Effect of temperature and rainfall on the distribution of the South African shelduck *Tadorna cana*

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The distribution of the South African shelduck *Tadorna cana* was mapped and related to temperature and rainfall. A multiple regression analysis based on quantified spatial abundance (the number of sixteenth degree squares recorded with shelduck in a degree square), mean annual rainfall, mean annual temperature and mean temperature of the coldest (July) and hottest (January) months indicated a significant ($P <$ 0,001) negative linear relation between shelduck distribution and temperature, but no significant ($P >$ 0,05) relation with rainfall. Mean annual rainfall in excess of 600 mm is however suggested to bring about unfavourable habitat within temperate southern Africa. The hypotheses formulated on the environmental relations of shelduck distribution are compared with habitat preference, breeding season, nest sites and feeding behaviour.

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Die verspreiding van die bergeend *Tadorna cana* is gekarteer en vergelyk met temperatuur en reënval. 'n Veelvoudige regressie-analise, gebaseer op verspreidingsdigtheid (die aantal sestiende graad vierkante waar bergeende waargeneem is in 'n graadvierkant), gemiddelde jaarlikse reënval, gemiddelde jaarlikse temperatuur en gemiddelde temperatuur van die koudste (Julie) en warmste (Januarie) maande het 'n beduidende ($P <$ 0,001) negatiewe verwantskap tussen bergeendverspreiding en temperatuur aangedui, hoewel geen beduidende ($P >$ 0,05) verwantskap met reënval gevind kon word nie. 'n Gemiddelde jaarlikse reënval bo 600 mm word egter beskou as rede vir ongunstige habitat in die gematigde streke van suidelike Afrika. Die hipoteses wat geformuleer is oor die verwantskappe tussen bergeendverspreiding en omgewingsfaktore word vergelyk met habitatvoorkeur, broeiseisoen, nesmaakplek en voeding.

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Apart from a single tropical species (*Tadorna radjah*), the seven shelduck (*Tadorna*) species of the world characteristically inhabit temperate regions (Delacour 1954). Four species, the South African shelduck *T. cana*, Australian mountain duck *T. tadornoides*, New Zealand paradise shelduck *T. variegata* and the ruddy shelduck *T. ferruginea* of Asia are more closely related in shape, plumage pattern and behaviour, and are generally referred to as Casarcas (Delacour 1954). The geographical isolation of these species in the temperate regions of different continents and islands may have involved different environmental adaptations. Among southern African waterfowl the distribution of the yellow-billed duck *Anas undulata* (Rowan 1963) and the Cape shoveller *A. smithii* (Siegfried 1965) are confined to the cooler regions of the subcontinent. The aim of this paper is to relate the distribution of the South African shelduck to temperature and rainfall on a quantitative basis, and to compare known habitat preferences with environmental relations.

Material and methods

A preliminary distribution map was drawn showing published records and data recorded personally. Only records that could be traced down to sixteenth degree squares were used. The data were divided between those denoting successful breeding, that is ducklings were observed, and other sight records. The maps were sent to various ornithologists familiar with different parts of southern Africa with a request to add reliable records. The following persons and institutions provided additional data: W.R.J. Dean and D.M. Skead (Transvaal Nature Conservation), W.R. Siegfried and R.A.C. Jensen (Percy FitzPatrick Institute), C.W. Heÿl and M.H. Currie (Cape Nature and Environmental Conservation), C.F. Clinning (South West Africa Nature Conservation and Tourism), C.J. Skead and J.M. Winterbottom. Data were also extracted from the nest record files of the Southern African Ornithological Society, the Transvaal (Kemp in prep.) and Natal (Cyrus & Robson 1980) bird atlasses and records compiled by Mentis (1974) and Milstein (1977).

The correlation and multiple regression analysis (Allen 1973) is based on quantified spatial abundance (the number of sixteenth degree squares recorded with shelduck in a degree square) and the mean annual rainfall, mean annual temperature, mean temperature of the hottest month (January) and the coldest month (July) for each degree square in southern Africa south of 21 °S ($n = 237$). The rainfall and temperature data were taken from Weather Bureau Reports (1954, 1957).

Results

Shelducks occur only within southern Africa south of Etosha in Namibia, Moremi in Botswana, Bulawayo in Zimbabwe and Ndumu in Natal (Figure 1). Most breeding records are restricted to areas south of 26 °S and generally there are few records outside the Orange Free State and central and southern Cape Province.

The species has a discontinuous distribution within southern Africa which appears to be correlated with environmental variables such as temperature and rainfall (Figures 2 and 3). Most sight records and 99% of the breeding records fall within the 18 °C isotherm. The scarceness of shelduck in the east of temperate southern Africa coincides with mean annual rainfall in excess of 600 mm. Breeding records beyond the 600 mm isohyet are rare.

Mean annual rainfall is not significantly ($P > 0{,}05$) correlated with shelduck distribution, but mean annual temperature, mean temperature of the coldest month (July) and mean temperature of the hottest month (January) all have significant ($P < 0{,}001$) negative linear correlations with shelduck distribution (Table 1), which shows

Table 1 Correlations between shelduck distribution, rainfall and temperature variables

	Shelduck distr.	Annual rainfall	Annual temp.	Temp. July
Annual rainfall	−0,084			
Annual temperature	−0,563[a]	0,038		
Temperature (July)	−0,620[a]	0,148	0,792[a]	
Temperature (Jan.)	−0,365[a]	−0,251[a]	0,811[a]	0,484[a]

[a] Significant at $P < 0{,}001$

an estimate of the degree to which the variables vary together (Sokal & Rohlf 1969). The regression analysis, which suggests the functional relation of one variable upon another (Sokal & Rohlf 1969), indicates that the mean temperature of the coldest month is the best predictor of shelduck distribution (Table 2). Mean annual temperature is a significant ($P < 0{,}05$) negative predictor of shelduck distribution independent of any correlation it may have with the other variables. Consideration of mean annual temperature in addition to the temperature of the coldest and hottest months fails to explain the discontinuous distribution of shelduck further (Table 2). The residuals of the computed values of dependent variables show 16 and two degree squares where unexpectedly dense and sparse distribution have been recorded respectively. The probable causes are an uneven

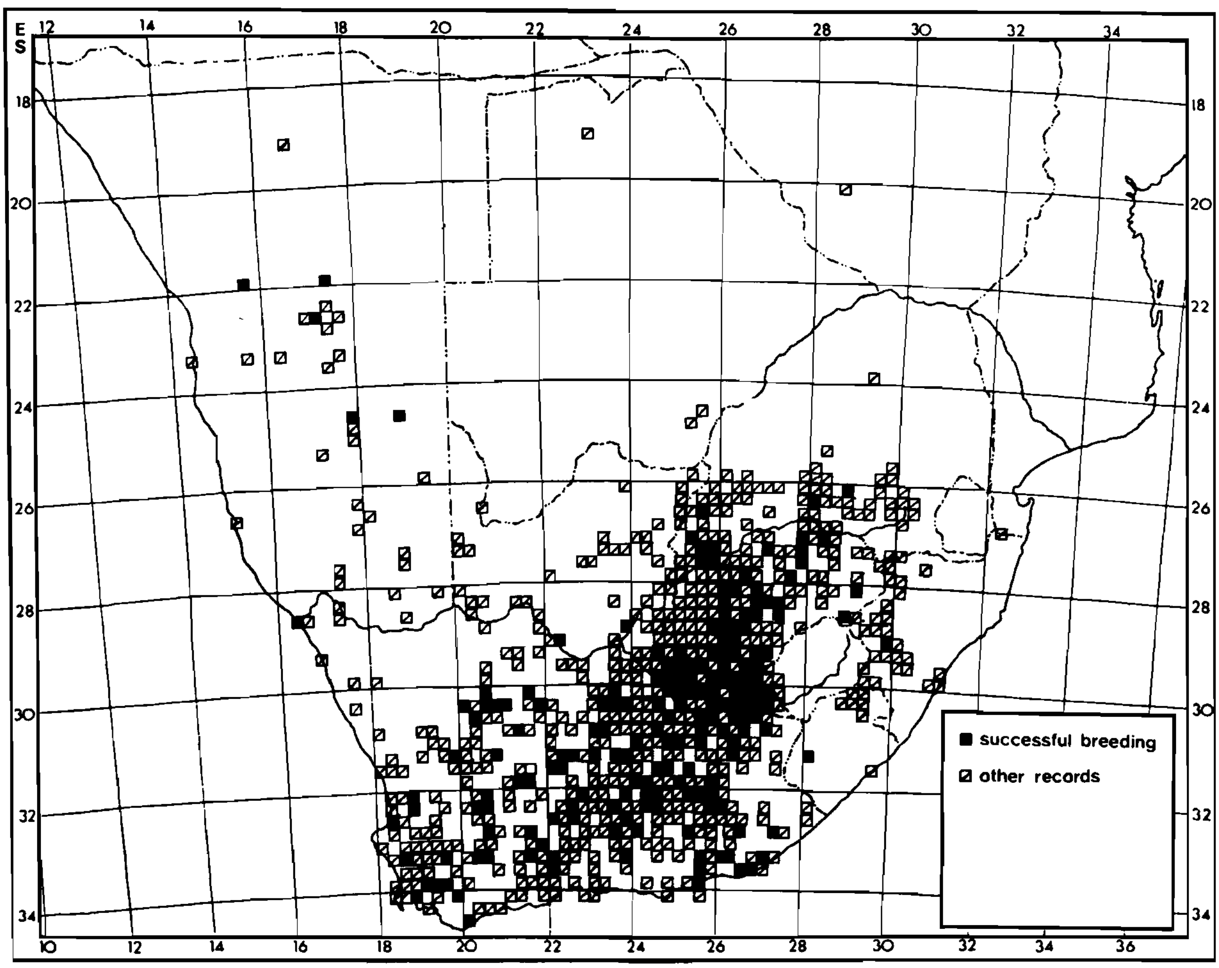

Figure 1 Geographical distribution of the South African shelduck. Each small square represents a particular one sixteenth degree square.

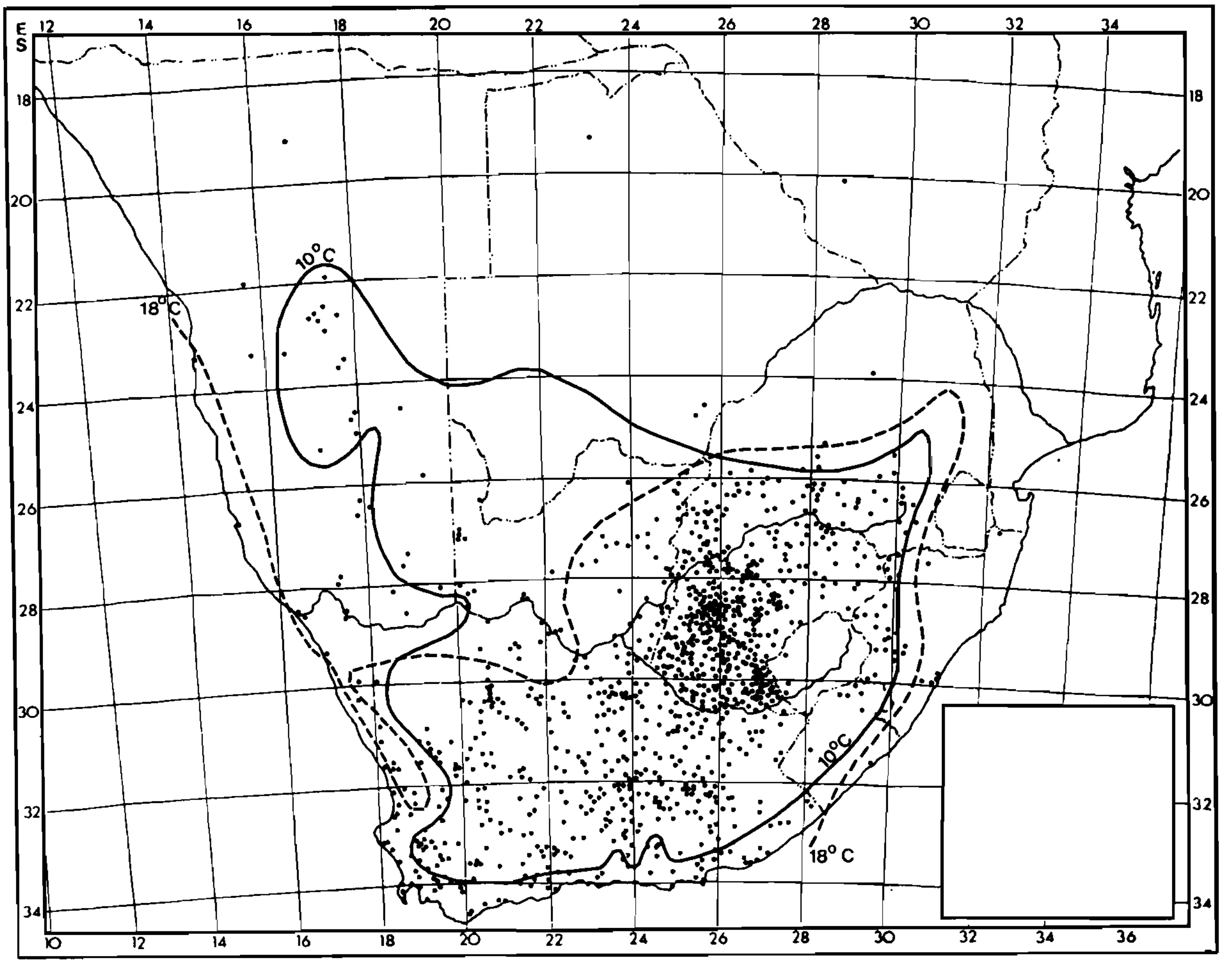

Figure 2 Comparison between the distribution of the South African shelduck, the 18 °C year-round isotherm and the 10 °C July isotherm. Each dot represents a recorded locality.

Table 2 Basic regression statistics of temperature variables in relation to shelduck distribution

	Temp. July	Annual temp.
Standard error of estimate	3,3922	3,3600
Multiple correlation coefficient	0,6198	0,6311
Coefficient of determination	0,3841	0,3983
Corrected coeff. of determination	0,3815	0,3932

distribution of observers and variation in wetland availability (Table 3).

Discussion

The quantification of distribution records into a density parameter may be criticized on the basis of a lack of a systematic data collecting procedure. The problem of an uneven distribution of observers and the tendency to record the unexpected more readily than the obvious was minimized by collecting data from regional ornithologists. However, the analysis of a residual plot shows the influence of many observers on the one hand, and a lack of observers on the other hand, particularly in the southwestern Cape and Lesotho respectively. The data proved, however, to be suitable for a quantitative, statistical analysis, which produced a testable hypothesis concerning the effect of temperature and rainfall on the distribution of shelduck. Crowe (1979) pointed out the advantage of a multiple regression analysis over correlation analysis when studying dependent-independent variable relations, and used the analysis to formulate

Table 3 Residual values of degree squares where unexpectedly few or many sixteenth degree squares have been recorded with shelduck, and possible main causes

°square	*y*-obs.	*y*-comp.	Residual	Possible cause
33S,18E	11,00	3,30	7,70	many observers
33S,19E	12,00	4,62	7,38	many observers
32S,23E	14,00	4,94	9,06	abundant habitat
32S,24E	12,00	4,94	7,06	abundant habitat
32S,25E	13,00	4,94	8,06	abundant habitat
31S,23E	14,00	6,63	7,37	abundant habitat
31S,24E	15,00	6,97	8,03	abundant habitat
30S,23E	14,00	5,63	8,37	abundant habitat
30S,24E	13,00	5,63	7,37	abundant habitat
30S,25E	16,00	6,95	9,05	abundant habitat
30S,26E	15,00	6,95	8,05	abundant habitat
30S,28E	0,00	7,95	−7,95	limited habitat
29S,25E	16,00	6,61	9,39	abundant habitat
29S,26E	16,00	6,95	9,05	abundant habitat
29S,28E	0,00	9,61	−9,61	limited observers
28S,25E	15,00	5,95	9,05	abundant habitat
28S,26E	16,00	6,29	9,71	abundant habitat
27S,25E	13,00	5,61	7,39	abundant habitat

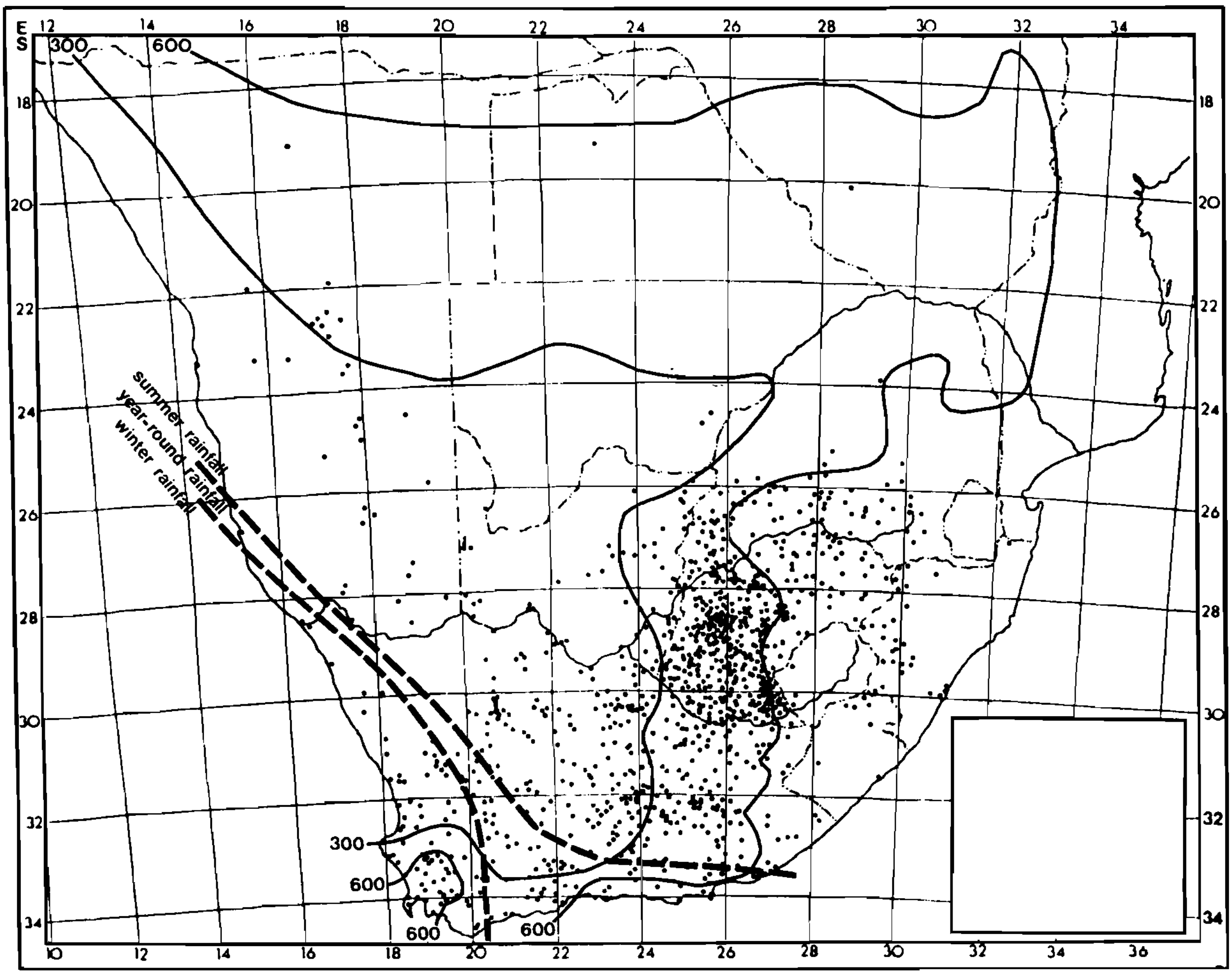

Figure 3 Comparison between the distribution of the South African shelduck, the seasonal rainfall regions and the 300 and 600 mm mean annual precipitation isohyets. Each dot represents a recorded locality.

several hypotheses on the relation between the morphological variation of helmeted guineafowl *Numida meleagris* and crested guineafowl *Guttera pucherani*, and environmental variation.

Winterbottom (1973) considered shelduck as a characteristic temperate species and Snow (1978) suggested that the distribution of shelduck is controlled by temperature. Rowan (1963) contended that animal distributions tend to be affected by extremes in the environment rather than means and suggested that although the distribution of the yellow-billed duck appears to be correlated with mean temperature, the species might be intolerant of the direct effect of temperature exceeding 32 °C. In shelduck, the present study indicates that consideration of both the mean temperature of the coldest and hottest months in addition to mean temperature does not further clarify the affinity. Because the mean temperature of the coldest month (July), when shelduck breed (Geldenhuys 1980a), appears to be the best predictor of distribution, a physiological response precipitating as a breeding intolerance to high temperature could be functioning. This would explain why shelduck nest in burrows (Edelsten 1932, Geldenhuys 1980b), where temperature extremes are considerably closer to average than at the ground surface (Vorhies 1945, Misonne 1959).

The absence of a significant linear correlation between rainfall and shelduck distribution does not exclude the possibility that a particular level of rainfall indirectly restricts distribution in a non-linear fashion. This is supported by the scarceness of shelduck in temperate areas beyond the 600 mm isohyet, which has previously been recognised in the Orange Free State (Geldenhuys 1976a) and the eastern Cape Province (Skead 1967). The limiting effect of high rainfall on shelduck distribution can be attributed to the intolerance of the species towards dense wetland vegetation. Shelduck inhabit wetlands characterized by an absence of emergent hydrophytes and dense littoral vegetation because they keep to open, bare areas where they are able to spot danger at a great distance and flee in time (Geldenhuys 1976b). The main feeding niches of shelduck are mudflats where they filter mud for invertebrates, and shallow littoral zones where they feed on soft plants such as filamentous algae (Zygnemaceae) and floating, rooted vegetation (Hydrocharitaceae) (Geldenhuys 1977). These habitat conditions, which are characteristic of wetlands with unstable water levels, are scarce in high rainfall regions, where luxuriant emergents and dense littoral hydrophytes dominate the wetland plant community (Sculthorpe 1967).

The sparse distribution of shelduck in the northern Cape Province, Namibia and southern Botswana probably reflects a paucity of wetlands as a result of low rainfall in combination with porous soils. The recent invasion of shelduck into farm dams in these areas (Clancey 1967) supports this view.

To conclude, temperature, in particular mean temperature of the coldest month (when shelduck also breed), is a reliable climatic indicator of the relation between shelduck distribution and environmental variables. Within temperate southern Africa the scarceness of shelduck in the east can be attributed to unfavourable habitat caused by high rainfall.

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