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Why do birds stand on one leg? – A pilot study of exotic and native New Zealand birds

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Abstract One-legged standing (or unipedal posture) in birds was investigated with a particular focus on the role of ambient air temperature on this behaviour in a variety of wading birds and waterfowl. Waterfowl (*Anas platyrhynchos* and *Cygnus atratus)* were less likely to be observed standing on 1 leg than long-legged species of wading birds (*Ardea novaehollandiae*, *Limosa lapponica*, *Platalea regia, Himantopus himantopus)*, perhaps because of differences in the length of their legs. Feeding behaviour and activities associated with disturbance influenced the frequency of unipedal posture. For captive flamingos (*Phoenicopterus roseus)* and pied stilts *(Himantopus himantopus*) the proportion of birds observed standing on 1 leg increased as the temperature increased from 8 to 19°C. This observation contradicts the theory that unipedal posture is a behavioural adaptation to minimise heat loss on cold days. An alternative theory based on unihemispheric slow wave sleep (USWS) patterns is proposed as an explanation for unipedal posture and is recommended as a focus for future research. Our results also confirm the importance of considering differences between species in leg anatomy and activity levels to measure the effects of temperature.

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INTRODUCTION

Birds have a number of behavioural and anatomical adaptations to cope with extreme cold: repositioning of feathers to trap air for insulation, altering flow of blood to reduce heat loss, migration to warmer regions, selection of warmer micro-habitats, sheltering within a flock, and body postures to minimise heat loss (van de Kam *et al*. 2004). Birds have a body temperature of 40 to 43ºC (Prinzinger 1990), but it is only at much lower temperatures that the energy required by resting birds to keep warm increases steeply – depending on the species, the critical temperature varies from 10-23°C (Kirsten & Piersma 1987). Some species, such as hummingbirds and nightjars, may go into torpor to minimise thermoregulatory costs (Maddocks & Geiser 2007). While torpor is usually thought to be associated with small birds, a recent study has observed this behaviour in the larger tawny frogmouth (Kortner *et al.* 2000). At less extreme conditions, it can still be advantageous to reduce heat loss through behavioural means such as repositioning of extremeties (e.g., tucking head under the wing).

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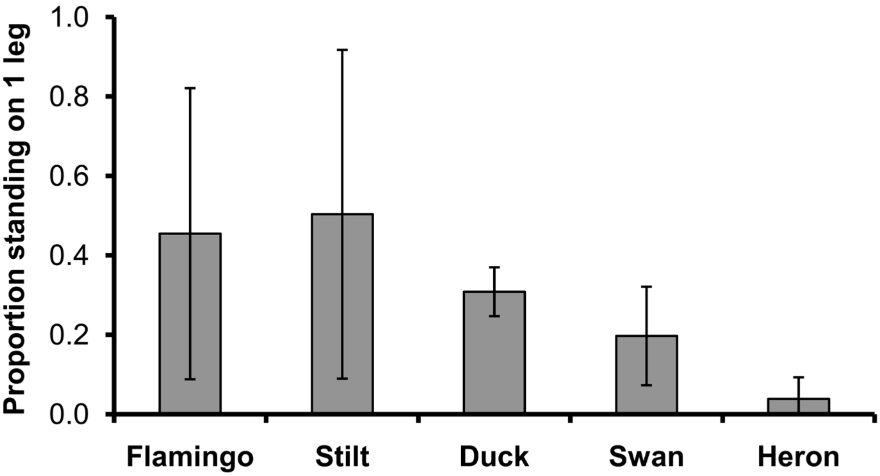

Fig. 1. Proportion of each species observed standing on 1 leg. Values represent means ± 1 standard deviation; the number of replicate assessments and total number of individual observations (in parentheses) were 10 (154), 6 (152), 5 (134), 3 (20), 2 (20) for flamingos, stilts, ducks, swans and herons, respectively.

Unipedal posture has been observed in wading birds and waterfowl as well as other major avian families, and has attracted much speculation over its function (Clark 1973; Anon 2008; Layton 2009). There are a range of explanations for unipedal posture including: avoidance of muscle fatigue, thermoregulation, improved balance in windy conditions, sleeping behaviour, and minimisation of risk of parasitic or fungal infection when standing in water (Clark 1973; Anderson & Williams 2010). However, the suggestion that unipedal posture is an adaptation that contributes to thermoregulation is predominant – the leg is lifted towards the body and tucked under the feathers as a way to minimise heat loss (Knufken 2009; Anderson & Williams 2010; Bouchard & Anderson 2010). This hypothesis is supported by research showing that a significant proportion of metabolic heat is lost through the legs (Steen & Steen 1965). If this explanation is correct, one could hypothesise that birds will be observed standing on 1 leg more frequently on colder days than on warmer days. Anecdotal observations appear to support this hypothesis (Clark 1973), as do recent studies on flamingos (Anderson & Williams 2010; Bouchard & Anderson 2010). The frequency with which flamingos stood on 1 leg increased as temperature decreased in accordance with the hypothesis (Anderson & Williams 2010).

The aim of this study was to determine if unipedal posture in birds was related to temperature. The proportion of birds standing on 1 leg was assessed at a range of ambient air temperatures and the relationship characterised by regression analysis.

METHODS

Observations of greater flamingos (*Phoenicopterus roseus*; N = 16) were made at the flamingo enclosure at Auckland Zoo, Auckland, New Zealand. The flamingos were hatched in quarantine in the United Kingdom before being brought to New Zealand. The flamingos were 8 years old at the time of this study. Further observations of free-living wading birds and waterfowl were made at the inner Manukau Harbour near Puketutu I, a distance of 16 km from Auckland Zoo. Observations at Puketutu I were made in 2 habitats: (1) freshwater ponds and (2) tidal mud flats. Seven species of birds were observed: mallard (*Anas platyrhynchos*), black swan (*Cygnus atratus*), white-faced heron (*Ardea novaehollandiae*), bar-tailed godwit, (*Limosa lapponica*), royal spoonbill (*Platalea regia*), pied stilt (*Himantopus himantopus*) and a black stilt (*Himantopus novaezelandiae*). The black stilt was observed at Puketutu I on 12 Jul 2009.

The air temperature was measured out of direct sunlight and sheltered from wind using a digital thermometer (Hanna Instruments K-thermocouple thermometer, Model HI 93530). Wind strength and cloud cover were estimated using 5-point category scales, where 1 = none and 5 = complete. When birds were too far away to see by eye, a pair of binoculars (7 x 50 magnification) were used. To record and confirm bird identifications, photographs were taken using a digital camera.

All observations were made during daylight (0940 to 1640 NZST) between 3 May and 15 Jul 2009. Measurements were made upon arrival at the flamingo enclosure and thereafter at hourly intervals. For other species, observation bouts were made opportunistically and varied in different locations around the estuary and at different times. Instantaneous counts of the number of birds standing on 1 leg were made and the proportion standing on 1 leg was calculated. For larger flocks, this was achieved by counting birds standing on 1 leg and then recounting for the total number of birds. Records of behaviour were also made during

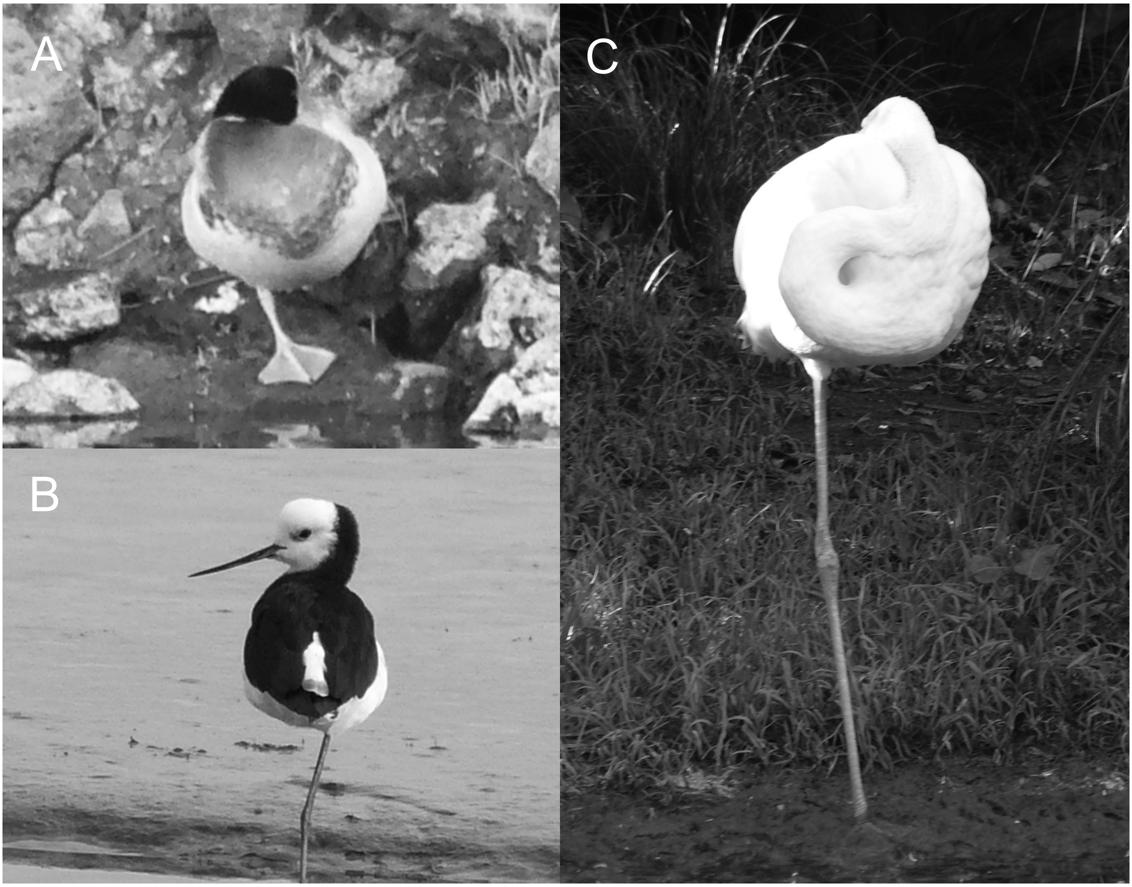

Fig. 2. The way birds balance on 1 leg. Photographs of ducks (A) and pied stilts (B) were taken at Puketutu I and photographs of flamingos (C) were taken at Auckland Zoo.

the observation (e.g., active, feeding, or resting). Data was transferred to spreadsheet for subsequent statistical analysis using ANOVA and regression.

RESULTS AND DISCUSSION

Variability in unipedal posture

Out of the species for which observations were made, only flamingos, pied stilts, ducks, swans and herons were observed on sufficient occasions to allow statistical analysis. For each of these species there was a large standard deviation in the proportion of birds observed standing on 1 leg on each of the different occasions, although it was notable that ducks showed the smallest standard deviations (Fig. 1). Analysis of variance did not identify any significant difference among species ($F_{4,21}$ = 1.26; P = 0.32). It was noted that much variability was due to activity associated with feeding or disturbance. For example, during observations of flamingos at Auckland Zoo, a lion in a neighbouring enclosure roared and the disturbed birds all started to stand on 2 legs.

The anatomy of the species was another factor that seemed to influence the propensity for birds to stand on 1 leg. The transition from bipedal to unipedal posture requires birds to alter the way they stand so that their remaining foot is in line with their centre of gravity. For ducks, the standing leg needed to be placed at an extreme angle to reach this point. Flamingos and stilts had much longer legs and the angle between the leg and body did not change when they stood on 1 leg; rather the leg tended to bend laterally at the joints. These differences in the ease with which these species can stand on 1 leg are apparent in Fig. 2. The difficulty with which ducks stood on 1 leg may be a factor that contributes to the lower frequency with which they were observed in this behaviour (Fig. 3). Furthermore, ducks at rest were observed standing on 2 legs, 1 leg or sitting on the ground. None of the other 7 species of wading birds were observed sitting.

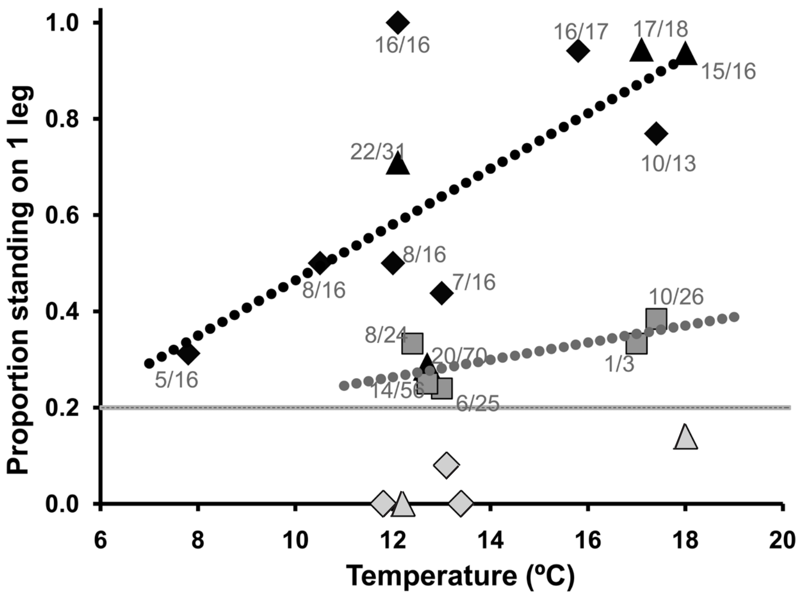

Fig. 3. The influence of temperature on the proportion of birds standing on 1 leg (◆= flamingos, ▲= pied stilts, ■= ducks). Figures indicate the number of birds standing on 1 leg and the total number of birds observed. Data where <20% of birds were standing on 1 leg were excluded from regression analysis on the basis that these birds were too active to be influenced by temperature. Regression for flamingos and pied stilts (●●●●). Regression for ducks was not signficant (●●●●).

Effect of temperature

Before it was possible to determine the effect of temperature on unipedal posture, it was necessary to account for the influences of bird activity (e.g. birds that were feeding or had been disturbed) and bird anatomy. Examination of records of bird activity could account for some of variability, for example in Fig 3 all data points located on the X-axis (*i.e.*, no birds observed standing on 1 leg) relate to groups of flamingos and pied stilts observed walking, feeding or observed after disturbance. However, it is likely that there may be other extraneous and/or unknown environmental factors that may affect unipedal posture, and for this reason all observations where less than 20% of birds in the flock were standing on 1 leg were excluded from the regression (but all points are plotted in Fig. 3). The influence of bird anatomy on unipedal posture was accounted for by analysing ducks and wading birds separately.

Both wading birds and ducks tended to stand on 1 leg more frequently at warmer temperatures than at colder temperatures (Fig. 3). While regression analysis did not show any significant relationship between temperature and unipedal posture for flamingos and pied stilts when analysed separately ($r^2 = 0.41$, $P = 0.12$ and $r^2 = 0.60$, $P = 0.23$, respectively), the regression was significant when both species were combined ($r^2 = 0.47$, $P = 0.02$). For wading birds (combined flamingos and pied stilts) the regression equation was: $Y = 0.058X - 0.113$, where Y was the proportion of birds standing on 1 leg and X was the temperature. The regression for ducks was not significant ($P = 0.17$).

While data presented in Fig 3 shows a relationship between temperature and unipedal posture, the relationship contradicts the hypothesis that birds will be observed standing on 1 leg more frequently on colder days than warmer days.

Resting behaviour and its link to unipedal posture

The majority of birds observed standing on 1 leg appeared to be resting at the time, suggesting that this behaviour may be associated with sleeping, rather than thermoregulation. The positive correlation between unipedal posture and temperature for wading birds (Fig. 3) could be explained by a tendency for birds to rest and therefore sleep at the warmer temperatures. Rattenborg *et al.* (1999) used electroencephalography to measure brain activity and demonstrated the ability of ducks to sleep with 1 eye open and 1 hemisphere of the brain active. This behaviour allows birds to rest while remaining alert to risks in their immediate surroundings including predators (Rattenborg *et al.* 1999). The ability to shut down 1 half of the brain is known as unihemispheric slow wave sleep (USWS; Rattenborg *et al.* 1999) and is also observed in cetaceans where this behaviour ensures that whales and dolphins do not drown when they sleep (Hecker 1998; Rattenborg 2006).

USWS may be a fundamental aspect of bird brain-activity that supports many aspects of behaviour. In terms of unipedal posture, one might expect that as the bird falls into USWS, the natural reflex may be for 1 leg to be lifted towards the body as if it were gently lowering the body onto the ground. Thus, unipedal posture may derive from a primitive and automatic response that occurs as birds become drowsy and prepare to settle just prior to sleep, and which is retained in species that exhibit USWS-related unipedal posture as the lifting of 1 leg towards the body. As such, it is the effect of environmental conditions on sleep that drives unipedal posture, rather than the behaviour being a direct adaptation to protect or minimise exposure of the leg. The adaptive advantage for birds standing on the foreshore and/or mud flats would be that they can sleep while 1 half of the brain always remains alert to any danger and predators as well as ensuing that they do not fall into the water.

The results from the current study seem to contradict those obtained on captive flamingos as studied at higher temperatures (21.3 to 38.4˚C – Anderson & Williams 2010; 17.8 to 31.2˚C – Bouchard & Anderson 2010), both of which found a greater incidence of unipedal posture at lower temperatures. We propose that the effect of temperature on unipedal behaviour in birds may differ depending on whether environmental temperature is lower, similar or higher than that at which birds need to expend energy to maintain their own body temperature or exhibit behaviours designed to lose metabolic heat. The insulation provided by feathers mean that it is only at much lower temperatures that the energy required by resting shorebirds to keep warm increases steeply. We are not aware of any information on flamingos, but for shorebirds the critical temperature varies from 10-23˚C (Kirsten & Piersma 1987) depending on the species. At high temperatures, thermoregulatory needs change to maximise loss of metabolic heat. Steen & Steen (1965) in their study of gulls and herons noted that while only 10% of metabolic heat is lost through legs at 10˚C, almost all metabolic heat is dissipated through legs at 35˚C.

Data collected in the current study does not support a thermoregulatory hypothesis for unipedal postures. Instead, it is proposed that resting behaviour, particular USWS sleep, is the primary factor effecting unipedal posture. Resting behaviour itself may be affected by temperature with the consequence that observational studies attempting to elicit correlations between temperature and unipedal posture may not be able to differentiate between thermoregulation and resting as an explanation. Thus, it is recommended that assessment of USWS be introduced as a component of any future research initiatives on unipedal posture in birds.

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