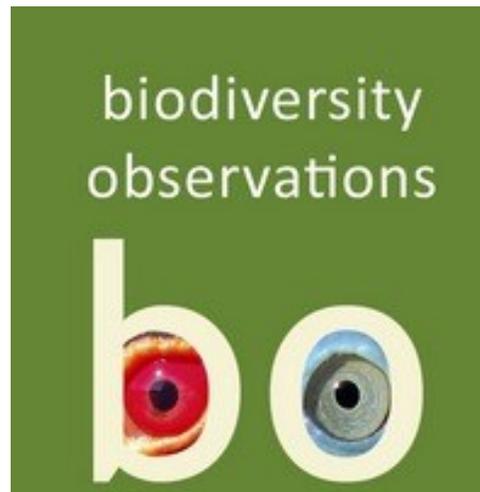


Impact of drought on the breeding of a subtropical South African bird community

Greg BP Davies, Hamish A Campbell, Richard GC Boon



Davies GBP, Campbell HA, Boon RGC 2026. Impact of drought on the breeding of a subtropical South African bird community. Biodiversity Observations 16: 19–40.

30 March 2026

DOI: [10.15641/bo.2032](https://doi.org/10.15641/bo.2032)

ORNITHOLOGY

Impact of drought on the breeding of a subtropical South African bird community

Greg BP Davies^{1*}, Hamish A Campbell², Richard GC Boon^{3§}

¹409 Alandele Avenue, Park La Brea, Los Angeles, California, U.S.A.

²145 North Ridge Road, Berea, Durban, South Africa; deceased

³Bews Herbarium, Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa

*email: seicercus@gmail.com

§email: kzntrees@gmail.com

Abstract

Drought is a common phenomenon in Africa. Its consequences for avian communities have been extensively documented in arid and semi-arid regions of the continent. The impacts in higher-rainfall areas, though, remain poorly-elucidated. Bird community data were assembled at a high-rainfall locality in KwaZulu-Natal Province, South Africa. The study coincided with a two-year drought (1991/92 and 1992/93) when annual precipitation dropped 32–45% below the site's long-term median (990 mm/annum). Impacts on breeding birds were severe but time-lagged. Breeding indices more than halved during

1992/93 to 1993/94. Low breeding indices continued into the 1994/95 and 1995/96 seasons, despite a normalization of annual rainfall. Breeding indices returned to pre-drought levels by 1996/97. The results demonstrate that drought is potentially important for avian population dynamics not only in arid and semi-arid parts of Africa, but in high-rainfall areas too.

Introduction

Like other parts of Africa, the province of KwaZulu-Natal, South Africa, is subject to periodic droughts (Erskine 1983, Dube & Jury 2000, Jury 2022). The impacts of such droughts are typically serious for human societies (Vetter et al. 2020, Lottering et al. 2021) and wild-life (Hillman & Hillman 1977, Walker et al. 1987, Smit & Bond 2020), including birds (Herremans 2004, Bourne et al. 2020a).

Amongst African birds, drought is reported to increase mortality (Maclean et al. 1973, Bourne et al. 2020a), reduce breeding productivity (Hustler & Howells 1990, Tarboton 1992, 1995, Osborne 1998), alter feeding behaviour (Cunningham-Van Someren 1984), induce nomadic movements (Brewster 1992, Hanmer & Chadder 1993, Hanmer 1999, 2003, Herremans 2004, Dean et al. 2009) and disrupt the phenology and spatial deployment of certain migrants (Herremans 1998, Tøttrup et al. 2012).

Breeding productivity is negatively impacted by a decrease in the number of breeders (Dowsett-Lemaire 1983, Tarboton 1982, 1992, 1995, Gargett et al. 1995, Osborne 1998), later initiation of the breeding season (Van Someren 1944, Lorber 1982, Kemp 1991, Kemp & Kemp 1991), fewer breeding attempts (Earlé 1981, Manry 1985, Osborne 1998, Friedl 2002, Bourne et al. 2020b), smaller clutches and broods (Hustler & Howells 1990, Osborne 1998, Friedl 2002), lower hatching success (Tarboton 1992, 1995), lower fledging success (Manry 1985), increased desertion of clutches (Jones & Ward 1979), and an increase of starvation amongst nestlings (Earlé 1982, Manry 1985). These diverse responses all lead to lowered annual breeding productivity, demographically-measured as the number of female offspring per female adult (Danchin et al. 1995).

In Africa, most studies of drought impacts on birds have been in arid (<500 mm rainfall/year) and semi-arid (<700 mm/year) areas, such as Botswana (Herremans 2004), Namibia (Osborne 1998), the Karoo

and Kalahari of South Africa (Milton et al. 2004, Dean et al. 2009, Bourne et al. 2020a,b) and the drier tropical savannas of Zimbabwe (Hustler & Howells 1990, Gargett & Gargett 1993, Gargett et al. 1995).

Reports in higher rainfall areas (>700 mm/year) are far fewer and usually anecdotal, but have been noted from the Eastern Cape (Vernon 1989: table 2, Pringle 1994), Kenya (Van Someren 1944, 1947, Cunningham-Van Someren 1984), Malawi (Dowsett-Lemaire 1983: p 366, 1985: p 142) and mesic parts of Zimbabwe (Vernon et al. 1989, Tree 1993, 1995, Hanmer 1999, 2003, 2009, Hanmer & Chadder 1993).

This knowledge deficiency applies particularly to KwaZulu-Natal, one of the wettest parts of the southern African sub-continent with rainfall >700 mm/year predominating over much of that province (Cyrus & Robson 1980: 18). Only a few publications (Maclean et al. 1973, Mentis et al. 1975: 25, Earlé 1981, Chittenden & Mendelsohn 1981, Manry 1985) mention the impacts of drought or 'dry years' on bird species in KwaZulu-Natal. Does this paucity of drought reports for KwaZulu-Natal imply the effects are comparatively benign on birds in that province?

From 1991 to 1994, southern Africa (Vernon 1993), south-central Africa (Mallalieu 1995) and Madagascar (Jolly 1993) experienced below-average rainfall. In KwaZulu-Natal, water supply shortages to urban areas occurred, dam and river levels were low (Dube & Jury 2000) and even perennial coastal lakes, such as Lake Teza, Mtubatuba, dried up (Scott & Steenkamp 1996). One of KwaZulu-Natal's largest, perennial, high-altitude wetlands, Franklin Vlei, became desiccated to the extent that, in November 1992, it was "possible to walk across the vlei without encountering saturated ground" (Taylor 1994: p 367). Extremely low trapping success for rodents, shrews and golden moles in coastal Zululand between July 1992 and March 1993 reflected reduced small mammal biomass at that time (Taylor 1998: table 2).

Although a significant natural phenomenon, the impact of the early 1990s drought on the avifauna of KwaZulu-Natal has not been published to our knowledge. The objective of this paper is to describe the effects this drought had on the breeding performance of an

avifaunal community at Vernon Crookes Nature Reserve. A long-term (25+ year) study of the bird community at that locality by the second author covered the period before, during and after this drought permitting us to explore its possible avifaunal consequences.

Methods

Study site description

Located ~5 km north-west of Umzinto, Vernon Crookes Nature Reserve (VCNR) (30.290°S; 30.601°E) is a ~2,200 ha nature reserve proclaimed in 1972 and administered by Ezemvelo KZN Wildlife (formerly Natal Parks Board). VCNR is a low-elevation locality (altitude 160–540 m asl) and has an undulating topography of moderately to deeply-dissected valleys, rolling hills and small plateaus.

The vegetation comprises ~1,400 ha of annually- and biennially-burnt coastal grassland, ~425 ha of semi-deciduous to evergreen escarpment forest, ~365 ha of secondary forest and moist thicket (lower Nyengelezi and Umzinto Valleys) and ~10 ha of seasonal and permanent wetlands (including two small man-made dams). Many tiny (<2–3 ha) forest-patches ('bush-clumps') are embedded in the grassland matrix, often nucleated around large granitic boulders or extending along small valley-head drainage lines.

The nature reserve is surrounded by a vast matrix of commercial agriculture (>9,000 ha sugarcane and >1,000 ha timber plantations) and a high-density of subsistence pastoralists and farmers, i.e. VCNR is an isolated fragment of natural vegetation in a mostly human-transformed landscape. On the northern boundary, VCNR adjoins the drier Umpambinyoni Valley that contains remnant expanses of xerophytic thicket ('valley bushveld'), a vegetation type which does not occur within the reserve boundaries.

There is no published floristic analysis of the grasslands and forests of VCNR. The forb-rich grasslands broadly resemble those described from coastal KwaZulu-Natal and the Eastern Cape by Shackleton et al. (1991), Roberts (1993: pp 299–302), le Roux (1995), Boon et al. (2016), Styles (2017) and Wragg (2017), while the escarpment forests are similar to those studied by Rogers & Moll (1975), Moll (1978) and Meter (1998).

Further details regarding Vernon Crookes Nature Reserve are availa-

ble in Bourquin & Sowler (1980), Maddock & Zaloumis (1987), Boon (1992) and Du Preez (1995). For nomenclature of sites within VCNR we follow the 1:10,000 Vernon Crookes Nature Reserve topographic map (1988), prepared by the late Prof S.E. Piper, then of the Department of Surveying and Mapping, University of Natal, Durban.

Study data acquisition

Between 1978 and 2008 near-weekly visits to VCNR were undertaken by the second author and bird-watchers accompanying him, including the first and second authors. Search effort typically comprised 2–8 observers traversing the dirt road network in the nature reserve between pre-dawn and midday (~5–7 hours). This road network accessed the three main habitats (grassland, forest and wetland) within the nature reserve.

All bird species recorded during a visit (from either aural or visual cues) were registered on a checklist, initially those used for the Natal Bird Atlas (Cyrus & Robson 1980), but from 1987 onwards those of the First Southern African Bird Atlas Project (SABAP1) (Harrison et al. 1997). Checklists compiled by other bird-watchers visiting VCNR were also solicited by the second author and added to the VCNR dataset.

By 2008, more than 1,500 checklists had been assembled, the majority by the second author. At the conclusion of the study a total of 331 species had been recorded from the nature reserve (plus a handful of unconfirmed species). Of this total, 158 species had a reporting rate $\geq 10\%$, i.e. these constituted the core avifauna of VCNR.

The bird fauna is notable for its mixture of tropical (e.g. Green Malkoha *Ceuthmochares aereus*, African Broadbill *Smithornis capensis*, Grey Waxbill *Estrilda perreini*) and temperate (e.g. Wailing Cisticola *Cisticola lais*, Chorister Robin-Chat *Cossypha dichroa*, Cape Weaver *Ploceus capensis*) bird species. This is a consequence of VCNR falling in the latitudinal transition zone where the warm, subtropical coastal margin is tightly juxtaposed against the cooler, temperate hills of the hinterland – part of the ‘subtropical species subtraction zone’ (Poynton 1961).

Prior to 1987, evidence of breeding was only opportunistically recorded on the checklists. Breeding data between 1978 and 1987 are thus

excluded from our analyses. From 1987, the seven breeding codes developed by SABAP1 were adopted for each checklist and any signs of breeding conscientiously recorded.

The breeding codes were ‘suspected breeding’ (Code 2), ‘proven breeding’ (Code 3), ‘eggs’ (Code 4), ‘chicks’ (Code 5), ‘eggs and chicks’ (Code 6), and ‘dependent fledglings’ (Code 7). From 1997, search effort for breeding evidence was substantially increased and thus breeding data after 1996/97 are also excluded from this paper. Therefore, this paper analyzes breeding data over the 10 field seasons from 1987/88 to 1996/97.

Because the same nest or breeding episode might be recorded more than once in a series of checklists, especially in birds with lengthy breeding seasons (e.g. cranes) or conspicuous nests (e.g. large raptors), the accumulated breeding data were carefully inspected to remove such duplication.

During the study period and from field observations, it was known that only single pairs were under observation of Grey Crowned Crane *Balearica regulorum* (nesting at either Elikhulu Dam or Ebthonga Pan), Black Sparrowhawk *Accipiter melanoleucus* (nesting in Mthakati Valley), Martial Eagle *Polemaetus bellicosus* (nesting in Hlatikulu East Valley), Long-crested Eagle *Lophaetus occipitalis* (nest not found but believed to be in riparian growth near Mbudlambudla Marsh) and Crowned Eagle *Stephanoaetus coronatus* (nesting in Mthakati Valley; in 1995 a second nesting pair was located at Godlimpi Valley). Consequently, if these species were recorded nesting in a given season, they were constrained to one breeding episode (unless available field notes indicated any re-laying).

For other species, in the absence of field notes to the contrary, if two breeding episodes were 30 days or more apart, they were treated as independent breeding records; if not they were lumped together as one breeding episode. This approach, while arbitrary, errs on the side of caution.

Analysis of productivity in communally-breeding species (e.g. certain Ploceidae) or species found with multiple nests during data collection for one checklist was also complicated because multiply-active nests would be reflected by a single breeding code in the checklist. *Post-hoc*, there is no way to account for such conflation. In such cases, the

data reported herein underreport the breeding productivity. However, because we are principally interested in determining the impact of the drought on the bird community, this bias in data collection does not preclude us from looking for such impacts as this bias was consistently applied across all the field seasons, whether they were dry or wet.

Annual precipitation

Monthly rainfall data were collected at the VCNR administrative office (30°16'14.37"S, 30°36' 23.07"E; 452 m asl) for 23 seasons between 1982/83 and 2004/05 (Figure 1, Table 1). In that time period, average annual precipitation was 1034.5 mm and median annual precipitation was 990 mm. Precipitation at VCNR was unimodal, peaking between September and March (82% of annual rainfall was recorded during those months).

Annual precipitation varied (Figure 1, Table 1) between a low of 546 mm (1992/93) and a high of 2,310 mm (1987/88), so that the wettest year had 4.2 times as much rainfall as the driest. The latter extreme was due to the exceptional September 1987 floods (Clarke & Maggs 1987, Kovacs 1988, Badenhorst et al. 1989). During that month >800 mm of rain was measured at VCNR or approximately 80% of the annual rainfall in one calendar month! Most of that rain was concentrated in the five-day period 26–30 September 1987 (Kovacs 1988).

Aside from the extreme September 1987 floods, the early part of 1988 also experienced remarkably heavy rainfall with 680 mm measured in February and March, or nearly treble the combined average of those two months (Table 1). This extraordinarily wet spring and summer of 1987/88 appeared to have a discernible effect on the length of that breeding season (see below).

For our purposes, a drought is arbitrarily defined as a 12-month period when rainfall falls ~25% or more below the median precipitation for the study site. Two years (1991/92, 1992/93) satisfied that criterion, when annual precipitation dropped 32–45% below the long-term median (Fig. 1; Table 1). These were the two driest years in the precipitation record (except for 1982/83, which had 583 mm of rainfall). Alternatively expressed, between December 1991 and August 1993 there was a consecutive series of 21 months with less than 100 mm precipitation/month. This is an astonishingly long dry streak for a coastal locality in southern KwaZulu-Natal.

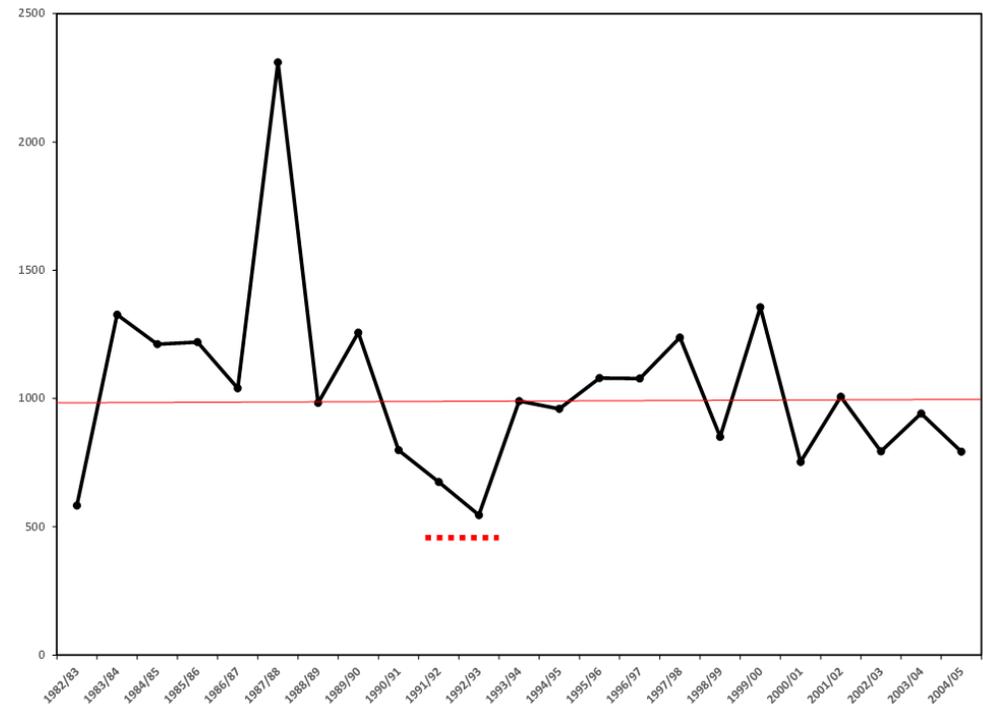


Figure 1: Annual precipitation (mm) at Vernon Crookes Nature Reserve (1982/83–2004/05). The drought period is highlighted with the dashed horizontal line. The long-term median rainfall is indicated by the solid horizontal line. Note the extraordinarily high rainfall of the 1987/88 season due to abnormal flooding in September 1987 (Clarke & Maggs 1987, Kovacs 1988, Badenhorst et al. 1989) and heavy rains of early 1988.

Table 1 (following page): Monthly and annual precipitation (mm) at Vernon Crookes Nature Reserve between 1982/83 and 2004/05. The study period years are highlighted in bold. Note the exceptionally heavy rainfall in September 1987 and March 1988 (shaded blue). Furthermore, note the long dry period between December 1991 and August 1993 (shaded yellow). Med = median, SD = standard deviation, LQ = lower quartile, UQ = upper quartile, IQR = inter quartile range = UQ–LQ, and IQR/Med is a robust estimate of the relative variability of the rainfall in the month.

Table 1: (legend in page 22)

Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
82/83	3	3.5	72.5	141	57	33	138	82	28	18	0	7	583
83/84	84	43	39	173	179	108	237	180	93	159	19	13	1327
84/85	50	29	53	51	98	78	129	597	32	25	10	60	1212
85/86	7	3	38	310	206	153	162	42	201	77	5	16	1220
86/87	0	138	40	98	144	114	131	43	119	38	94	81	1040
87/88	13	53	838	78	229	91	107	305	375	32	140	49	2310
88/89	13	111	25	50	89	203	72	233	37	133	17	0	983
89/90	36	3	90	152	410	55	54	79	314	40	10	14	1257
90/91	1	107	41	130	24	144	91	95	74	18	71	3	799
91/92	3	4	150	172	140	49	59	58	28	11	1	0	675
92/93	5	14	55	73	40	94	98	78	27	34	2	26	546
93/94	11	12	199	142	61	276	85	14	164	12	4	10	990
94/95	70	32	2	96	71	129	149	44	164	120	42	41	960
95/96	3	9	23	118	111	323	146	186	99	42	17	3	1080
96/97	172	0	13	166	137	69	131	48	74	117	22	129	1078
97/98	57	15	125	124	271	108	91	170	72	173	30	2	1238
98/99	9	102	26	56	88.5	165	79	137	121	12	35.8	19.9	851.2
99/00	5.5	13	75	356	64.7	314	142	176	103	37.5	64.5	4.5	1355.7
00/01	11	43.5	84.5	79	106	109	84.5	85.5	37	47	65.5	0	752.5
01/02	10.5	10	99.5	126	172	162	177	89	19	81.5	25	35	1006.5
02/03	198	111	46.5	12.5	66.5	105	70.5	63.5	69	35	6	10	793.5
03/04	0	79.5	110	38.5	105	154	237.5	132	59	16	10	0	941.5
04/05	67	17	72.5	66	183.5	57.5	116	131.5	27	33	8	13.5	792.5
Mean	36.0	41.4	100.8	122.1	132.7	134.5	121.2	133.4	101.6	57	30.4	23.3	1034.4
Med.	11	17	55	118	106	109	116	89	74	37.5	17	13	990
SD	53.6	43.7	167.3	80.6	87.5	79.5	49.8	123.1	91.8	49.4	35.1	31.4	360.1
LQ	4.0	9.5	38.5	69.5	68.8	84.5	84.8	60.8	34.5	21.5	7.0	3.0	796.3
UQ	53.5	66.3	94.8	147.0	175.5	158.0	144.0	173.0	120.0	79.3	38.9	30.5	1216.0
IQR	49.5	56.8	56.3	77.5	106.8	73.5	59.3	112.3	85.5	57.8	31.9	27.5	419.8
IQR/Med	4.50	3.34	1.02	0.66	1.01	0.67	0.51	1.26	1.16	1.54	1.88	2.12	0.42

Additionally, 1990/91 was also a fairly dry year (799 mm), falling ~20% below the long-term median. Therefore, three consecutive years (1990/91 to 1992/93) had <800 mm/annum. The severity of the early 1990s drought may have stemmed, in part, from the successive run of dry years, rather than a drought year being intercalated between two wetter years.

The drought was eventually broken by substantial rainfall in September 1993 (199 mm), October 1993 (142 mm) and December 1993 (276 mm). By 1993/94 (990 mm) and 1994/95 (960 mm), annual rainfall had recovered to approximate to the long-term median.

Analysis

To control for the variable number of checklists per field season (crude observer effort), rudimentary breeding and breeding species indices were computed. The breeding index was $Br = x/y * 100$ where x was the total number of breeding records for a season (Sep-Mar inclusive) and y was the total number of checklists for that same period. The breeding species index was $Br.Sp = a/y * 100$ where a was the total number of breeding species for a season (Sep-Mar inclusive) and y was the total number of checklists for that same period. Correlations of these simple indices with rainfall of the current and preceding seasons was sought using Spearman's Rank Correlation Coefficient following Fowler & Cohen (1996).

Results

Breeding summary and seasonality

Four hundred and forty-six breeding episodes of 102 bird species were recorded during spring and summer of the 10 field seasons (Appendix 1). Far less breeding took place in autumn and winter with 57 breeding episodes of 34 bird species (Appendix 2). The combined total of spring/summer and autumn/winter was 503 breeding episodes. However, 11 breeding episodes (four by Martial Eagle, three by Crowned Eagle, three by Grey Crowned Crane and one by Cape Wagtail *Motacilla capensis*) spanned the spring/summer and autumn/winter periods and could not rationally be allocated exclusively to one or the other category. Therefore the total number of breeding episodes during the study period was 492. These 492 records were obtained for 108 species or ~68% of the core avifauna. The long-term

median number of breeding species recorded per season in spring/summer was 38 or ~25% of the core avifauna. The median number of breeding records per spring/summer was 47. The long-term median number of breeding species and breeding records per autumn/winter were both five.

Drought impact

The initial spring/summer of the drought (1991/92) had moderately depressed breeding indices (Figures 2 and 3) and the number of breeding species and number of breeding records actually exceeded the long-term medians (Appendix 1). Possibly this was a lagged effect from the preceding wet years (1987–1991) and the good spring rains of that season when 462 mm was recorded between September and November 1991 inclusive (Table 1).

The drought made itself felt, however, in the subsequent spring/summer of 1992/93 and 1993/94 when the number of breeding species (17 and 18 species, respectively) was less than half the long-term median and the number of breeding records (18 and 20 records, respectively) was also less than half of the median. Concordantly, the spring/summer breeding indices were strongly depressed during those two seasons (Figures 2 and 3).

Breeding performance remained poor into 1994/95 and 1995/96 with low breeding indices (Figures 2 and 3), even though rainfall had recovered to around the long-term median (Figure 1). This continued limited breeding by the VCNR bird community suggested lag effects from the preceding drought years.

There was no significant correlation between the current season of rainfall and current season's Br (Spearman Rank $r_s = 0.32$, n.s.) and $Br.Sp$ (Spearman Rank $r_s = 0.25$, n.s.). There was, however, a statistically significant relationship between the previous season's rainfall and the current season's Br (Spearman Rank $r_s = 0.84$, $P < 0.01$) and $Br.Sp$ (Spearman Rank $r_s = 0.85$, $P < 0.01$).

No consistent guild or taxonomic patterns were discovered in those species ceasing to breed as the drought progressed and after it was broken, but rather all dietary and habitat types were impacted by the drought (Appendix 1). It is notable that between 1992/93 and 1993/94 there was only two sunbird (Nectariniidae) and five weaver

(Ploceidae) breeding episodes. Both of those families are common at VCNR and construct nests that are usually fairly easy for observers to locate.

The resident pair of Grey Crowned Crane ceased breeding for two seasons from 1991/92 to 1992/93 as no dependent fledglings were observed in those years. Although there was a single breeding registration in 1993/94 (Code 3, 27 Feb 1994) there was no Code 7 record nor any annotation in the field notes of a dependent chick/s seen that year, suggestive of failed breeding. Therefore, there may have been three consecutive seasons of unsuccessful or suspended reproduction in this crane species. There was no sign of breeding by the Black Sparrowhawk pair in the winter of 1995, the only occasion that this

occurred in the 10-year study period. Similarly, the Mthakati Valley pair of Crowned Eagle showed no evidence of nesting in 1993/94 and 1994/95, while the resident pair of Martial Eagle did not breed in 1994/95, the only time this happened during the study period.

Drought nomadism and vagrancy

The occurrence of species hitherto unrecorded or sparsely recorded at VCNR was observed among certain granivores and xerophytic thicket species. These are presumed to reflect drought-induced nomadism and vagrancy into the nature reserve: Jacobin Cuckoo *Clamator jacobinus* (3 February 1992), Long-billed Crombec *Sylvietta rufescens* (16 February 1992), Magpie Mannikin *Lonchura*

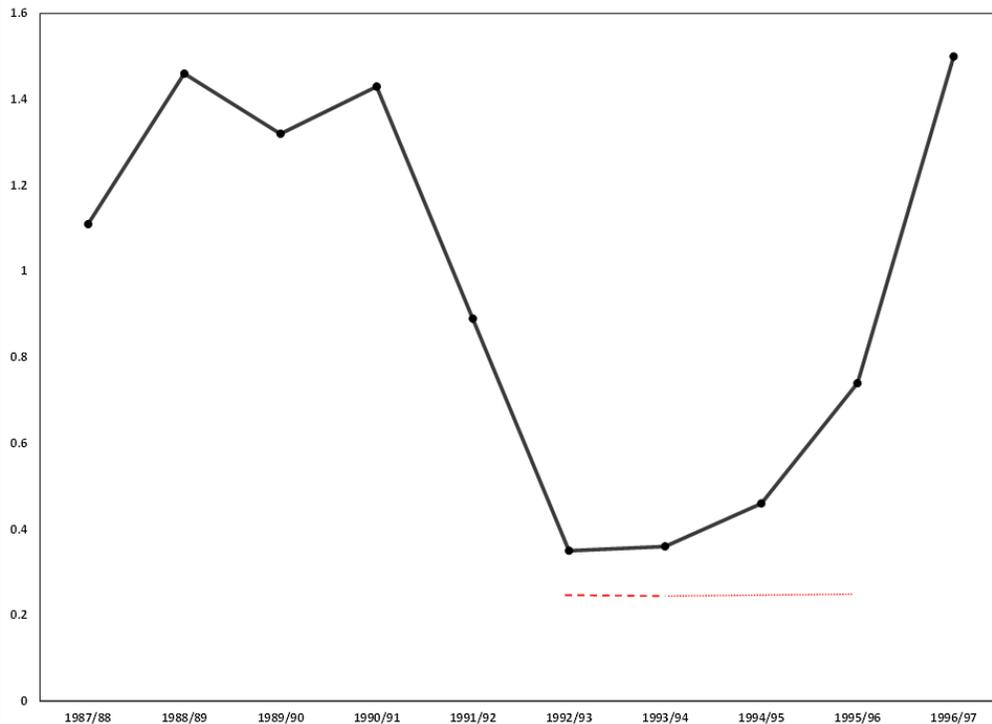


Figure 2: Spring and summer breeding index (*Br*) at Vernon Crookes Nature Reserve (1987/88 to 1996/97). Note the sharp decline during 1992/93–1993/94 (large dashes) and lag effects into 1994/95 and 1995/96 (small dashes).

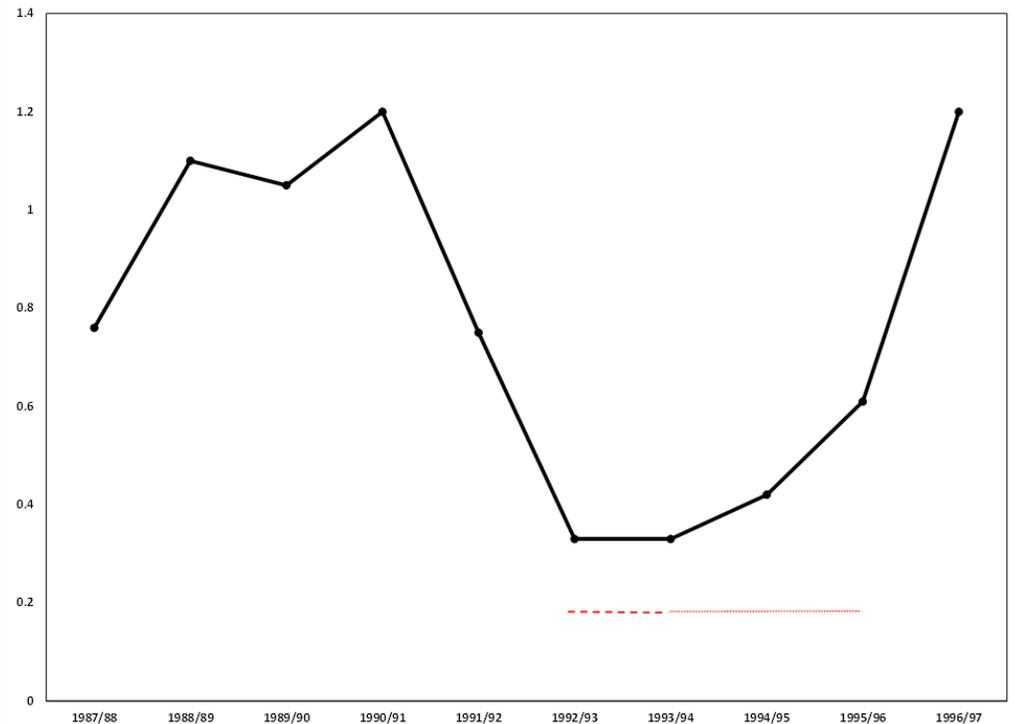


Figure 3: Spring and summer breeding species index (*Br.Sp*) at Vernon Crookes Nature Reserve (1987/88 to 1996/97). Note the sharp decline during the 1992/93–1993/94 (large dashes) and apparent lag effect in 1994/95 and 1995/96 (small dashes).

fringilloides (May-June 1994), Blue Waxbill *Uraegithus angolensis* (4 June 1995), White-winged Widowbird *Euplectes albonotatus* (25 October 1992, 20 December 1992, 17 November 1996, 22 December 1996), and Golden-breasted Bunting *Emberiza flaviventris* (13 August 1995). A small influx of Quail Finch *Ortygospiza atricollis* was recorded with reporting rate rising from ~10% in the years 1985-1992 to ~25-38% in 1993 and 1994 before declining back to pre-drought levels by 1996.

September 1987 floods and subsequent wet summer

Only two species had breeding registrations for September 1987 (Crowned Eagle, Code 5, 13 September and Bar-throated Apalis *Apalis thoracica*, Code 2, 6 September). Both of those records occurred before the floods of late September. For October 1987 breeding registrations were made for 15 species beginning from 10 October 1987. Most birds at VCNR usually begin nesting in the first to third weeks of October, evidently therefore the start of 1987/88 breeding season was not impacted by the extreme rains at the end of September.

The nesting season for 1987/88 was, however, apparently more extended than usual as the highest number of breeding records for autumn and winter (12) were obtained in 1988 (Appendix 2). Several of these also represented unseasonal reproduction by the species involved, viz. African Cuckoo Hawk *Aviceda cuculoides* (Code 7, 10 April 1988), Brown-hooded Kingfisher *Halcyon albiventris* (Code 3, 8 May 1988), Olive Woodpecker *Mesopicos griseocephalus* (Code 3, 10 April 1988), Rufous-naped Lark *Mirafra africana* (Code 2, 17 April 1988), Yellow-throated Longclaw *Macronyx croceus* (Code 2, 16 April 1988), Dark-backed Weaver *Ploceus bicolor* (Code 2, 10 April 1988) and Streaky-headed Seedeater *Crithagra gularis* (Code 2, 1 May 1988). Although the breeding season was extended in 1987/88, the breeding indices were nonetheless rather low (Figures 2 and 3).

Discussion

Caveats with the interpretation of the data

The data for this study were assembled during recreational birdwatching trips to VCNR mainly led by the second author. These visits did not prioritize nest-finding nor the close study of the breeding perfor-

mance of any species. Breeding evidence was recorded as incidentally encountered by the second author and other bird-watchers. We also only employed simple enumeration and crude indices to explore the impacts. Therefore, any conclusions have to be cautiously applied. Nonetheless, several patterns do seem to be accurate reflections of breeding performance by the avifaunal community.

Seasonality of avian reproduction

Avian breeding at VCNR during the study period was seasonal with nearly 90% of the breeding episodes falling during the wet season (September to March inclusive). This concurs with other breeding data from KwaZulu-Natal (Dean 1971, Earlé 1981) and summer-rainfall regions of southern Africa (Harrison et al. 1997). The few species reproducing in the dry season at VCNR (Appendix 2) are known to be winter breeders in KwaZulu-Natal (Dean 1971) and/or elsewhere in the region (Hockey et al. 2005, Tarboton 2011). The ecological reasons for winter reproduction in such species appear obscure, but at least in Greater Double-collared Sunbird *Cinnyris afer* is probably linked to winter-flowering at VCNR by *Aloe arborescens*, *A. candelabrum*, *Erythrina lysistemon*, *Halleria lucida* and *Leonotis leonurus*.

Impact of drought on avian reproduction

Overall, the early 1990s drought had a severe impact on breeding productivity at VCNR. Although intuitively expected, such depressed reproduction has seldom been quantitatively demonstrated in a mesic part of the sub-continent. Breeding indices were more than halved with the worst impacts in the second year of drought (1992/93) and the subsequent year (1993/94). Species that did breed during the drought did not seem to have any consistent biological traits that might have allowed them to breed, but rather comprised a phylogenetically and ecologically diverse set of species (Appendix 1). It is unknown if those species that attempted to breed during the drought incurred lower nesting success compared to years of higher rainfall.

We suspect poor reproduction by the bird community stemmed primarily from lack of food resources. Unfortunately, we have no relevant data or field notes on plant, invertebrate and small vertebrate

resources available at VCNR during the drought, and nor was any collected in KwaZulu-Natal during the early 1990s drought to our knowledge. It is likely, however, that invertebrate and small vertebrate biomass was lowered and the production of buds, flowers, fruits, and ripening and germinating seeds was depressed at VCNR.

In the Eastern Cape, qualitative observations of 10 coastal forest tree species showed that nine of them incurred smaller, aborted or failed fruit crops in the wake of the severe 1982/83 drought (Vernon 1989: table 4). Invertebrate biomass assessed from sweep-netting in *Acacia* savanna near Pietermaritzburg dropped by about half in the dry summer of 1979/80 relative to the wetter preceding summer (Earlé 1981: figure 4). Presumably, analogous responses occurred at VCNR.

The negative consequences of the drought were felt community-wide in all habitat types and foraging guilds. While breeding productivity was negatively affected at VCNR, the coarse nature of the data-set, especially the opaque Code 3 ('proven breeding'), makes it difficult to determine (i) where in the breeding cycle the deleterious impacts were most felt (e.g. at nest-building phase, egg-laying stage, nestling or fledgling stages), (ii) if the timing of egg-laying, hatching and fledging was delayed or (iii) if clutch and brood sizes were lower during the drought.

Four regularly breeding species (Grey Crowned Crane, Black Sparrowhawk, Crowned Eagle, Martial Eagle), which could be monitored with some degree of assurance, appeared to not even begin nest-building in some years. Such nest-building behaviour could have been expected from Code 2 registrations – typically used when a bird was seen carrying nest material or present at a nascent nest structure. This implies that deleterious effects of the drought manifested before the nest-building phase in those species. Speculatively, some physiological constraint was preventing them from coming into reproductive condition, e.g. abnormal gametogenesis (Keast & Marshall 1954), insufficient protein and fat reserves (Fogden & Fogden 1979, Jones & Ward 1979) or elevated corticosterone plasma levels (Cain & Lien 1985).

While severe, responses by the VCNR bird community to the drought were curiously time-lagged. The initial dry season (1991/92) only showed moderately depressed indices (Figures 2 and 3) despite the

overall low rainfall for that year. Analogously, while rains had normalized by 1994/95 and 1995/96, breeding continued to be moderate (Figures 2 and 3). This time-lagged impact was borne out by the simple correlation statistic employed. In the raptors with sufficient information, it was striking that breeding suspension occurred in 1994 and 1995 and not during the actual drought years.

How and why these lag effects manifested themselves we are unable to explain. It is notable, though, that ostensibly similar time-lagged effects on breeding productivity and egg-laying phenology have been reported elsewhere in southern Africa from a wide variety of bird species (Craig 1982: 113, Kemp 1991, 1994, Masterson & Weaving 1975: pp 34–35, Vernon 1978: pp 108, Vernon et al. 1989: pp 117–118). In those studies, the rainfall of the preceding season appeared to influence reproduction in the subsequent year.

Possibly, the salient ecological factors operating in these time-lagged effects are (1) delayed responses in primary (vegetative) production and (2) attenuated population-level responses by invertebrates and small vertebrates. Delayed response by vegetation might be due to the role of subterranean aquifers and pan-horizons used by perennial vegetation (Tinley 1982). These aquifers and pan-horizons could, in an initial season of drought, carry sufficient water from preceding wet years for primary production to continue unimpeded. Progressive dehydration (and subsequent slow recharging) of these subterranean sources of water would conceivably lead to a time-lagged decline (and recovery) in fresh foliage, fruit and seed output in subsequent seasons, at least in perennial vegetation using such water sources.

Additionally, physiological deterioration and mortality in perennial grasses, shrubs and trees might also take more than one season of adverse conditions to assert itself. These hypothetical impacts on the vegetation would, in turn, progressively impact the survival and fecundity of invertebrates and small vertebrates (e.g. rodents). Once reduced by heightened mortality in droughts, recovery of populations of these animals (and perennial plants) might also take more than a season of compensatory reproduction to attain pre-drought levels, even if rains had already normalized.

Nomadic movements into the nature reserve

At VCNR, there was limited evidence for drought-associated movements by several granivore and thicket species. Aside from Quail Finch and small flocks of Magpie Mannikin (Campbell 1994), these nomads were singletons evidently dispersing briefly into VCNR and not large-scale influxes.

The source of the thicket species appears to have been from the Umpambinyoni Valley adjoining the northern boundary of VCNR (Campbell 1992b). These vagrants may thus have only dispersed a few kilometres from their source areas. Movement by the Magpie Mannikins into VCNR, however, must have been over a distance greater than 20 km, as no close resident population was known at that time.

During the same drought, Golden-breasted Bunting was also recorded as a vagrant to Pigeon Valley, Durban (Campbell 1992a), and much earlier, Garland (1970) reported the unusual occurrence of Blue Waxbill, White-winged Widowbird, and Golden-breasted Bunting at Mtunzini, a consequence of drought conditions then prevailing in Zululand (cf. Keep 1973). Evidently, these three granivore species display nomadic tendencies during dry years in coastal KwaZulu-Natal. Are existing ringing retraps and recoveries of these species found at greater distances in drought years relative to years of normal precipitation?

Potential impact of the September 1987 floods and abnormally wet 1987/88 season

There is no evidence that the late September 1987 floods negatively impacted avian breeding. This was probably because this remarkable outlier event occurred about 1-3 weeks prior to the typical upsurge in nest-building and egg-laying period for most VCNR birds. Whether there was increased avian mortality due to the floods and extreme rains is unknown.

In the subsequent months, together with the unusually heavy rains of February-March 1988, the influence of the September 1987 floods was apparently positive by extending the breeding season into the autumn and early winter. At least 12 species engaged in autumnal and early winter that season and, for seven of these species, the

nesting was outside of recognized breeding times (Dean 1971, Hockey et al. 2005, Tarboton 2011). Ecologically, this abnormal autumnal and early winter breeding was presumably a consequence of rains boosting primary production and invertebrate and small vertebrate biomass.

How this unseasonal breeding in April and May 1988 interacted with the postnuptial moult of the species involved is unknown. It is possible that the moult in some or all of the 12 species was suspended to allow renesting, as has been documented or suspected elsewhere in Africa (Fogden & Fogden 1979, Dittami 1986, Hanmer 2002).

Demographic impacts

As no bird-ringing was undertaken during the VCNR study, we are not in a position to analyse annual survival, immigration/emigration, moult or the overall demographic impact on bird populations at VCNR. No overt signs of mortality such as dying or dead birds were noted during the drought (cf. Maclean et al. (1973) who reported dead and emaciated White Storks in an earlier drought in KwaZulu-Natal). At a forested Durban locality, Piper (2002: 121) found reduced annual adult survival in his study species during the early 1990s, but this decreased survival was attributed to the effects of environmental pollution and not drought. We are not entirely persuaded that the drought had no impact on the survival rate in a passerine closely-tied to an aquatic habitat.

It seems probable that the VCNR pairs of Grey Crowned Crane, Black Sparrowhawk and Crowned and Martial Eagles suspended breeding for at least one to two seasons. Reproductive productivity in Accipitridae and Gruidae is typically of the order of 0.3–1.0 fledged chicks/pair/season (Gargett 1977, Brown & Pomeroy 1984, Piper 1994, Allan 2005) or 0.15–0.5 female chicks/breeding female/season (assuming an equal sex ratio). A suspension of reproduction for two seasons, therefore, suggests an overall loss of 0.6–2.0 potential fledglings/pair in these larger-bodied species. As very high annual survival rates (> 80%), and thus long-life, have been reported for African raptors and large-bodied species (Brown & Pomeroy 1984, Piper 1994: table 5.1), the loss of offspring over a couple of breeding seasons could be buffered by the evolved longevity of such birds.

However, this is dependent on adult annual survival not also being compromised by drought.

It also seems likely that many passerines at VCNR suspended or had failed reproduction for one to two seasons. Productivity in KwaZulu-Natal passerines is in the region of 1.5–1.7 fledglings/pair/season (Piper & Oatley 1999) or 0.75–0.85 female fledglings/breeding female/season (assuming equal sex ratio). If we assume that suspended or failed reproduction also occurred in VCNR passerines, potential losses over two seasons would have amounted to approximately 1.5–1.7 female fledglings/breeding female or 3–5 fledglings/breeding pair in such taxa. Fairly high annual survival rates (> 65%) are known or estimated for many southern African passerines (Piper & Oatley 1999, Peach et al. 2001, Piper 2002, Collingham et al. 2014). As with the larger species, it is therefore possible that this evolved longevity could compensate for the loss of nesting success. However, certain passerine families (e.g. Estrildidae, Fringillidae) have low adult survival rates, in the range of ~25-60% (Peach et al. 2001, Collingham et al. 2014), even in seasons of adequate precipitation. *Prima facie*, the potential loss of reproduction over a succession of years could have substantive population level influence in such granivores. Modelling these scenarios using Leslie Matrices or basic life tables based on mortality and fecundity schedules could be illuminating.

A further unknown demographic factor of significance is the negative drought impacts on the survival rates of sub-adults and non-breeding adults ('floaters'). Such individuals represent potential recruitment to the breeding segment of the population and even in 'normal' years suffer from lower annual survival rates than territory-holders (Piper & Oatley 1999) or high-ranking adults in non-territorial species. Plausibly, droughts would worsen their already adverse survival prospects, thereby negatively impacting the population growth rate by reducing the pool of recruits.

There is little data addressing these vital demographic factors for southern Africa, but adult survival has been compromised by droughts in certain southern African studies (Gargett & Gargett 1993, Hanmer 2003, 2009, Bourne et al. 2020a). Therefore, droughts can reduce both breeding productivity and annual adult survival, leading to population declines or negative population growth rates. We can

only presume that annual survival was negatively impacted for many species at VCNR during the drought years.

Overall, these reflections reveal that our understanding of the demographic effects of droughts in the wetter-parts of the sub-continent remains meagre. Long-term studies in such mesic areas that combine both ringing (for survival estimates) and breeding studies (for fecundity estimates) and which span both wet and dry climatic cycles are warranted. Integrated with the simultaneous monitoring of available plant, invertebrate and vertebrate food resources, deeper comprehension of the impacts on population dynamics might be achieved. Particularly intriguing are potentially different demographic responses to drought (and high rain episodes) by short-lived versus longer-lived passerines. The demographic expectation is that impacts of such perturbations would be more consequential for short-lived species. Is this partly why small granivores are amongst the most prominent nomadic species during droughts?

From a broad ecological perspective, it is conceivable that droughts, floods and other extreme episodic perturbations such as rodent outbreaks (Byrom et al. 2014), irregular inundation of ephemeral wetlands (Tree 1978, Ginn 2007, Read et al. 2014: pp 375–376), disease epidemics (van Heerden 1974), periods of rain combined with unseasonal cold (Vincent 1969, Skead & Skead 1970, Piper 1998) and violent thunderstorms (Vincent 1989: pp 189, Pietersen & Symes 2010, Chittenden 2015, Allan 2019) exert a disproportionate and underappreciated influence on African avian demography relative to a series of years without such perturbations (cf. Caughley & Walker 1983: pp 19–20, Oatley et al. 1992, Newton 1998: pp 304–307, Altwegg et al. 2006, Frederiksen et al. 2008). Monitoring, ringing and research programs in southern Africa are regrettably often inadequately structured to capture the full import of these episodic events.

Conclusions

To recapitulate, the VCNR dataset suggests that (1) a two-year long drought caused a sharp decline in breeding indices, but (2) the effects were time-lagged. There were also indications that (3) resident pairs of large-bodied species suspended breeding for 1–2 years, (4) there was increased nomadism by certain seedeaters and thicket-

dwelling species into the nature reserve, and (5) the 1987/88 breeding season was prolonged into the autumn/winter for some species from the effects of the September 1987 floods and heavy rains of February–March 1988.

These VCNR data add to the limited published information on drought impacts in mesic parts of the sub-continent. With modelled predictions of hotter temperatures and altered precipitation due to anthropic climate change awaiting in KwaZulu-Natal's future (Jewitt et al. 2015), they also serve as a descriptive baseline.

Acknowledgements

We would like to thank the many bird-watchers who accompanied the second author on more than 1000 memorable and convivial visits to Vernon Crookes Nature Reserve in search of birds. Successive Officers-In-Charge (C. Wex, J. van Rensburg, G. Zaloumis, J. Vermuelen, P. Pillay, Z. Dindekazi) provided logistical assistance and valued co-operation for this endeavour.

References

- Allan D** 2019. Annihilation: storms wreak havoc on Amur Falcons. *African BirdLife* 7(5): 22–24.
- Allan DG** 2005. Grey Crowned Crane. In: Hockey PAR, Dean WRJ, Ryan PG (eds), Roberts – Birds of Southern Africa. 7th ed, pp. 307–308. John Voelcker Bird Book Fund, Cape Town.
- Altwegg R, Roulin A, Kestenholz M, Jenni L** 2006. Demographic effects of extreme winter weather in the Barn Owl. *Oecologia* 149: 44–51. Available online at <https://link.springer.com/article/10.1007/s00442-006-0430-3>
- Badenhorst P, Cooper JAG, Crowther J, Gonsalves J, Grobler NA, Illenberger WK, Laubscher WI, Mason TR, Moller JP, Perry JE, Rodering JSV, van der Merwe L** 1989. Survey of the September 1987 Natal Floods. South African National Scientific Programme Report 164: 1–134.
- Boon R** 1992. Vernon Crookes Nature Reserve. *Birding in Southern Africa* 44(1): 12–14.
- Boon RGC, Cockburn J, Govender N, Ground L, Slotow R, McLean C, Douwes E, Rouget M, Roberts D** 2016. Managing a threatened savanna ecosystem (KwaZulu-Natal Sandstone Sourveld) in an urban biodiversity hotspot: Durban, South Africa. *Bothalia* 46(2): 1–12. Available online at <https://journals.co.za/doi/abs/10.4102/abc.v46i2.2112>
- Bourne A, Cunningham SJ, Spottiswoode CN, Ridley AR** 2020a. Hot droughts compromise inter-annual survival across all groups sizes in a cooperatively breeding bird. *Ecology Letters* 23: 1776–1788. Available online at <https://onlinelibrary.wiley.com/doi/abs/10.1111/ele.13604>
- Bourne A, Cunningham SJ, Spottiswoode CN, Ridley AR** 2020b. Compensatory breeding in years following drought in a desert-dwelling cooperative breeder. *Frontiers in Ecology & Evolution* 8(190): 1–10. Available online at <https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2020.00190/full>
- Bourquin O, Sowler SG** 1980. The vertebrates of Vernon Crookes Nature Reserve. *Lammergeyer* 28: 20–32.
- Brewster CA** 1992. Notes on the effect of drought on birds in the Sehare area from February–September 1992. *Babbler* 24: 31–32.
- Brown LH, Pomeroy DE** 1984. The age structure of populations of wild birds in tropical Africa, as demonstrated by plumage characters and marking techniques. In: Ledger J (ed.), Proceedings of the Fifth Pan-African Ornithological Congress, pp. 97–119. Southern African Ornithological Society, Johannesburg.
- Byrom A, Craft ME, Durant SM, Nkwabi AJK, Metzger K, Hampson K, Mduma SAR, Forrester GJ, Ruscoe WA, Reed DN, Bukombe J, Mchetto J, Sinclair ARE** 2014. Episodic outbreaks of small mammals influence predator community dynamics in an East African savanna ecosystem. *Oikos* 123: 1014–1024. Available online at <https://nsojournals.onlinelibrary.wiley.com/doi/abs/10.1111/oik.00962>

- Cain JR, Lien RJ** 1985. A model for drought inhibition of Bobwhite Quail (*Colinus virginianus*) reproductive systems. *Comparative Biochemistry & Physiology A* 82: 925–930. Available online at <https://www.sciencedirect.com/science/article/abs/pii/0300962985905067>
- Campbell H** 1992a. Pigeon Valley – April 1992. *Albatross* 310: 11–12.
- Campbell H** 1992b. A new dimension in Vernon Crookes bird expectations. *Albatross* 310: 13–14.
- Campbell H** 1994. Sudden appearance of Pied Mannikins at Vernon Crookes. *Albatross* 319: 22.
- Caughley G, Walker B** 1983. Working with ecological ideas – ecological concepts. In: Ferrar A (ed.), *Guidelines for the management of large mammals in African conservation areas*, pp. 13–33. South African National Scientific Programme Report Series, Pretoria.
- Chittenden H** 2015. Storm wreaks havoc in northern KwaZulu-Natal. *KZN Birds* 45: 22.
- Chittenden H, Mendelsohn J** 1981. Recent breeding records. *Albatross* 262: 9–10.
- Chittenden H, Davies G, Weiersbye I** 2016. *Roberts Bird Guide*. 2nd edition. John Voelcker Bird Book Fund, Cape Town.
- Clarke L, Maggs J** 1987. Izikhukhula – the Natal '87 floods. *Sunday Tribune and Trust Bank*, Durban.
- Collingham YC, Huntley B, Altwegg R, Barnard P, Beveridge OS, Gregory RD, Mason LR, Oschadleus D, Simmons RE, Willis SG, Green RE** 2014. Prediction of mean adult survival rates of southern African birds from demographic and ecological covariates. *Ibis* 156: 741–754. Available online at <https://onlinelibrary.wiley.com/doi/abs/10.1111/ibi.12195>
- Cunningham-Van Someren GR** 1984. Birds and drought at Miotoni, Karen. *East Africa Natural History Society Bulletin* 14: 100–103.
- Craig AJFK** 1982. The breeding season of the Red Bishop. *Ostrich* 53: 112–114. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1982.9634735>
- Cyrus D, Robson N** 1980. *Bird Atlas of Natal*. University of Natal Press, Pietermaritzburg.
- Danchin E, Gonzalez-Davila G, Lebreton J-D** 1995. Estimating bird fitness correctly using demographic models. *Journal of Avian Biology* 26: 67–75. Available online at <https://www.jstor.org/stable/3677214>
- Dean WRJ** 1971. Breeding data for birds of Natal and Zululand. *Durban Museum Novitates* 9: 59–91.
- Dean WRJ, Barnard P, Anderson MD** 2009. When to stay, when to go: trade-offs for southern African arid zone birds in times of drought. *South African Journal of Science* 105: 24–28. Available online at <https://journals.co.za/doi/abs/10.10520/EJC96880>
- Dittami JP** 1986. Seasonal reproduction, moult and their endocrine correlates in two tropical Ploceidae species. *Journal of Comparative Physiology B* 156: 641–647. Available online at <https://link.springer.com/article/10.1007/BF00692741>
- Dowsett-Lemaire F** 1983. Ecological and territorial requirements of montane forest birds on the Nyika Plateau, south-central Africa. *Le Gerfaut* 73: 345–378.
- Dowsett-Lemaire F** 1985. Breeding productivity and the non-breeding element in some montane forest birds in Malawi, south-central Africa. *Biotropica* 17: 137–144. Available online at <https://www.jstor.org/stable/2388506>
- Dube LT, Jury MR** 2000. The nature of climate variability and impacts of drought over KwaZulu-Natal, South Africa. *South African Geographical Journal* 82: 44–53. Available online at <https://www.tandfonline.com/doi/abs/10.1080/03736245.2000.9713692>
- Du Preez L** 1995. Anuran community structure in the Vernon Crookes Nature Reserve, South Africa. *Madoqua* 19: 25–29.

Available online at https://journals.co.za/doi/abs/10.10520/AJA10115498_550

- Earlé RA** 1981. Factors governing avian breeding in *Acacia* savanna, Pietermaritzburg, part 1: extrinsic factors. *Ostrich* 52: 65–73. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1981.9633587>
- Earlé RA** 1982. Aspects of the breeding biology and ecology of Whitebellied Sunbird. *Ostrich* 53: 65–73. Available online at <https://www.tandfonline.com/doi/abs/10.108/00306525.1982.9634728>
- Erskine JM** 1983. Impact of the drought in KwaZulu-Natal. *South African Journal of Science* 79: 439.
- Fogden MPL, Fogden PM** 1979. The role of fat and protein reserves in the annual cycle of the Grey-backed Camaroptera in Uganda (Aves: Sylviidae). *Journal of Zoology* 189: 233–258. Available online at <https://zslpublications.onlinelibrary.wiley.com/doi/abs/10.1111/j.1469-7998.1979.tb03961.x>
- Fowler J, Cohen L** 1996. *Statistics for Ornithologists*. 2nd ed. British Trust for Ornithology, United Kingdom.
- Frederiksen M, Daunt F, Harris MP, Wanless S** 2008. The demographic impact of extreme events: stochastic weather drives survival and population dynamics in a long-lived seabird. *Journal of Animal Ecology* 77: 1020–1029. Available online at <https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2656.2008.01422.x>
- Friedl TWP** 2002. The effect of rainfall on the breeding behaviour of the Red Bishop, *Euplectes orix*. *Ostrich* 73: 181–184. Available online at <https://www.tandfonline.com/doi/pdf/10.1080/00306525.2002.11446748>
- Gargett V** 1977. A 13-year population study of the Black Eagles in the Matopos, Rhodesia, 1964–1976. *Ostrich* 48: 17–27. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1977.9634075>
- Gargett V, Gargett E** 1993. Hard times for the Matobo Black Eagles. *Honeyguide* 39: 7–15.
- Gargett V, Gargett E, Damania D** 1995. The influence of rainfall on Black Eagle breeding over 31 years in the Matobo Hills, Zimbabwe. *Ostrich* 66: 114–121. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1995.9632715>
- Garland I** 1970. News from Zululand. *Natal Bird Club News Sheet* 183: 1.
- Ginn P** 2007. Breeding frenzy. *Africa Birds & Birding* 12(1): 18–19.
- Hanmer DB** 1999. Dry season refuges for survival in Africa. *Bulletin of the African Bird Club* 6(1): 13–16.
- Hanmer DB** 2002. Measurements and moult of four species of canary from Mozambique and Malawi. *Honeyguide* 48: 47–68.
- Hanmer DB** 2003. Survival at Seldomseen – the last twenty-four years. *Honeyguide* 49: 28–45.
- Hanmer DB** 2009. What is the longevity of birds in the Eastern Highlands? *Honeyguide* 55: 41–44.
- Hanmer DB, Chadder B** 1993. Birds and the 1991/92 summer drought in the Mutare district. *Honeyguide* 39: 123–127.
- Harrison JA, Allan DG, Underhill LG, Herremans M, Tree AJ, Parker V, Brown CJ** 1997. *The Atlas of Southern African Birds*. Vols 1 & 2. BirdLife South Africa, Johannesburg.
- Herremans M** 1998. Strategies, punctuality of arrival and ranges of migrants in the Kalahari basin, Botswana. *Ibis* 140: 585–590. Available online at <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1474-919X.1998.tb04703.x>
- Herremans M** 2004. Effects of drought on birds in the Kalahari, Botswana. *Ostrich* 75: 217–227. Available online at <https://www.tandfonline.com/doi/abs/10.2989/00306520409485448>
- Hillman JC, Hillman AKK** 1977. Mortality of wildlife in Nairobi National Park, during the drought of 1973–1974. *African Journal of Ecology* 15: 1–18. Available online at <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2028.1977.tb00374.x>

- Hockey PAR, Dean WRJ, Ryan PG (eds)** 2005. Roberts – Birds of Southern Africa. 7th ed. John Voelcker Bird Book Fund, Cape Town.
- Hustler K, Howells WW** 1990. The influence of primary production on a raptor community in Hwange National Park, Zimbabwe. *Journal of Tropical Ecology* 6: 343–354. Available online at <https://www.cambridge.org/core/journals/journal-of-tropical-ecology/article/abs/influence-of-primary-production-on-a-raptor-community-in-hwange-national-park-zimbabwe/8A59EAE91D8F242D55D3CF0378CDA01D>
- Jewitt D, Erasmus BFN, Goodman PS, O'Connor TG, Hargrave WW, Maddalena DM, Witkowski ETF** 2015. Climate-induced change of environmentally defined floristic domains: a conservation based vulnerability framework. *Applied Geography* 63: 33–42. Available online at <https://www.sciencedirect.com/science/article/abs/pii/S0143622815001484>
- Jolly A** 1993. Drought of the century. *Lemur News – Newsletter of the Madagascar Section of the IUCN/SSC Primate Specialist Group* 1(1): 5.
- Jones PJ, Ward P** 1979. A physiological basis for colony desertion by Red-billed Queleas (*Quelea quelea*). *Journal of Zoology* 189: 1–19. Available online at <https://zslpublications.onlinelibrary.wiley.com/doi/abs/10.1111/j.1469-7998.1979.tb03949.x>
- Jury MR** 2022. Historical and projected climatic trends in KwaZulu-Natal: 1950–2010. *Water SA* 48: 369–379. Available online at <https://www.ajol.info/index.php/wsa/article/view/235324>
- Keast JA, Marshall AJ** 1954. The influence of drought and rainfall on reproduction in Australian desert birds. *Proceedings of the Zoological Society of London* 124: 493–499. Available online at <https://zslpublications.onlinelibrary.wiley.com/doi/abs/10.1111/j.1469-7998.1954.tb07790.x>
- Keep ME** 1973. Factors contributing to a population crash of nyala in Ndumu Game Reserve. *Lammergeyer* 19: 16–23.
- Kemp AC** 1991. Timing of laying by Greater Kestrels *Falco rupicoloides* near Pretoria, South Africa. *Ostrich* 62: 35–39. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1991.9639638>
- Kemp AC** 1994. Rain or food trigger breeding? *Laniarius* 52: 6–7.
- Kemp AC, Kemp MI** 1991. Timing of egg-laying by Southern Ground Hornbills *Bucorvus leadbeateri* in the central Kruger National Park, South Africa. *Ostrich* 62: 80–82. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1991.9639643>
- Kovacs Z** 1988. Preliminary hydrological assessment of the Natal flood. *Civil Engineer in South Africa* 1988(1): 7–13.
- Le Roux NP** 1995. Grasslands of Umtamvuna Nature Reserve: a description and recommendations for monitoring. MSc thesis, University of Natal, Pietermaritzburg. Available online at <https://researchspace.ukzn.ac.za/items/1933ef92-6bb1-4aa1-b162-fa366bc28e16>
- Lorber P** 1982. Late breeding by bee-eaters in a drought year. *Honeyguide* 111/112: 58–59.
- Lottering SJ, Mafongoya P, Lottering R** 2021. The impacts of drought and adaptive strategies of small-scale farmers in uMsinga, KwaZulu-Natal, South Africa. *Journal of Asian and African Studies* 56: 267–289. Available online at <https://journals.sagepub.com/doi/abs/10.1177/0021909620916898>
- Maclean GL, Gous RM, Bosman T** 1973. Effects of drought on the White Stork in Natal, South Africa. *Vogelwarte* 27: 134–136.
- Maddock AH, Zaloumis G** 1987. Additional and confirming records of the vertebrates at Vernon Crookes Nature Reserve with indications of rodent and ungulate abundances. *Lammergeyer* 38: 40–54.
- Mallalieu M** 1995. Crakes in the Lilongwe area: results of fieldwork 1991–1993. *Nyala* 18: 1–10.
- Manry DE** 1985. Reproductive performance of the Bald Ibis *Geronticus calvus* in relation to rainfall and grass-burning. *Ibis* 127:

- 159–173. Available online at <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1474-919X.1985.tb05052.x>
- Masterson ANB, Weaving AJ** 1975. A survey of breeding activity in *Brachystegia* woodland. Honeyguide 83: 31–38.
- Mentis MT, Poggenpoel B, Maguire RRK** 1975. Food of Helmeted Guineafowl in highland Natal. Journal of Southern African Wildlife Management Association 5: 23–25. Available online at https://journals.co.za/doi/abs/10.10520/AJA03794369_3090
- Meter EB** 1998. A synfloristic comparison of Oribi Gorge and Um-tamvuna Nature Reserves. MSc thesis, University of Natal, Pietermaritzburg. Available online at <https://researchspace.ukzn.ac.za/items/960df28f-572e-4fd0-b9a0-7695f3778ef5>
- Milton SJ, Dean WRJ, Leuteritz TEJ** 2004. Opportunistic and multiple breeding attempts in plants and vertebrates of semi-deserts with unpredictable rainfall events through the year. Transactions of the Royal Society of South Africa 59: 43–53. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00359190409519161>
- Moll EJ** 1978. A quantitative floristic study of a forest in Krantzklouf Nature Reserve, Natal. Lammergeyer 26: 29–37.
- Newton I** 1998. Population limitation in birds. Academic Press, London.
- Oatley TB, Underhill LG, Ross GJB** 1992. Recovery rate of juvenile Cape Gannets: a potential indicator of marine conditions. Colonial Waterbirds 15: 140–143. Available online at <https://www.jstor.org/stable/1521365>
- Osborne TO** 1998. Suspended breeding: effects of current drought in Etosha. Laniorudus 31: 17–19.
- Peach WJ, Hanmer DB, Oatley TB** 2001. Do southern African songbirds live longer than European counterparts? Oikos 93: 235–249. Available online at <https://nsojournals.onlinelibrary.wiley.com/doi/abs/10.1034/j.1600-0706.2001.930207.x>
- Pietersen DW, Symes CT** 2004. Assessing the diet of Amur Falcon *Falco amurensis* and Lesser Kestrel *Falco naumanni* using stomach content analysis. Ostrich 81: 39–44. Available online at <https://www.tandfonline.com/doi/abs/10.2989/00306525.2010.455817>
- Piper SE** 1994. Mathematical demography of the Cape Vulture. PhD thesis, University of Cape Town, South Africa. Available online at <https://open.uct.ac.za/handle/11427/19843>
- Piper SE** 1998. Swallows in the mist. Albatross 332: 19.
- Piper SE** 2002. Survival of adult, territorial Longtailed Wagtails *Motacilla clara*: the effects of environmental factors and individual covariates. Journal of Applied Statistics 29: 107–124. Available online at <https://www.tandfonline.com/doi/abs/10.1080/02664760120108485>
- Piper SE, Oatley TB** 1999. Two-tier populations: territory holders versus the rest. In: Adams NJ, Slotow RH (eds), Proceedings of the 22nd International Ornithological Congress, Durban, pp. 306–324. BirdLife South Africa, Johannesburg. Available online at https://www.internationalornithology.org/PROCEEDINGS_Durban/Symposium/S06/S06.3.htm
- Poynton JC** 1961. Biogeography of south-east Africa. Nature 4767: 801–803. Available online at <https://www.nature.com/articles/189801a0>
- Pringle VL** 1994. Bird notes from Huntly Glen. Bee-eater 45: 4–5.
- Read C, Tarboton WR, Davies GBP, Anderson MD, Anderson TA** 2014. An annotated checklist of the birds of the Vilanculos Coastal Wildlife Sanctuary, southern Mozambique. Ornithological Observations 5: 370–408. Available online at <https://journals.uct.ac.za/index.php/BO/article/view/254>
- Roberts DC** 1993. The vegetation ecology of municipal Durban, Natal – floristic classification. Bothalia 23: 271–326. Available online at <https://journals.abcjournal.aosis.co.za/index.php/ABC/article/view/813>

- Rogers DJ, Moll EJ** 1975. A quantitative description of some coast forests of Natal. *Bothalia* 11: 523–537. Available online at <https://journals.abcjournal.aosis.co.za/index.php/ABC/article/view/1500>
- Scott L, Steenkamp M** 1996. Environmental history and recent human influence at Lake Teza, KwaZulu-Natal. *South African Journal of Science* 92: 348–350.
- Shackleton CM, Granger JE, McKenzie B, Mentis MT** 1991. Multivariate analysis of coastal grasslands at Mkambati Game Reserve, north-eastern Pondoland, Transkei. *Bothalia* 21: 91–107. Available online at <https://journals.abcjournal.aosis.co.za/index.php/abc/article/view/869>
- Skead DM, Skead CJ** 1970. Hirundid mortality during adverse weather November 1968. *Ostrich* 41: 247–251. Available online at <https://www.tandfonline.com/doi/pdf/10.1080/00306525.1970.9634378>
- Smit IPJ, Bond WJ** 2020. Observations on the natural history of a savanna drought. *African Journal of Range and Forage Science* 37: 119–136. Available online at <https://www.tandfonline.com/doi/abs/10.2989/10220119.2020.1723695>
- Styles DGA** 2017. Challenges in resolving and protecting biodiversity in a developing city: the case of the Cato Ridge grasslands, Durban. MSc thesis, University of KwaZulu-Natal, Durban, South Africa. Available online at <https://researchspace.ukzn.ac.za/items/be04b6b0-e54a-4060-867d-c3fde364d09a>
- Tarboton WR** 1982. Breeding status of the Black Stork in the Transvaal. *Ostrich* 53: 151–156. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1982.9634745>
- Tarboton WR** 1992. Aspects of the breeding biology of the African Jacana. *Ostrich* 63: 141–157.
- Tarboton WR** 1995. Polyandry in the African Jacana: the roles of male dominance and rate of clutch loss. *Ostrich* 66: 49–60. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1995.9633759>
- Tarboton WR** 2011. Roberts – Nests and Eggs of southern African birds. John Voelcker Bird Book Fund, Cape Town.
- Taylor PB** 1994. The biology, ecology and conservation of four flufftail species, *Sarothrura* (Aves, Rallidae). PhD dissertation, University of Natal, Pietermaritzburg, South Africa. Available online at <https://researchspace.ukzn.ac.za/items/ea76b8e5-0a66-43e2-8d31-195232fb7160>
- Taylor PJ** 1998. Regional patterns of small mammal abundance and community composition in protected areas in KwaZulu-Natal. *Durban Museum Novitates* 23: 42–51. https://journals.co.za/doi/abs/10.10520/AJA0012723X_1573
- Tinley KL** 1982. The influence of soil moisture balance on ecosystem patterns in southern Africa. In: Huntley BJ, Walker BH (eds), *Ecology of Tropical Savannas*, pp. 175–192. Springer Verlag, Berlin. Available online at https://link.springer.com/chapter/10.1007/978-3-642-68786-0_9
- Tøttrup AP, Klaassen RHG, Kristensen MW, Strandberg R, Vardanis Y, Lindström A, Rahbek C, Alerstam T, Thorp K** 2012. Drought in Africa caused delayed arrival of European songbirds. *Science* 338: 1307. Available online at <https://www.science.org/doi/abs/10.1126/science.1227548>
- Tree AJ** 1978. A visit to Makgadigadi in April 1974. *Honeyguide* 95: 39–41.
- Tree AJ** 1993. Recent reports. *Honeyguide* 39: 152–164.
- Tree AJ** 1995. Recent reports. *Honeyguide* 41: 242–255.
- Van Heerden J** 1974. Botulism in the Orange Free State goldfields. *Ostrich* 45: 182–184. Available online at <https://www.tandfonline.com/doi/pdf/10.1080/00306525.1974.9634055>
- Van Someren VGL** 1944. Incubation and nestling periods. *Ibis* 86: 223–225. Available online at <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1474-919X.1944.tb03881.x>

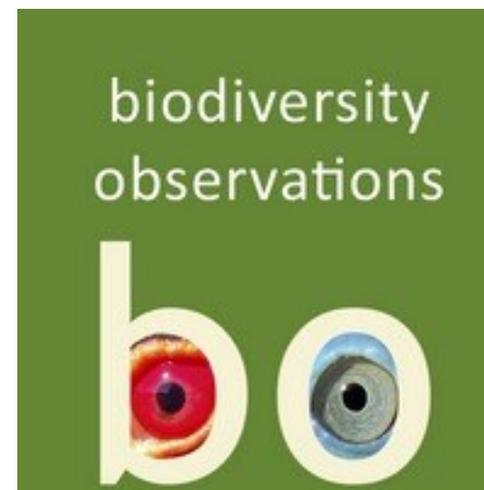
- Van Someren VGL** 1947. Onset of sexual activity. *Ibis* 89: 51–56. Available online at <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1474-919X.1947.tb04916.x>
- Vernon CJ** 1978. Breeding seasons of birds in deciduous woodland at Zimbabwe, Rhodesia, from 1970 to 1974. *Ostrich* 49: 102–115. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1978.9633516>
- Vernon CJ** 1989. Observations on the forest birds around East London. *Ostrich Supplement* 14: 75–84. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1989.9639622>
- Vernon CJ** 1993. The greatest drought in living memory – a drought index derived from rainfall. *The Naturalist* 37: 19–23.
- Vernon CJ, Macdonald IAW, Dean WRJ** 1989. Birds of an isolated tropical lowland rainforest in eastern Zimbabwe. *Ostrich Supplement* 14: 111–122. Available online at <https://www.tandfonline.com/doi/abs/10.1080/00306525.1989.9639626>
- Vetter S, Goodall VL, Alcock R** 2020. Effect of drought on communal livestock farmers in KwaZulu-Natal, South Africa. *African Journal of Range and Forage Science* 37: 93–106. Available online at <https://www.tandfonline.com/doi/abs/10.2989/10220119.2020.1738552>
- Vincent J** 1969. Mortality among swallows *Hirundo rustica*. *Lammergeyer* 10: 97–98.
- Vincent J** 1989. *Web of Experience – an autobiography*. Privately published, Mooi River.
- Walker BH, Emslie RH, Owen-Smith N, Scholes RJ** 1987. To cull or not to cull: lessons from a southern African drought. *Journal of Applied Ecology* 24: 381–401. Available online at <https://www.jstor.org/stable/2403882>
- Wragg PD** 2017. Multiple nutrients control threatened grassland vegetation in eastern South Africa. *South African Journal of Botany* 112: 225–236. Available online at <https://www.sciencedirect.com/science/article/pii/>

Biodiversity Observations

The scope of Biodiversity Observations includes papers describing observations about biodiversity in general, including animals, plants, algae and fungi. This includes observations of behaviour, breeding and flowering patterns, distributions and range extensions, foraging, food, movement, measurements, habitat and colouration/plumage variations. Biotic interactions such as pollination, fruit dispersal, herbivory and predation fall within the scope, as well as the use of indigenous and exotic species by humans. Observations of naturalized plants and animals will also be considered. Biodiversity Observations will also publish a variety of other interesting or relevant biodiversity material: reports of projects and conferences, annotated checklists for a site or region, specialist bibliographies, book reviews and any other appropriate material. Further details and guidelines to authors are on the journal website (<https://journals.uct.ac.za/index.php/BO/>).

ISSN 2219-0341

Editor: LG Underhill



Appendix 1: Spring and summer (September–March) breeding records per species at Vernon Crookes Nature Reserve (1987/88 to 1996/97).

English names follow Chittenden et al. (2016).

Species	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	Total
Yellow-billed Duck	1	2	0	1	1	0	1	0	0	2	8
Spur-winged Goose	0	0	0	0	1	1	1	0	0	1	4
Little Grebe	2	2	1	1	1	0	0	0	1	1	9
Hadada Ibis	0	1	0	1	1	0	0	0	1	1	5
Black-headed Heron	0	0	1	0	0	0	0	0	0	0	1
Yellow-billed Kite	0	0	1	0	1	0	0	1	1	1	5
Martial Eagle	1	1	1	1	1	1	1	0	1	1	9
Crowned Eagle	1	1	1	1	1	1	0	0	2	1	9
Long-crested Eagle	0	0	0	1	0	0	0	1	0	2	4
Black Sparrowhawk	0	1	1	0	1	1	1	0	0	1	6
Jackal Buzzard	1	0	0	0	0	0	0	0	1	0	2
Common Moorhen	1	1	0	0	0	0	0	0	0	0	2
African Jacana	0	0	0	0	0	0	0	0	1	1	2
Grey Crowned Crane	2	1	1	1	0	0	1	1	2	1	10
Tambourine Dove	1	0	0	0	0	0	0	0	0	1	2
Black-collared Barbet	0	0	0	0	0	0	1	0	1	1	3
Knysna Turaco	0	0	1	0	0	0	0	0	0	0	1
Burchell's Coucal	0	0	0	0	0	0	0	0	1	0	1
Green Malkoha	0	0	1	0	0	0	0	0	0	0	1
African Grass Owl	0	0	0	0	0	0	0	0	0	1	1
Crowned Hornbill	1	1	1	1	1	0	0	0	0	2	7
Green Woodhoopoe	1	1	0	1	0	0	0	0	0	1	4
Afr. Pygmy Kingfisher	2	0	1	1	1	1	1	1	1	1	10
Brown-hooded Kingfisher	1	0	0	2	0	1	1	0	1	1	7
Golden-tailed Woodpecker	0	0	0	0	1	0	0	0	0	0	1
Olive Woodpecker	0	0	0	1	0	0	0	0	0	1	2
Red-throated Wryneck	0	1	0	0	0	0	0	0	0	0	1
Lanner Falcon	0	0	0	0	0	0	0	0	1	1	2
Cape Batis	1	1	0	0	1	0	0	0	0	2	5
Chinspot Batis	0	0	1	0	0	0	0	0	0	0	1
Southern Boubou	0	0	0	0	0	0	0	1	0	0	1
Black-backed Puffback	2	1	1	0	0	0	0	0	1	2	7
Southern Tchagra	0	0	0	0	0	1	0	0	0	0	1
Southern Fiscal	0	0	0	1	1	0	0	0	0	0	2

Appendix 1: continued...

Species	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	Total
Black Cuckooshrike	0	0	0	1	0	0	0	0	0	0	1
Black-headed Oriole	0	0	0	0	0	1	0	0	0	1	2
Fork-tailed Drongo	0	0	0	0	0	0	0	0	1	0	1
Square-tailed Drongo	0	0	0	0	1	0	0	0	0	0	1
African Paradise Flycatcher	0	0	0	0	0	0	1	0	2	1	4
White-necked Raven	1	1	0	0	0	0	0	0	0	0	2
Southern Black Tit	0	0	0	0	1	0	0	1	0	1	3
Rufous-naped Lark	1	1	1	2	0	1	0	0	0	0	6
Dark-capped Bulbul	0	2	2	1	2	0	1	1	1	1	11
Sombre Greenbul	0	0	1	0	0	0	0	1	0	0	2
Yellow-bellied Greenbul	0	0	1	0	0	0	0	0	0	0	1
Lesser Striped Swallow	1	2	1	0	0	0	0	0	0	1	5
Black Saw-wing	2	3	1	2	2	0	1	2	1	3	17
Fan-tailed Grassbird	0	0	1	0	0	0	0	0	0	0	1
Croaking Cisticola	1	2	1	0	1	0	1	1	1	3	11
Pale-crowned Cisticola	1	1	0	0	1	0	0	1	1	2	7
Wing-snapping Cisticola	0	0	0	0	1	0	0	0	0	1	2
Zitting Cisticola	0	0	0	0	1	0	0	0	0	2	3
Lazy Cisticola	2	1	1	2	1	0	0	0	2	1	10
Neddicky	1	0	0	1	0	0	1	0	0	1	4
Wailing Cisticola	0	0	0	0	0	0	0	0	0	1	1
Tawny-flanked Prinia	1	1	2	0	1	0	0	0	2	0	7
Bar-throated Apalis	1	0	0	0	0	0	0	0	0	0	1
Yellow-breasted Apalis	0	0	0	0	1	0	0	0	0	0	1
Green-backed Camaroptera	0	1	0	0	0	0	0	0	0	0	1
Cape White-eye	1	1	0	0	2	0	0	0	0	0	4
Black-bellied Starling	2	3	3	1	1	2	0	0	0	1	13
Cape Glossy Starling	0	0	0	0	2	0	0	1	0	0	3
Violet-backed Starling	0	0	0	0	0	0	0	0	1	1	2
Olive Thrush	0	0	0	1	0	0	0	0	1	1	3
White-starred Robin	0	0	0	0	0	0	1	0	0	0	1
Brown Scrub Robin	0	0	0	0	0	0	0	0	0	1	1
African Stonechat	2	0	0	0	0	0	0	0	0	2	4
Familiar Chat	0	0	0	0	0	0	0	0	0	1	1

Appendix 1: continued...

Species	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	Total
Southern Black Flycatcher	0	1	0	0	1	0	0	0	1	0	3
Ashy Flycatcher	0	0	0	1	0	0	0	0	0	0	1
African Dusky Flycatcher	0	3	0	1	2	1	2	0	1	1	11
Amethyst Sunbird	3	1	1	0	1	0	1	1	1	2	11
Greater Double-collared Sunbird	2	3	0	1	0	0	0	0	0	2	8
Grey Sunbird	0	1	0	0	0	0	0	0	0	0	1
Collared Sunbird	1	2	1	0	2	0	0	0	0	1	7
Olive Sunbird	0	1	0	0	0	0	0	0	1	2	4
Dark-backed Weaver	2	1	3	0	2	1	0	0	1	1	11
Eastern Golden Weaver	2	1	1	0	0	0	0	1	1	0	6
Spectacled Weaver	2	2	2	1	1	0	2	1	0	3	14
Thick-billed Weaver	2	1	1	2	2	1	1	2	2	2	16
Cape Weaver	0	1	0	0	0	0	0	1	0	2	4
Village Weaver	0	1	1	1	1	0	0	0	0	0	4
Red-collared Widowbird	2	1	1	1	0	0	0	0	0	0	5
Fan-tailed Widowbird	2	1	1	2	1	1	0	1	0	1	10
Green Twinspot	0	0	1	1	0	0	0	0	0	0	2
Grey Waxbill	0	0	0	0	1	0	0	0	0	1	2
Common Waxbill	1	0	1	2	1	0	0	0	0	0	5
Sweet Waxbill	0	1	0	0	0	0	0	0	0	0	1
Bronze Mannikin	0	0	1	1	0	0	0	0	0	1	3
Red-backed Mannikin	0	0	0	0	1	0	0	1	2	1	5
Pin-tailed Whydah	2	0	0	0	0	0	0	0	0	0	2
Cape Longclaw	0	0	2	1	1	1	0	0	0	0	5
Yellow-throated Longclaw	2	1	1	0	1	1	0	1	1	1	9
Cape Wagtail	0	0	0	0	0	1	0	0	0	0	1
Mountain Wagtail	0	0	0	0	0	0	0	0	1	0	1
African Pipit	0	0	0	0	0	0	0	0	0	1	1
Plain-backed Pipit	1	2	2	1	0	0	0	0	0	1	7
Short-tailed Pipit	0	1	2	1	0	0	0	0	0	0	4
Brimstone Canary	0	0	0	0	1	0	0	1	0	1	3
Cape Canary	0	1	0	1	0	0	0	0	0	0	2
Streaky-headed Seedeater	1	0	0	0	0	0	0	0	0	1	2
Yellow-fronted Canary	0	0	0	0	0	0	0	0	1	1	2
Total	60	61	50	43	50	18	20	23	42	79	446

Appendix 2: Autumn and winter (April–August) breeding records per species at Vernon Crookes Nature Reserve (1987 to 1996).

English names follow Chittenden et al. (2016).

Species	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Total
Natal Spurfowl	0	0	1	0	0	0	0	0	0	0	1
Yellow-billed Duck	0	0	0	1	0	0	0	0	0	0	1
Yellow-billed Kite	1	0	1	0	0	0	0	0	0	0	2
African Cuckoo-Hawk	0	1	0	0	0	0	0	0	0	0	1
Long-crested Eagle	0	1	0	0	0	0	0	0	0	0	1
Martial Eagle	1	1	0	0	1	1	1	0	0	0	5
Crowned Eagle	0	0	1	1	0	0	0	0	0	1	3
Jackal Buzzard	0	0	0	1	0	0	0	0	0	1	2
Little Sparrowhawk	0	0	1	0	0	0	0	0	0	0	1
Black Sparrowhawk	1	1	1	1	1	1	1	1	0	1	9
Grey Crowned Crane	0	1	0	0	1	0	0	0	0	0	2
African Jacana	0	0	0	0	0	0	0	0	0	1	1
African Olive Pigeon	0	0	0	0	0	0	0	1	0	0	1
Burchell's Coucal	0	0	0	0	0	0	0	0	0	1	1
Brown-hooded Kingfisher	0	1	0	0	0	0	0	0	0	0	1
Black-collared Barbet	0	0	0	0	0	0	0	0	0	1	1
Olive Woodpecker	0	1	0	0	0	0	0	0	0	0	1
Red-throated Wryneck	1	0	0	0	0	0	0	0	0	0	1
Rufous-naped Lark	0	1	0	0	0	0	0	0	0	1	2
Black Saw-wing	1	0	0	0	0	0	0	0	0	0	1
White-browed Scrub Robin	0	0	0	1	0	0	0	0	0	0	1
Cape Wagtail	0	0	0	0	0	1	0	0	0	0	1
Plain-backed Pipit	1	0	0	0	0	0	0	0	0	0	1
Yellow-throated Longclaw	0	1	1	0	0	0	0	0	0	0	2
Black-bellied Starling	1	0	0	0	0	0	0	0	0	0	1
Greater Double-collared Sunbird	0	1	0	0	0	0	1	0	0	1	3
Amethyst Sunbird	0	0	0	0	0	0	0	0	0	1	1
Collared Sunbird	1	0	0	0	0	0	0	1	1	0	3
Dark-backed Weaver	0	1	0	0	0	0	0	0	0	0	1
Fan-tailed Widowbird	0	0	0	0	1	0	0	0	0	0	1
Red-collared Widowbird	0	0	0	0	0	0	0	0	1	0	1
Swee Waxbill	0	0	0	0	1	0	0	0	0	0	1
Red-backed Mannikin	0	0	0	0	0	0	0	0	0	1	1
Streaky-headed Seedeater	0	1	0	0	0	0	0	0	0	0	1
Total	8	12	6	5	5	3	3	3	2	10	57