

**Has clutch size changed over time in North Atlantic seabirds, a meta-analysis**

**Abstract**

Clutch size is a **key determinant of reproductive output** and population viability, yet its response to environmental change **remains unclear**. While phenological shifts in birds have been well documented, comparatively little is known about how clutch size varies across species over time, particularly in North Atlantic seabirds. This meta-analysis investigates whether clutch sizes in North Atlantic seabirds have changed over multiple decades and whether environmental variables such as latitude, temperature, and the North Atlantic Oscillation (NAO) help explain interspecies differences. Using 29 estimates across six species, I found no consistent trend in clutch size changes, with regression slopes varying in both direction and magnitude. Multivariate models revealed no significant effect of the selected moderators. The limited number of species and geographic bias toward well-monitored colonies in Northern Europe highlight gaps in current research. These findings suggest that clutch size in seabirds may be relatively conserved, reinforcing the need for broader, standardised monitoring to detect subtle reproductive shifts under ongoing climate change.

**Introduction**

Reproductive output is a fundamental determinant of population stability, yet, unlike well documented shifts in breeding phenology, temporal trends in clutch size remain understudied. Changes in clutch size, even when small, can accumulate over time to affect recruitment and population viability especially in long lived species such as seabirds1,2. However, variation in this trend is likely to differ both within and across species, influenced – much like breeding phenology, by environmental gradients such as latitude and local climate conditions, which may mediate the strength of climatic drivers3. Species unable to maintain reproductive output under changing conditions may face long term population declines, especially in marine ecosystems where trophic interactions are tightly coupled4,5. Understanding long term changes in clutch size, and whether they stem from environmental drivers such as temperature and climate cycles, is critical for gauging the resilience of marine bird populations as they contend with increasingly erratic environmental change.

Impacts on reproduction when associated with climate are rarely uniform across taxa. In seabirds, differences in foraging strategies, migratory behaviours and nesting ecologies can mediate distinct responses to the same environmental shifts6,7. Even intraspecies populations exposed to varying local conditions may exhibit divergent trends in reproductive output8. Large scale climate indices, such asNAO, influence marine ecosystems across broad regions, affecting food availability, migration and breeding in ways that depend on both life history and geography9. Classical life history theory also suggests that extrinsic environmental gradients particularly latitude, photoperiod, and seasonal resource abundance underlie systematic variation in clutch size across species10. For example, northern birds are thought to lay larger clutches due to longer daylight hours and seasonal pulses of food availability during the breeding season11. These complexities make it difficult to generalise climate impacts without accounting for ecological, spatial and climatic variation. Cross species comparisons that account for ecological and geographic gradients are essential to detect overarching reproductive trends and to pinpoint where responses diverge most strongly, particularly across ocean basins like the North Atlantic12. Examining temporal shifts in clutch size across multiple species, can reveal how different seabird populations are responding to increasingly variable environmental conditions.

Seabirds are amongst the most closely monitored marine vertebrates, with decades of data collected through long term population surveys, nest monitoring and national census programmes13. Their conspicuous breeding colonies and high site fidelity have made them ideal candidates for sustained demographic tracking, particularly in the North Atlantic where multiple monitoring efforts operate at national and regional levels14,15. As a result, seabirds provide one of the richest data sources for investigating subtle reproductive change in marine systems16. While phenological responses to climate in seabirds have been extensively researched, comparable efforts to synthesise trends in reproductive output (clutch size) remain limited. This is because direct comparisons of clutch size across species are challenging; inherent differences in reproductive strategies and variation in study periods necessitate the use of species-specific regression slopes to detect and compare temporal trends.

To address this, I will compile long term reproductive data across North Atlantic seabird species and use species-specific regression slopes to assess temporal trends in clutch size. Then apply a meta-analytical model to test whether variation in these trends is explained by environmental drivers, including temperature, latitude, and NAO. By focusing on a regional dataset of well monitored species, this study provides a comparative framework for evaluating whether climate associated reproductive shifts are occurring in North Atlantic seabirds, and if so, whether those shifts reflect consistent environmental patterns.

**Methods**

To conduct my search I first explored the literature covering the subject via ‘**Web of Science**’ with the following search string: *ALL=((Seabird\*) AND (Atlantic OR 'North Atlantic' OR 'Atlantic ocean' OR Europ\*) AND ("Clutch" OR "Clutch size" OR "Egg number" OR "Number of eggs" OR "Egg count" OR "Average clutch" OR "Mean clutch" OR "Maximum clutch" OR "Minimum clutch") AND (Declin\* OR Increas\*) AND (Time OR Year\* OR Month\*)).* This search was carried out on 13/03/25 generating 138 published papers. Using ‘**metRscreen**’17 a screening package in R, I accepted and read through 45 of which I gathered 6 effects sizes from (**Appendix 1**).

To quantify temporal trends in reproductive output, I used the slope of mean clutch size (a count based reproductive measure) over time (year) as the effect size. However, substantial discrepancies in study duration and inherent differences in baseline clutch size between species made direct visualisation or pooled modelling of raw data impractical. Instead, I extracted mean clutch size, year and standard error values from each study and applied a linear meta-regression model using the rma() function from the ‘**metafor**’18 package, with year as the predictor and mean clutch size as the response. For five of the six included studies, either the regression slope and its associated standard error (SE) were directly reported, or the original data included sample sizes or proportions that allowed SEs to be calculated (**Appendix 1**). In the remaining study, where no measure of variance was provided, I approximated the SE by fitting a linear model (**lm()**) to the reported mean clutch sizes over years and extracting the standard error from the model output. This approach of running species-specific models to obtain effect sizes enabled standardised comparisons across six species with inherently different reproductive strategies, allowing their temporal trends in clutch size to be synthesised and visualised within a single plot19-24.

Latitude, mean annual temperature, and the North Atlantic Oscillation were included as continuous moderator variables. The decision to account for these predictors was informed by classic work from Lack (1947), who proposed that latitude and temperature influence clutch size through seasonal variation in resource availability10. NAO was included following Hüppop et al. (2003), who demonstrated that large scale climatic indices can influence seasonal prey abundance which in turn, is thought to affect reproductive output9. To extract these variables, I first identified breeding locations of each study species using coordinates provided in the original publications or derived approximate locations using site descriptions and Google Earth Pro25. Latitude when not reported, was simply recorded directly from each site. Mean annual temperature values were extracted using the ‘**WorldClim**’26 dataset at 10-minute resolution, and ‘**rnaturalearth**’27 package in R. For the Arctic Tern study site, the WorldClim raster data did not return a valid temperature value, likely due to its offshore location. Given the small overall sample size and the importance of retaining this species in the analysis, I adopted a conservative approach by minimally adjusting the coordinates inland to obtain a valid mean annual temperature from the raster20. To obtain NAO values, I used the NOAA Climate Prediction Centre’s historical index dataset28. For each species, I averaged monthly NAO values across the core breeding months (May–July) for each study year, then calculated an overall mean for the full study duration. This produced a representative NAO score per species, capturing broad scale climatic conditions during the breeding season. NAO values were matched to each study based on location and duration, assuming site fidelity and reflecting the potential influence of regional climate patterns on reproductive investment.

To assess the influence of environmental variables on clutch size trends, I fitted a multivariate mixed effects model using the rma.mv() function in the ‘**metafor**’ package18. Regression slope estimates and standard errors for each species were included as effect sizes, with species treated as a random effect. Latitude, mean annual temperature, and NAO were included as continuous moderators to explain variation across species. This structure allowed me to test whether broad scale environmental gradients were associated with observed differences in clutch size change over time. To visualise effect sizes and their confidence intervals across species, I produced a forest plot using the ‘**metafo**r’ package18. A map was created to display the geographic distribution of study sites across the North Atlantic, using ‘**ggplot2**’29, ‘**maps**’30 and ‘**dplyr**’31 for visualisation of any study biases. Model selection outcomes were summarised in a formatted AIC comparison table using the ‘**gt**’32 package. While an Egger’s regression test is often used to assess funnel plot asymmetry and potential publication bias, this method could not be applied to my rma.mv model due to current package limitations and the small number of effect sizes33.

All code available: [Github link](https://github.com/Matty-Plumtree/MetaAnalysis/tree/main)

**Results**

In total, I extracted six effect sizes each representing a species-specific slope of clutch size regressed against time from six published studies. Of the 138 papers initially identified, 45 were shortlisted following abstract and full text screening, but only six provided sufficient data for inclusion. Three studies directly reported regression slopes with accompanying standard errors, while the remaining three required manual calculation of slopes using year and mean clutch size values. Two of these also reported standard errors, enabling meta-analysis using the rma() function, while for the final study, standard errors were approximated using a linear model.

Although the study sites span a broad North Atlantic range, the dataset is limited by both taxonomic and geographic scope. Five of the six species Arctic Tern (*Sterna paradisaea*), Common Eider (*Somateria mollissima*), Great Cormorant (*Phalacrocorax carbo*), Gull-billed Tern (*Gelochelidon nilotica*), and Lesser Black-backed Gull (*Larus fuscus*) were represented by European studies, with only Black-legged Kittiwake (*Rissa tridactyla*) originating from North America (**Figure 1**). This results in a slight bias toward northeastern Atlantic ecosystems. Additionally, all six species are colonial breeders, and most are relatively well monitored, which may overrepresent populations from well established long term monitoring programs and exclude more cryptic species33. As such, the included effect sizes likely reflect data availability more than true ecological representativeness.

**A map of the north atlantic ocean

AI-generated content may be incorrect.**

**Figure 1*.*** *Map of the study sites surrounding the North Atlantic. Blue points represent the approximate breeding locations of the six seabird species included in the meta-analysis. Arctic Terns were studied in Denmark, Black-legged Kittiwakes in Canada (Labrador), Common Eiders, Great Cormorants, and Lesser Black-backed Gulls in Norway, and Gull-billed Terns in Germany..*

Across the six seabird species, effect sizes varied widely in direction and magnitude, indicating no consistent trend in clutch size over time (**Figure 2**). The intercept only model (**Figure 2a)** yielded an overall effect estimates of 0.00 (95% CI: -0.03 to 0.04), suggesting little evidence for uniform temporal change. Species responses were notably mixed: Great Cormorants and Lesser Black-backed Gulls showed declining trends, while Common Eiders and Gull-billed Terns displayed increases. When moderator variables were included (**Figure 2b)** latitude, mean annual temperature, and NAO the overall pattern remained broadly unchanged. The inclusion of these covariates did not reduce the variance substantially, and no fixed effects emerged as significant predictors. These results point to substantial heterogeneity in how seabird clutch size has shifted across species, underscoring the complexity of linking reproductive trends to broad-scale environmental gradients.

A diagram of a graph

AI-generated content may be incorrect.A graph of a graph with a line

AI-generated content may be incorrect.

**2b**

**2a**

**Figure 2.** *Forest plots of regression slopes showing temporal trends in clutch size for six North Atlantic seabird species. (2a) Model without moderators; (2b) Model including latitude, mean annual temperature, and NAO as continuous moderators. Points represent species specific slope estimates with 95% confidence intervals.*

To account for variability in clutch size trends across species, I fitted a multivariate meta-regression model using latitude, mean annual temperature, and NAO as continuous moderators. These predictors as discussed prior9,10, were chosen based on ecological relevance and prior studies linking broad scale environmental gradients to reproductive output. Model selection was based on AICc values, with two models falling within 2 ΔAICc units of one another. The top ranked model included all three moderators, yet none emerged as statistically significant (**Table 1**). Latitude and temperature had negligible slopes close to zero, while NAO showed a modest negative association with clutch size trend (estimate = –0.090), though with wide uncertainty (p = 0.321). These results suggest that, within this small sample, large scale climatic predictors were poor explainers of the observed variation in temporal clutch size trends.

A screenshot of a computer

AI-generated content may be incorrect.

**Table 1.** *Results of the multivariate meta-regression model testing the influence of latitude, mean annual temperature, and NAO on temporal clutch size trends.*

Together, these results suggest no consistent temporal trend in clutch size across North Atlantic seabirds, nor any clear explanatory power of the included environmental predictors. The implications of this lack of pattern are explored in the discussion below.

**Discussion**

This study found no consistent trend in clutch size across North Atlantic seabird species, with regression slopes varying in direction and magnitude across the six species analysed. Unlike well documented phenological shifts in response to warming such as breading success and fledging success observed across numerous bird species35-40, reproductive output (measured as clutch size) did not show a consistent response to environmental change. The use of long term datasets spanning multiple decades and regions provides a valuable opportunity to detect subtle reproductive trends, yet the absence of a consistent trend suggests that clutch size may be a more conserved trait in these marine birds. This aligns with life history theory, which suggests that reproductive traits like clutch size, particularly in long lived species with low reproductive rates, are less plastic and slower to respond to environmental change41. Nonetheless, detecting whether subtle shifts are occurring remains critical, given clutch size’s central role in recruitment and long term population viability.

Despite the broad ecological relevance of seabird reproduction, my dataset was limited both taxonomically and geographically. Only six species met inclusion criteria, with the majority of studies concentrated in Northern Europe. This geographic clustering, combined with a reliance on well monitored colonial species, introduces potential sampling bias. These limitations reflect long standing research inequalities in marine ornithology, where species with established monitoring infrastructure are overrepresented in the literature42. As a result, observed trends may not fully capture reproductive responses in less accessible, data poor or declining species. Although many studies reported clutch size across several years, they often didn’t include key information such as the number of nests or breeding pairs observed making it difficult to calculate reliable yearly averages. Without these details, I couldn’t include some otherwise relevant studies in the meta-analysis. In addition, much of the available data focused on a few well studied species, leading to repetition and reducing the generality of cross species comparisons. This underscores the importance of expanding long term monitoring efforts to include a wider diversity of species.

Attempts to assess potential publication bias were limited by the small sample size. A funnel plot was generated for visual inspection (**Figure 3**), but formal regression tests for asymmetry (e.g. Egger’s test) were not feasible due to the use of multivariate models and low statistical power43. For this reason, the plot has been included in the discussion rather than the results, where its role is more interpretative than diagnostic. Nonetheless, the apparent lack of studies reporting nonsignificant or increasing clutch size trends may itself reflect broader biases in ecological publishing where null results are underreported or difficult to access44. It is also possible that trends are genuinely rare, or that methodological heterogeneity obscures their detection. In this context, the funnel plot does not reveal any clear asymmetry suggesting no publication bias. While the distribution of effect sizes appears relatively balanced, the limited number of studies lacks interpretation and reflects broader challenges in detecting subtle ecological trends with sparse data.

A pyramid with black dots

AI-generated content may be incorrect.

**Figure 3.** *Funnel plot of residual values against standard error for included studies. Used for visual inspection of publication bias.*

The absence of a consistent temporal trend in clutch size may reflect the inherently conservative nature of reproductive investment in seabirds, but it could also mask subtle, context dependent responses. Species with differing foraging ecologies, prey specialisation, or nesting habitats may be exposed to distinct pressures that influence clutch size in opposing directions. For example, in central place foragers like the Arctic Tern changes in prey distribution or provisioning costs could suppress clutch size even in the absence of temperature driven effects45. On the other hand, generalist feeders such as Herring Gulls may be more buffered46. Furthermore, while this analysis captures broad scale climate indices, it does not resolve fine scale ecological drivers such as phenological mismatches with prey, energetic constraints, or intracolonial density effects. Future studies should seek to link environmental variation more directly to mechanisms of reproductive decision making distinguishing between plastic adjustments and adaptive change. If clutch size begins to shift consistently in response to climate pressures, the demographic consequences for slow reproducing seabirds could be profound, affecting recruitment and long term persistence in already vulnerable populations.

In this study, I examined long term trends in clutch size across six North Atlantic seabird species using a meta-analytical approach. Despite the ecological importance of reproductive investment, I found no consistent direction of change and environmental moderators such as latitude, mean annual temperature and NAO did not significantly explain variation among species. While this may reflect the conservative nature of clutch size in seabirds, it also underscores ongoing limitations in data availability, reporting consistency and taxonomic scope. By compiling regression based effect sizes from disparate sources and testing large scale climate predictors, this analysis provides a foundation for future studies seeking to quantify seabird reproductive responses to environmental change. Broader inference will require more comprehensive datasets across species, regions and time periods, but this study contributes important early insight into the potential resilience of clutch size in marine birds under shifting climates.

A diagram of a flowchart

AI-generated content may be incorrect.

**Appendix 1:** *flow diagram summarising the screening and selection process for studies included in the meta analysis.*

References

1. Hoegh-Guldberg, O. and Bruno, J.F., 2010. The impact of climate change on the world’s marine ecosystems. *Science*, *328*(5985), pp.1523-1528.
2. Burger, J., Kannan, K., Giesy, J.P., Grue, C. and Gochfeld, M., 2002. Effects of environmental pollutants on avian behaviour.
3. Romano, A., Garamszegi, L.Z., Rubolini, D. and Ambrosini, R., 2023. Temporal shifts in avian phenology across the circannual cycle in a rapidly changing climate: A global meta‐analysis. *Ecological Monographs*, *93*(1), p.e1552.
4. Radchuk, V., Reed, T., Teplitsky, C., van de Pol, M., Charmantier, A., Hassall, C., Adamík, P., Adriaensen, F., Ahola, M.P., Arcese, P. and Miguel Avilés, J., 2019. Adaptive responses of animals to climate change are most likely insufficient. *Nature communications*, *10*(1), p.3109.
5. Both, C., Van Asch, M., Bijlsma, R.G., Van Den Burg, A.B. and Visser, M.E., 2009. Climate change and unequal phenological changes across four trophic levels: constraints or adaptations?. *Journal of Animal Ecology*, *78*(1), pp.73-83.
6. Grémillet, D. and Boulinier, T., 2009. Spatial ecology and conservation of seabirds facing global climate change: a review. *Marine Ecology Progress Series*, *391*, pp.121-137.
7. Biagiotti Barchiese, M.C., Biondi, L.M. and García, G.O., 2023. A systematic review of trends in research on seabird behavioral flexibility.
8. Li, X., Liu, Y. and Zhu, Y., 2022, April. The effects of Climate Change on birds and approaches to response. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1011, No. 1, p. 012054). IOP Publishing.
9. Hüppop, O. and ppop, K.H., 2003. North Atlantic Oscillation and timing of spring migration in birds. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *270*(1512), pp.233-240.
10. Lack, D., 1947. The significance of clutch-size. *Ibis*, *89*, pp.302-352.
11. Ashmole, N.P., 1963. The regulation of numbers of tropical oceanic birds. *Ibis*, *103*(3), pp.458-473.
12. Møller, A.P., 2002. North Atlantic Oscillation (NAO) effects of climate on the relative importance of first and second clutches in a migratory passerine bird. *Journal of Animal Ecology*, *71*(2), pp.201-210.
13. Diamond, A.W. and Devlin, C.M., 2003. Seabirds as indicators of changes in marine ecosystems: ecological monitoring on Machias Seal Island. *Environmental monitoring and assessment*, *88*, pp.153-181.
14. Schreiber, E.A. and Burger, J., 2001. Colonial breeding in seabirds. In *Biology of Marine Birds* (pp. 105-132). CRC Press.
15. Coulson, J.C., 2016. A review of philopatry in seabirds and comparisons with other waterbird species. *Waterbirds*, *39*(3), pp.229-240.
16. Coulson, J.C., 2010. A long‐term study of the population dynamics of Common Eiders Somateria mollissima: Why do several parameters fluctuate markedly?. *Bird Study*, *57*(1), pp.1-18.
17. Ivimey-Cook E, Pick J (2025). \_metRscreen: metRscreen\_. R package version 0.0.0.9000, commit 61cbd2ee0ab467402c37d9c4f8686594c685a1a8, <https://github.com/EIvimeyCook/metRscreen>.
18. Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. Journal of Statistical Software, 36(3), 1-48. <https://doi.org/10.18637/jss.v036.i03>
19. Schnelle, A., Winter, M., Bouwhuis, S. and Risch, M., 2024. Diet Composition and Reproductive Performance in Central Europe's Last Gull-Billed Tern Population–a Long-Term Study. *Ardea*, *112*(2), pp.247-258.
20. Møller, A.P., Flensted-Jensen, E. and Mardal, W., 2007. Agriculture, fertilizers and life history of a coastal seabird. *Journal of Animal Ecology*, pp.515-525.
21. Bårdsen, B.J. and Ove Bustnes, J., 2022. Multiple stressors: negative effects of nest predation on the viability of a threatened gull in different environmental conditions. *Journal of Avian Biology*, *2022*(7), p.e02953.
22. Bårdsen, B.J., Hanssen, S.A. and Bustnes, J.O., 2018. Multiple stressors: modeling the effect of pollution, climate, and predation on viability of a sub‐arctic marine bird. *Ecosphere*, *9*(7), p.e02342.
23. Hipfner, J.M., Adams, P.A. and Bryant, R., 2000. Breeding success of black-legged kittiwakes, Rissa tridactyla, at a colony in Labrador during a period of low capelin, Mallotus villosus, availability. *Canadian Field-Naturalist*, *114*(3), pp.413-416.
24. Lorentsen, S.H., Anker-Nilssen, T., Barrett, R.T. and Systad, G.H., 2022. Population status, breeding biology and diet of Norwegian Great Cormorants. *Ardea*, *109*(3), pp.299-312.
25. Google Earth Pro (Version 10.49.0.0). (2024). *Google LLC*. Available at: <https://www.google.com/earth/> (Accessed: 16/03/25).
26. Fick, S.E. & Hijmans, R.J., 2017. *WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas.* International Journal of Climatology, 37(12), pp.4302–4315. https://doi.org/10.1002/joc.5086
27. Massicotte P, South A (2023). \_rnaturalearth: World Map Data from Natural Earth\_. R package version 1.0.1, <https://CRAN.R-project.org/package=rnaturalearth>.
28. NOAA Climate Prediction Center, 2024. *Monthly North Atlantic Oscillation (NAO) Index*. [online] Available at: <https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml>.
29. Massicotte P, South A (2023). \_rnaturalearth: World Map Data from Natural Earth\_. R package version 1.0.1, <https://CRAN.R-project.org/package=rnaturalearth>.
30. Becker OScbRA, Minka ARWRvbRBEbTP, Deckmyn. A (2023). \_maps: Draw Geographical Maps\_. R package version 3.4.2, <https://CRAN.R-project.org/package=maps>.
31. Wickham H, François R, Henry L, Müller K, Vaughan D (2023). \_dplyr: A Grammar of Data Manipulation\_. R package version 1.1.4, <https://CRAN.R-project.org/package=dplyr>.
32. Iannone R, Cheng J, Schloerke B, Hughes E, Lauer A, Seo J, Brevoort K, Roy O (2024). \_gt: Easily Create Presentation-Ready Display Tables\_. R package version 0.11.1, <https://CRAN.R-project.org/package=gt>.
33. Pustejovsky, J.E. and Rodgers, M.A., 2019. Testing for funnel plot asymmetry of standardized mean differences. *Research Synthesis Methods*, *10*(1), pp.57-71.
34. Buckley, N.J., 1997. Spatial-concentration effects and the importance of local enhancement in the evolution of colonial breeding in seabirds. *The american naturalist*, *149*(6), pp.1091-1112.
35. Harding, A.M., Piatt, J.F. and Hamer, K.C., 2003. Breeding ecology of Horned Puffins (Fratercula corniculata) in Alaska: annual variation and effects of El Nino. *Canadian Journal of Zoology*, *81*(6), pp.1004-1013.
36. Cleeland, J.B., Pardo, D., Raymond, B., Tuck, G.N., McMahon, C.R., Phillips, R.A., Alderman, R., Lea, M.A. and Hindell, M.A., 2021. Disentangling the influence of three major threats on the demography of an albatross community. *Frontiers in Marine Science*, *8*, p.578144.
37. Frederiksen, M., Anker‐Nilssen, T., Beaugrand, G. and Wanless, S., 2013. Climate, copepods and seabirds in the boreal Northeast Atlantic–current state and future outlook. *Global change biology*, *19*(2), pp.364-372.
38. Robinson, J.P., Dornelas, M. and Ojanguren, A.F., 2013. Interspecific synchrony of seabird population growth rate and breeding success. *Ecology and evolution*, *3*(7), pp.2013-2019.
39. Kadin, M., Österblom, H., Hentati-Sundberg, J. and Olsson, O., 2012. Contrasting effects of food quality and quantity on a marine top predator. *Marine Ecology Progress Series*, *444*, pp.239-249.
40. Regular, P.M., Hedd, A., Montevecchi, W.A., Robertson, G.J., Storey, A.E. and Walsh, C.J., 2014. Why timing is everything: Energetic costs and reproductive consequences of resource mismatch for a chick‐rearing seabird. *Ecosphere*, *5*(12), pp.1-13.
41. Ricklefs, R.E., 2000. Lack, Skutch, and Moreau: the early development of life-history thinking. *The Condor*, *102*(1), pp.3-8.
42. Fischer, S.E., Otten, J.G., Lindsay, A.M., Miles, D. and Streby, H., 2025. Six-decade research bias towards fancy and familiar bird species. *Proceedings B*, *292*(2044), p.20242846.
43. Egger, M., Smith, G.D., Schneider, M. and Minder, C., 1997. Bias in meta-analysis detected by a simple, graphical test. *bmj*, *315*(7109), pp.629-634.
44. Cassey, P., Ewen, J.G., Blackburn, T.M. and Møller, A.P., 2004. A survey of publication bias within evolutionary ecology. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *271*(suppl\_6), pp.S451-S454.
45. Morten, J.M., Burgos, J.M., Collins, L., Maxwell, S.M., Morin, E.J., Parr, N., Thurston, W., Vigfúsdóttir, F., Witt, M.J. and Hawkes, L.A., 2022. Foraging behaviours of breeding arctic terns Sterna paradisaea and the impact of local weather and fisheries. *Frontiers in Marine Science*, *8*, p.760670.
46. van den Bosch, M., Baert, J.M., Müller, W., Lens, L. and Stienen, E.W., 2019. Specialization reduces foraging effort and improves breeding performance in a generalist bird. *Behavioral Ecology*, *30*(3), pp.792-800.