Just One Leg to Stand On

Do varying weather conditions affect the energy conservation of roosting birds?

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Abstract

Roosting is when birds settle or congregate for rest. While roosting many wading birds with long legs stand on one leg, tucking the other inside their belly feathers. This is called unipedal roosting. The function of standing on one leg in birds has long been attributed to reducing heat loss from the unfeathered legs to the external environment. This roosting position also conserves energy, because if one leg is used at a time, it reduces muscle fatigue and allows the non-used leg to rest.

Birds also lose heat through their bills, or more commonly known as beaks, and you can often see them with their heads turned and their bills tucked under their feathers. The aim of this study is to determine whether varied weather conditions, namely temperature, wind speed and precipitation, have an impact on birds' roosting positions. High winds especially could have a negative impact on the birds standing on one leg, unbalancing them, and not allowing them to conserve their heat and energy.

The study hypothesis is that if the weather conditions vary, then birds' ability to conserve heat and energy through unipedal roosting and beak-tucking will be impacted. An observational methodology was employed to record birds at roost in Harper's Island Wetlands, a key roost site for waterbirds. The following species were recorded; black-tailed godwits, curlews, gulls, redshanks, oystercatchers, little egrets, lapwings, shelduck, teal and widgeon. The number of each species standing on one leg or two, or had their beaks tucked or not was recorded over twenty occasions to create a sample size of 1800 birds. The weather data was also recorded using a reliable weather app.

Correlation analyses were conducted to determine associations between independent variables and roosting positions. Significant associations were examined further using a series of multiple regression analyses to determine the unique contribution of independent variables whilst controlling for confounding variables. Results indicated that as temperatures increased more black-headed gulls exhibited bipedal roosting. This result remained significant even when controlling for other variables such as wind speed and precipitation. Lapwings were shown to display the opposite behaviour, possibly due to them not relying on unipedal roosting for heat conservation. Precipitation was found to affects bill-tucking in black-headed gulls, with more of them tucking their bills under their feathers in wet conditions.

This study accepts the null hypothesis and establishes that varying weather conditions affect many species of water birds while roosting, and their ability to conserve heat and energy, thus contributing to the literature on varying ecosystems in Ireland.

Introduction

Harper’s Island Wetlands

Harper’s Island Wetlands Nature Reserve was established to protect the internationally important population of wetland birds that use it, and at the same time create a place where people can engage with nature and learn about the natural heritage they have on their doorstep. Most of Harper's Island lies within the Cork Harbour Special Protection Area and parts of it lie within the Great Island Channel Special Area of Conservation and within the Great Island Channel proposed Natural Heritage Area. The recently published Birds of Conservation Concern in Ireland (2020-2026) [1] contains a red list of bird species that are endangered for reasons ranging from loss of suitable habitats to climate change. Of the 54 species on that red list, 19 have been recorded at Harpers Island, making it a crucial habitat for these birds.[2]

127 bird species have been recorded on the reserve. As well as birds that spend the year in Ireland, the reserve plays host to many migration birds that come here from places as far away as Canada, Greenland, Iceland, Scandinavia, Siberia, and Sub-Saharan Africa. One of the main driving forces in the establishment of the nature reserve was the recognition of its international importance for the Icelandic black tailed godwit, a very elegant wading bird that breeds in Iceland and spends the rest of the year on wetlands along the West Coast of Europe, including Cork Harbour and Harper’s Island. On a spring high tide, an enormous number of the godwits use the reserve to rest and preen in safety. As much as 3% of the world's population of the Icelandic black tailed godwit has been seen there in a single flock. Black-tailed godwits are a crucial part of this study. Cork Harbour is an internationally important wetland regularly supporting over 20,000 wintering waterbirds, making it one of the top ten wetlands in the country. At high tide, up to 20% of water birds recorded in Cork Harbour use the island itself, including 41% of the black tailed godwits, 30% of the lapwings, 27% of the black headed gulls and 26% of the golden plovers [2].

When black-tailed godwits and other waders, like curlews, redshanks, lapwings, and oystercatchers are feeding in tidal systems they have a limited amount of time each day to access the shellfish and worms that make up their diet. These foods are unavailable over the high-tide period as the mudflats where they source their food is covered, so birds conserve energy by gathering at safe and sheltered sites to roost. Harper’s Island is an ideal roost site as it is surrounded by a seawall, built originally to create farmland in the 1800s. A one way tidal flap was placed in the sea wall and this allowed water to drain out from the area enclosed by the sea wall when the tide was low, while stopping any water flowing in when the tide was high. Since the 1800s the tide flap has fallen into disrepair, allowing seawater to flood the borrow dyke and this along with fresh water from the landward side have created a wetland of brackish water, saltmarsh habitat and wet grassland ideal for birds and other wildlife [2]. This means that at high tide when the mudflats in the surrounding harbour are underwater, the seawall here holds a lot of the water back from the island, creating a safe and sheltered place for the birds to roost. It creates a fantastic place to observe and record these birds also.

The research team was inspired to do this project after a visit to Harper’s Island, and seeing how crucial it was to the many birds in Ireland and around the world. We have been advised by Jim Wilson, ornithologist, previous National Chairperson of BirdWatch Ireland, broadcaster on Irish radio, author of several books on various aspects of Irish nature and founder of the Harper's Island Wetlands

Nature Reserve. He has been central to our project and has advised the research team hugely. We are also in contact with Tom Gittings, an ecological consultant specialising in ecological surveying, monitoring and evaluation, ecological impact assessment, habitat management, and invertebrate, bird, wetland, and woodland ecology. He has assisted in further developing the project and providing facilities to do so. The research team has been in contact with several ornithology experts and ecologists from around the world including Jenny Gill, Tómas Gunnarsson, Graham Appleton, Camilo Carnero, José Alves and Theunis Piersma who have provided valuable insight and background research.

Thermal Regulation in Birds

Thermal regulation is the ability of an organism to keep its body temperature within a temperature range that is usually different from that of the surrounding environment. Birds and mammals are the only group of animals that produce heat to keep their internal environment at a constant temperature, making them endothermic homeotherms. Endothermy means that the metabolic rate, and thus the capacity for heat generation, is high enough to maintain a core body temperature different from that of the ambient temperature [3]. In fact, by adjusting metabolic rates in accordance with the ambient temperatures, birds and mammals can maintain a constant core body temperature. Maintaining a high core body temperature means that birds spend a substantial proportion of their total energy consumption to achieve homeothermy. This energy is not available for body growth or reproductive output. For a bird to maintain constant body temperature, its heat production must increase as outside temperatures decrease. The bird can change its own rate of thermal conductance to keep heat loss constant at essentially no energy cost. A bird can affect heat exchange simply by changing posture: facing into the sun, tucking its bill under a wing, fluffing up his feathers, opening/closing 'thermal windows' in the feathers by raising/lowering its wings or feather patches to expose/hide unfeathered areas of the skin, or standing on one leg and tucking the other leg into its belly feathers [4]. This project focuses on unipedal roosting and bill-tucking behaviours.

Unipedal Roosting

Many birds stand on one leg when resting on the ground, this is called unipedal roosting. The leg is positioned in a way that does not require much energy. A recently discovered sense organ of equilibrium in the lumbosacral vertebral canal which controls leg movements may play a significant role in standing on one leg. Hiding one foot in the plumage reduces heat loss in a cold environment (Figure 1). However, the foot is not always hidden in the plumage and standing on one leg occurs also in a warm environment, so thermoregulation is not the only function of standing on one leg. Another function of standing on one leg may be to avoid muscle fatigue [5]. In a study by Ryeland and colleagues, it was found that six out of nine species of wading birds examined used unipedal standing more frequently as temperatures decrease, indicating its role as a heat conservation behaviour. They also found that species with longer legs roosted on one leg more frequently across a wide range of temperatures. Species with shorter leg lengths rely less on this posture to insulate smaller legs. Their findings showed that the long-accepted notion that birds stand on one leg more at colder temperatures holds, and that species with smaller relative leg length were less reliant on this behaviour to minimise heat loss from these bare appendages [5].

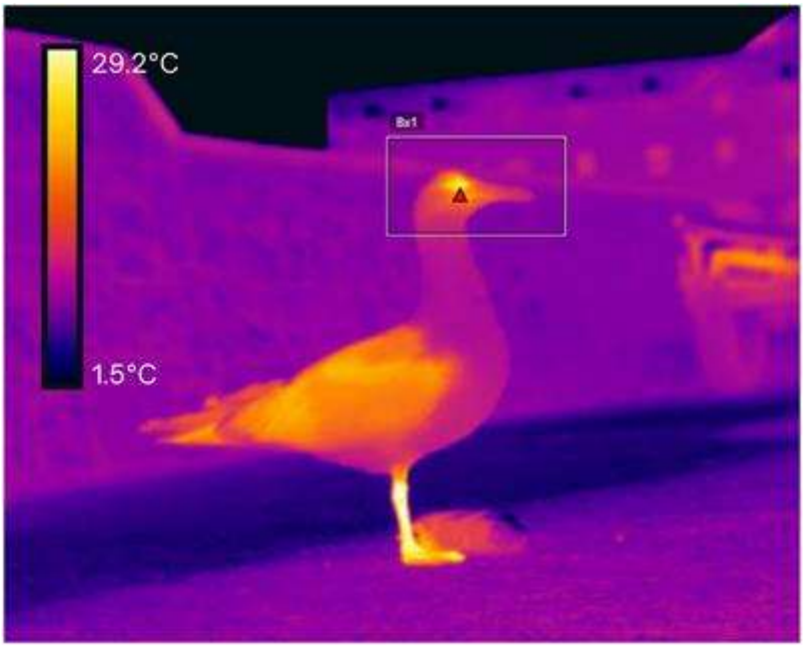

Figure 1. Thermal image of gull in a cold environment. The legs are hot compared to the remainder of the body. Heat is easily lost to environment as there are no feathers to insulate. Figure adapted[6].

The research team will aim to determine whether weather influences birds' ability to use this technique to conserve heat and energy when roosting, through observation and recording various bird species at Harper's Island Wetlands and monitoring the weather conditions at the time. As supported by existing evidence, temperature is hypothesized to have an impact. Moreover, stronger winds could unbalance the birds that are only using one leg, and high winds will result in more air (and temperature) turnover on the legs. Other weather factors such as precipitation could also affect the birds' roosting positions. When unable to roost properly, wading birds cannot rest or conserve their energy, leading to a worse quality of life and reduced chance of survival.

Bill-tucking Behaviour

Another common roosting habit of birds is to rotate and tuck the bill into the feathers. The bill (beak) is another structure where heat loss occurs, which is why birds tend to turn their heads, fluff out their down feathers and tuck the bill under their back feathers. Most songbirds and waterbirds fluff out their down feathers and bury the vulnerable parts of their body in their feathers to protect them. When a bird tucks its bill under its feathers, less body heat is lost. A bird's feathers help it stay warm by creating insulating air pockets. A bird can breathe air warmed by its body heat when its bill is buried deep within its feathers [7]. Bill-tucking behaviour will be observed and recorded in the various species present in Harper's Island, and analysed against the wind conditions, aiming to determine whether birds tuck their bills in their feathers more in colder temperatures or higher winds.

Our hypothesis is that if the weather conditions vary, then birds' ability to conserve heat and energy through unipedal roosting and beak-tucking will be impacted. Our results will establish whether varying weather conditions affect water birds while roosting, and their ability to conserve heat and energy thus contributing to the literature on roosting waders in Ireland and around the world. This has received little attention in Ireland, and thus requires more studies to help understand energy conservations in wading birds.

Methods

Sample Size

Using opportunistic random sampling methods, the research team observed and recorded birds at roost in Harper's Island Wetlands to determine whether varying weather conditions affect them. Three species were focused on; black-tailed godwits, curlews, and gulls. Other species of birds present were also recorded; redshanks, oystercatchers, little egrets, lapwings, shelduck, teal and widgeon. Data for unipedal roosting was gathered on 20 occasions, with a total sample size of 1800 birds. The study protocol was adjusted halfway through the study to include data on bill-tucking behaviour. The same bird species were recorded.

Equipment

The birds were observed using a Swarovski Habicht AT 80 spotting scope with 20-60x zoom eyepiece. The weather was recorded each visit by using a reliable weather app (YR Weather). The same app was used throughout the study to ensure a steady variable. The temperature, wind speed, direction, and precipitation were recorded, as well as the tide times, tide heights and observation period. To avoid bias by a few extreme values we tried to get samples spread as evenly as possible across the range of parameter values.

Procedure

One member of the research team observed one of the species, calling out whether they were standing on one or two legs, while the other took a tally count of each.

Inclusion and Exclusion Criteria

Birds were recorded if it was clear that they were standing on one or two legs, when they were roosting only, not while wading or feeding. It was determined that if the birds stayed in the same position for 30 seconds, they were roosting. The leg position was recorded if the birds were preening (cleaning its feathers) but only if its feet remained still. Due to vegetation and other birds obscuring the birds' legs, not all individuals present could be counted reliably. Only clearly visible birds were recorded.

Variables

Unipedal roosting and bill-tucking were the primary outcome variables. Independent variables included temperature, precipitation, wind direction, wind speed, and high tide times.

Analytical Approach

Pearson correlational analyses were conducted to determine associations between independent and dependent variables. Significant associations were examined further using a series of multiple regression analyses to determine the unique contribution of independent variables whilst controlling for confounding variables.

Results

Unipedal Roosting

The data gathered from our fieldwork was analysed using Excel and SPSS software. Correlation analyses were conducted to determine associations between independent variables and roosting positions. A medium negative correlation was observed for unipedal black-tailed godwits and wind speed, $r = -.475$, $p = .034$. A medium negative correlation was also observed for unipedal black-headed gulls and temperature, $r(19) = -.623$, $p = .003$. All unipedal correlations are shown in Table 1.

Correlations for bipedal roosting positions are shown in Table 2. A medium positive correlation was observed for bipedal curlews and wind speed, $r = .547$, $p = .013$. A strong negative correlation was observed for bipedal lapwings and temperature, $r = -0.684$, $p = .001$. A medium positive correlation was observed for bipedal other waders and wind speed, $r = .494$, $p = .027$. Lastly, a medium negative correlation was observed for bipedal total waders and temperature, $r = -.477$, $p = .033$.

Based on significant correlation values, a simple linear regression analysis was conducted to evaluate the extent to which wind speed could predict unipedal roosting in black-tailed godwits. A significant regression was observed $F(1) = 5.257$, $p = .034$ (Figure 2). However, when controlling for temperature and precipitation a non-significant observation was found $F(3) = 2.691$, $p = 0.81$.

Likewise, temperature was found to predict unipedal roosting in black-headed gulls $F(1) = 11.426$, $p = .003$. When wind speed and precipitation were controlled, temperature remained significantly predictive of unipedal roosting in black-headed gulls $F(3) = 4.279$, $p = .021$ (Figure 3). This is a particularly important and reliable finding due to the high F-value and low p-value.

A multiple linear regression was conducted to evaluate the extent to which wind speed could predict bipedal roosting in curlews when controlling for temperature and precipitation. An insignificant regression was observed $F(3) = 3.075$, $p = .058$. Similarly, the extent to which temperature could predict bipedal roosting in lapwings when controlling for wind speed and precipitation, was statistically significant $F(3) = 6.236$, $p = .005$ (Figure 4).

A simple linear regression was conducted to evaluate the extent to which wind speed could predict bipedal roosting in all other waders, with a significant regression observed $F(1) = 5.826$, $p = .027$. However, when controlling for temperature and precipitation, this resulted in an insignificant finding $F(3) = 2.192$, $p = .129$. A comparable evaluation to measure the extent to which temperature could predict bipedal roosting in all wading birds was conducted with a significant regression noted ($F(1) = 5.303$, $p = .033$. However, when controlling for wind speed and precipitation, a non-significant regression resulted $F(3) = 2.522$, $p = .095$.

		WS	Temperature	Precipitation
Black-tailed Godwit	r	-.475*	.310	-.064
	p	.034	.184	.787
Curlew	r	.429	.215	-.041
	p	.059	.364	.865
Lapwing	r	-.410	-.410	.036
	p	.073	.073	.881
Black-Headed Gull	r	-.203	-.623*	-.126
	p	.390	.003	.598
All Waders	r	-.175	.217	-.078
	p	.462	.358	.743
Total Birds	r	-.315	-.027	-.115
	P	.176	.909	.628

Table 1. Pearson correlations for unipedal roosting position. *Correlation significant at p = .05. WS; wind speed, r; Pearson's correlation coefficient, p; p-value, *correlation is significant at ≤.05.

		WS	Temperature	Precipitation
Black-tailed Godwit	r	.099	-.158	-.163
	p	.676	.505	.493
Curlew	r	.547*	.213	-.166
	p	.013	.368	.486
Lapwing	r	-.233	-.684**	-.129
	p	.322	.001	.589
Black-Headed Gull	r	.113	-.388	-.261
	p	.636	.091	.267
All Waders	r	.494*	-.065	-.264
	p	.027	.784	.260
Total Birds	R	.212	-.477*	-.287
	P	.369	.033	.219

Table 2. Pearson correlations for bipedal roosting positions. *Correlation significant at p = .05. **Correlation significant at p =.01. WS; wind speed, r; Pearson's correlation coefficient, p; p-value, *correlation is significant at ≤.05.

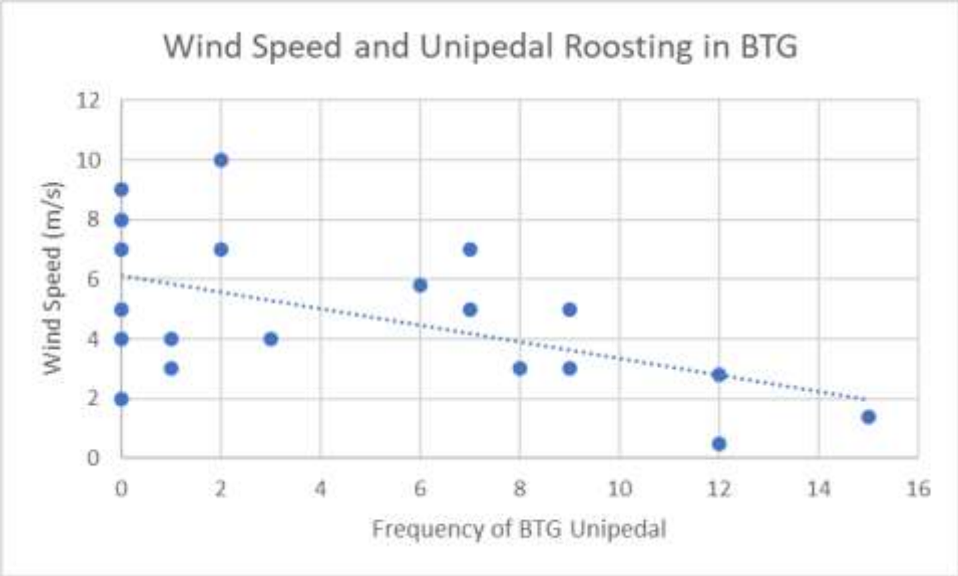

Figure 2. Wind speed predicts unipedal roosting in black-tailed godwits F(1) = 5.257, p = .034. BTG; black-tailed godwits.

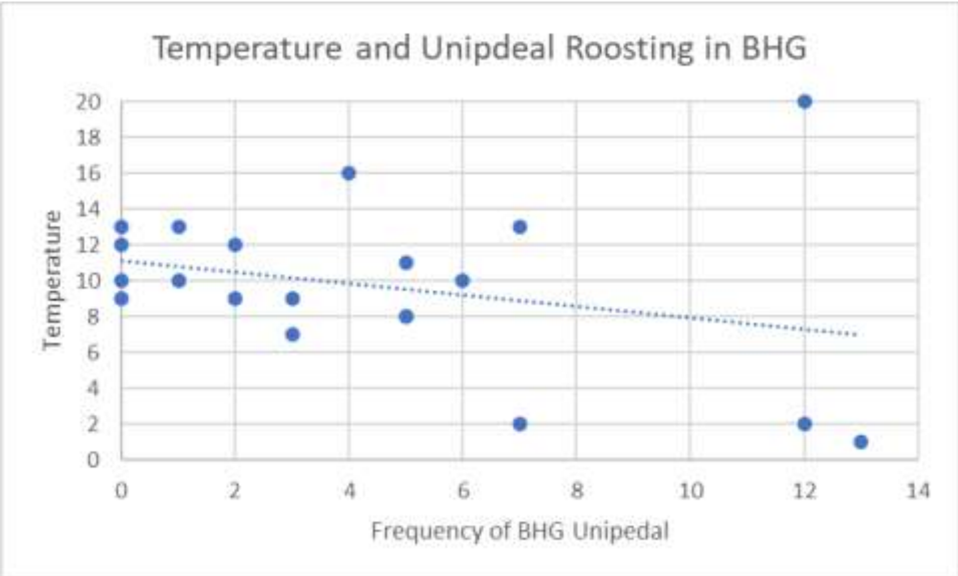

Figure 3. Temperature predicts unipedal roosting in black-headed gulls F(1) = 11.426, p = .003. BHG; black-headed gulls.

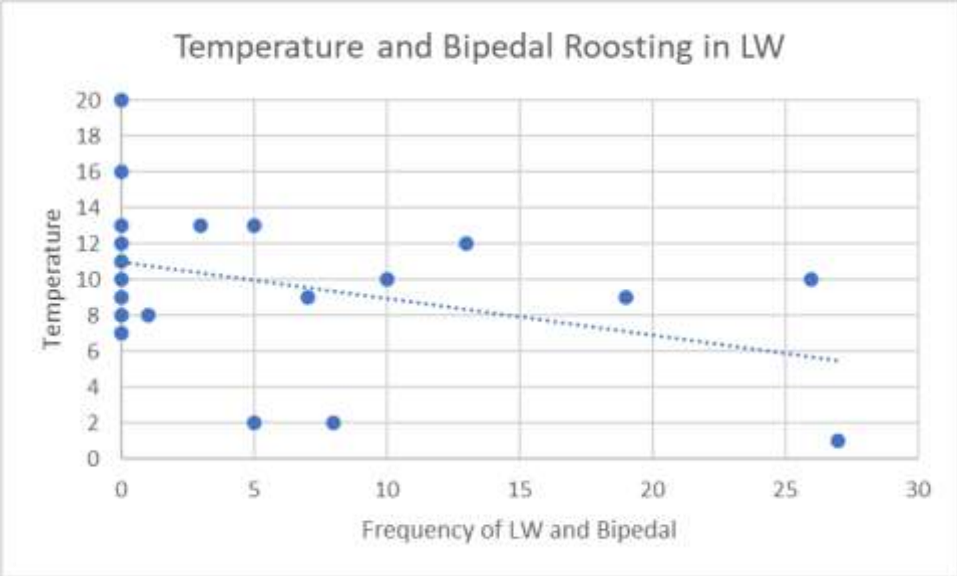

Figure 4. Temperature predicts bipedal roosting in lapwings F(3) = 6.236, p = .005. LW; lapwings.

Bill-tucking Behaviour

Correlation analyses were conducted to determine associations between independent variables and bill tucking. A strong positive correlation was observed for inward bill tucking in black-headed gulls and precipitation, r = .666, p = .013. All inward bill tucking correlations are shown in Table 3.

Similarly, a series of correlations were conducted for non-bill tucking behaviour. When bird species were analysed independently, there were no significant associations between the independent variables and non-bill-tucking behaviour. However, a strong positive correlation was observed for all wading birds and wind speed, r = .614, p = .026. Likewise, a strong positive correlation was found for total birds and wind speed, r = .658, p = .014. The remaining non-bill tucking correlations are shown in Table 4.

To determine the unique contribution of each of these significant findings, a series of multiple linear regression analyses were conducted. When controlling for wind speed and temperature, precipitation remained statistically predictive of inward bill tucking in black-headed gulls F(3) = 4.105, p = .043. This indicates that as precipitation increased the frequency of black-headed gulls that displayed inward bill tucking behaviour also increased (Figure 5).

Regarding non-bill tucking behaviour in all other wading birds, when controlling for temperature and precipitation, wind speed was no longer predictive F(3) = 2.227, p = .154. Similarly, when controlling for temperature and precipitation, wind speed was not predictive of non-bill tucking behaviour in all wading birds F(3) = 3.869, p = .051. This indicates that wind speed does not uniquely impact non-bill tucking behaviour in wading birds.

		WS	Temperature	Precipitation
Black-tailed Godwit	r	.083	-.029	.354
	p	.788	.924	.236
Curlew	r	.474	.297	-.077
	p	.102	.325	.801
Lapwing	r	-.380	.111	-.234
	p	.201	.718	.441
Black-Headed Gull	r	-.115	-.244	.666*
	p	.707	.422	.013
All Waders	r	.085	.249	-.109
	p	.782	.411	.722
Total Birds	r	-.120	-.170	.110
	p	.697	.579	.720

Table 3. Pearson correlations for inward bill tucking. WS; wind speed, r; Pearson's correlation coefficient, p; p-value, *correlation is significant at ≤.05.

		WS	Temperature	Precipitation
Black-tailed Godwit	r	.504	.248	-.060
	p	.079	.414	.847
Curlew	r	.540	.310	-.156
	p	.057	.303	.611
Lapwing	r	.217	.310	-.260
	p	.477	.303	.392
Black-Headed Gull	r	.216	-.068	.152
	p	.479	.825	.619
All Waders	r	.614*	.487	-.294
	p	.026	.092	.329
Total Birds	r	.658*	.236	-.165
	p	.014	.437	.591

Table 4. Pearson correlation for non-bill tucking. WS; wind speed, r; Pearson's correlation coefficient, p; p-value, *correlation is significant at ≤.05.

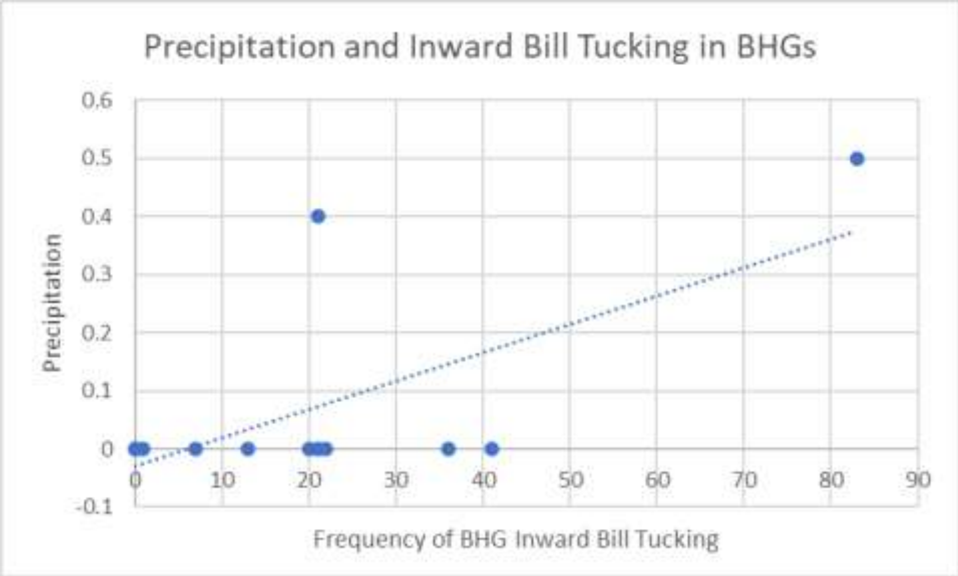

Figure 5. Precipitation predicts inward bill tucking in black-headed gulls $F(3) = 4.105$, $p = .043$. BHG; black-headed gulls.

Discussion

Unipedal Roosting

After investigating wind speed, temperature and precipitation weather conditions and their effects on the various species of bird present in Harper's Island, the research team hypothesised that as wind speeds increase, the number of birds standing on one leg will decrease. As seen in figure 2, as wind speeds increase, the number of black-tailed godwits standing on one leg decreases. The regression trend line has a negative slope indicating that stronger winds are unbalancing the birds on one leg, they prefer to stand on two legs to have a steadier stance while they roost. However, when controlling for temperature and precipitation, this independent effect was no longer significant, meaning wind speed was not the sole reason the black-tailed godwits were standing on one leg or two, and multiple variables could have an effect. Due to the constrained time limit of the study, and unusually diminished wind speeds for October and November 2023, future investigations may uncover differing results.

It was found that temperature can predict unipedal roosting in black-headed gulls (Figure 3). As temperature increased, less gulls stood on one leg, as they did not need to conserve as much heat in warmer temperatures. Critically this finding remains significant even when controlling for wind speed and precipitation, showing that temperature has a definite effect on the frequency at which these birds roost on one leg. However, figure 4 contradicts this result. Lapwings display the opposite behaviour, as temperature decreases the number of lapwings standing on two legs increases, and this stays true even when controlling for wind speed and precipitation. Both sets of data were proven to be statistically dependable but there are multiple reasons why the results contradict each other. They are two distinct species, and it could be that lapwings simply do not use this behaviour often to conserve their heat, instead relying on other methods such as fluffing up their feathers or tucking in their bills, whereas black-headed gulls use this behaviour to conserve heat especially in cold temperatures as demonstrated in figure 3.

When considering all wading birds – including godwits, curlews, lapwings, golden plovers, dunlins, and redshank – temperature predicts bipedal roosting, as increased temperatures lead to more birds using two legs rather than one (Table 2). Again, this finding did not remain significant when controlling for wind speed and precipitation. With a larger sample size, this finding may approach significance and lead to a reliable outcome.

Bill-tucking Behaviour

Regarding bill-tucking behaviour in birds, less data was gathered as this part of the study was only conducted over thirteen occasions. For this reason, less correlations were found to be significant, except between black-headed gulls and precipitation. This finding yielded that as precipitation increased, the frequency of black-headed gulls that displayed inward bill tucking behaviour also increased (Figure 5). This result remained statistically significant even when controlling for other variables. The birds tuck their bills under their feathers when it is raining to avoid this featherless area becoming wet and cold.

As seen in table 4, a strong positive correlation was observed for all wading birds and wind speed. Likewise, a strong positive correlation was found for total birds and wind speed. This indicates that more birds do not tuck their bills under their feathers in higher winds, however when controlling for other variables, these findings did not remain significant.

Whilst conducting this data collection the team could not control the presence of disturbances, like a flock of birds landing nearby, which caused birds who had previously tucked their bills under their feathers to perk their heads up.

The research team hypothesised that if the weather conditions vary, then birds' ability to conserve heat and energy through unipedal roosting and beak-tucking will be impacted. Consistent with previous literature[5], this study supports the finding that unipedal roosting is a feature of heat conservation behaviour in black-headed gulls. Future investigations with larger sample sizes over a sustained study period may improve findings.

Conclusion

The most significant finding in this project was that temperature affects unipedal roosting in black-headed gulls. As temperature increases, less gulls stood on one leg, even when accounting for other variables. However, lapwings display the opposite behaviour, perhaps due to differences among species. Precipitation affects bill-tucking in gulls, with more of them tucking their bills under their feathers in wet conditions.

Our hypothesis “If the weather conditions vary, then birds' ability to conserve heat and energy through unipedal roosting and beak-tucking will be impacted” was proven to be correct, as there were correlations found between unipedal roosting in black-headed gulls and decreasing temperature as well as inward bill tucking in gulls and precipitation.

The major obstacle was the short timeframe, as more significant associations could be found with a larger sample size and over a greater time period to assess the impact of varying weather conditions. This limitation would be addressed in potential future studies. Further expansion of this project could be to compare male/female roosting position as well as to investigate the effect of wind direction on where birds choose to roost. This study adds to the literature on roosting waders in Ireland helping to contribute to wildlife conservation projects both nationally and internationally.

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Jim Wilson. Ornithologist, wildlife writer, broadcaster, tour leader, founding member of Harper's Island Wetlands nature reserve and former chairperson of Birdwatch Ireland. Assisted with project design and development, equipment, and background research.

Harper's Island Wetlands nature reserve Steering Group (Cork County Council, Glounthaune Community and BirdWatch Ireland). Allowed us to carry out the study on the reserve.

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Tómas Gunnarsson Director in South Iceland Research Centre, University of Iceland. Provided studies and papers for background research.

Graham Appleton Author of the WaderTales blog. Provided studies and papers for background research.

Camilo Carnero South Iceland Research Centre, University of Iceland. Provided studies and papers for background research.

José Alves Principal Researcher, University of Aveiro, Department of Biology & CESAM. Provided studies and papers for background research.

Theunis Piersma. Dutch ornithologist, ecologist, and educator. He is among the most influential ornithologists, particularly in the wader bird area, in the world. Provided studies and papers for background research.

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Appendices

Appendix 1 - Cover letter from External Facility

Dearbhla Cullinane

Discipline of Anatomy

School of Medicine

Trinity Biomedical Sciences Institute

Trinity College Dublin

152-160 Pearse Street

Dublin 2

D02 R590

2nd January 2024

Dear Reviewers and Judges at BT Young Scientist,

It was my pleasure to assist Éadaoin and Ciarán Farrell on their study ‘Just One Leg to Stand On: Do varying weather conditions affect the energy conservation of roosting birds?’ for entry to the BT Young Scientist 2024. The work presented herein was designed and developed by Éadaoin and Ciarán. I was delighted to assist with statistical analysis of their data set. I have proofread their final document and accept responsibility for statistical errors.

Yours sincerely,

Ms. Dearbhla Cullinane