Science

Cite as: M. Bulla *et al.*, *Science*
10.1126/science.aaw8529 (2019).

Comment on "Global pattern of nest predation is disrupted by climate change in shorebirds"

Martin Bulla[1,2,3]*†, Jeroen Reneerkens[2,4]†, Emily L. Weiser[5]†, Aleksandr Sokolov[6], Audrey R. Taylor[7], Benoît Sittler[8,9], Brian J. McCaffery[10], Dan R. Ruthrauff[11], Daniel H. Catlin[12], David C. Payer[13], David H. Ward[11], Diana V. Solovyeva[14], Eduardo S. A. Santos[15], Eldar Rakhimberdiev[4,16], Erica Nol[17], Eunbi Kwon[12], Glen S. Brown[18], Glenda D. Hevia[19], H. River Gates[20], James A. Johnson[21], Jan A. van Gils[2], Jannik Hansen[22], Jean-François Lamarre[23], Jennie Rausch[24], Jesse R. Conklin[4], Joe Liebezeit[25], Joël Bêty[26], Johannes Lang[9,27], José A. Alves[28,29], Juan Fernández-Elipe[30], Klaus-Michael Exo[31], Loïc Bollache[32], Marcelo Bertellotti[19], Marie-Andrée Giroux[33], Martijn van de Pol[34], Matthew Johnson[35], Megan L. Boldenow[36], Mihai Valcu[1], Mikhail Soloviev[16], Natalya Sokolova[6], Nathan R. Senner[37], Nicolas Lecomte[38], Nicolas Meyer[9,32], Niels Martin Schmidt[22,39], Olivier Gilg[9,32], Paul A. Smith[40], Paula Machín[30], Rebecca L. McGuire[41], Ricardo A. S. Cerboncini[42], Richard Ottvall[43], Rob S. A. van Bemmelen[44], Rose J. Swift[45], Sarah T. Saalfeld[21], Sarah E. Jamieson[46], Stephen Brown[47], Theunis Piersma[2,4], Tomas Albrecht[48,49], Verónica D'Amico[19], Richard B. Lanctot[21]†, Bart Kempenaers[1]*†

[1]Department of Behavioural Ecology and Evolutionary Genetics, Max Planck Institute for Ornithology, 82319 Seewiesen, Germany. [2]NIOZ Royal Netherlands Institute for Sea Research, Department of Coastal Systems and Utrecht University, 1790 AB Den Burg, Texel, Netherlands. [3]Faculty of Environmental Sciences, Czech University of Life Sciences, 16521 Prague, Czech Republic. [4]Conservation Ecology Group, Groningen Institute for Evolutionary Life Sciences (GELIFES), University of Groningen, 9700 CC Groningen, Netherlands. [5]Upper Midwest Environmental Sciences Center, U.S. Geological Survey, La Crosse, WI 54603, USA. [6]Arctic Research Station, Institute of Plant and Animal Ecology, 629400 Labytnangi, Russia. [7]Department of Geography and Environmental Studies, University of Alaska, Anchorage, AK 99508, USA. [8]Nature Conservation and Landscape Ecology, University of Freiburg, 79106 Freiburg, Germany. [9]Arctic Ecology Research Group (GREA), F-21440 Francheville, France. [10]Yukon Delta National Wildlife Refuge, U.S. Fish and Wildlife Service, Grand View, WI 54839, USA. [11]Alaska Science Center, U.S. Geological Survey, Anchorage, AK 99508, USA. [12]Department of Fish and Wildlife Conservation, Virginia Tech, Blacksburg, VA 24061, USA. [13]Natural Resource Sciences, National Park Service, Anchorage, AK 99501, USA. [14]Institute of Biological Problems of the North, FEB RAS, Magadan 685000, Russia. [15]BECO do Departamento de Zoologia, Rua do Matão, Universidade de São Paulo, 05508-090 São Paulo, Brazil. [16]Department of Vertebrate Zoology, Lomonosov Moscow State University, 119234 Moscow, Russia. [17]Biology Department, Trent University, Peterborough, ON K9J 7B8, Canada. [18]Wildlife Research and Monitoring, Ministry of Natural Resources and Forestry, Peterborough, ON K9L 1Z8, Canada. [19]Grupo de Ecofisiología Aplicada al Manejo y Conservación de Fauna Silvestre, Centro para el Estudio de Sistemas Marinos (CESIMAR)-CCT CONICET-CENPAT, 9120 Puerto Madryn, Argentina. [20]Pacific Flyway Program, National Audubon Society, Anchorage, AK 99501, USA. [21]Migratory Bird Management, U.S. Fish and Wildlife Service, Anchorage, AK 99503, USA. [22]Department of Bioscience, Aarhus University, 4000 Roskilde, Denmark. [23]Science & Technology Program, Polar Knowledge Canada, Cambridge Bay, NU X0B 0C0, Canada. [24]Canadian Wildlife Service, Environment and Climate Change Canada, P.O. Box 2310, Yellowknife, NT X1A 2P7, Canada. [25]Audubon Society of Portland, Portland, OR 97210, USA. [26]Department of Biology and Center for Northern Studies, University of Quebec, Rimouski, QC G5L 3A1, Canada. [27]Clinic for Birds, Reptiles, Amphibians and Fish/Working Group for Wildlife Biology, Giessen University, 35392 Giessen, Germany. [28]DBIO & CESAM-Centre for Environmental and Marine Studies, Department of Biology, University of Aveiro, 3810-193 Aveiro, Portugal. [29]South Iceland Research Centre, University of Iceland, Fjolheimar IS-800 Selfoss & IS-861 Gunnarsholt, Iceland. [30]Aptdo. Correos 32, 5480 Candeleda, Spain. [31]Institute of Avian Research "Vogelwarte Helgoland," 26386 Wilhelmshaven, Germany. [32]Laboratoire Chrono-environnement, Université de Franche-Comté, UMR 6249 CNRS-UFC, F-25000 Besançon, France. [33]Faculty of Sciences, Université de Moncton, Moncton, NB E1A 3E9, Canada. [34]Department of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW), 6708PB Wageningen, Netherlands. [35]Plumas National Forest, USDA Forest Service, Quincy, CA 95971, USA. [36]Biology and Wildlife Department, University of Alaska, Fairbanks, AK 99775, USA. [37]Department of Biological Sciences, University of South Carolina, Columbia, SC 29208, USA. [38]Department of Biology, Uninversité de Moncton, Moncton, NB E1A 3E9, Canada. [39]Arctic Research Centre, Aarhus University, 8000 Aarhus C, Denmark. [40]National Wildlife Research Centre, Environment and Climate Change Canada, Ottawa, ON K1S 5B6, Canada. [41]Arctic Beringia Program, Wildlife Conservation Society, Fairbanks, AK 99709, USA. [42]Departamento de Zoologia, Universidade Federal do Paraná, 81531-980 Curitiba, Brazil. [43]Frostavallsvägen 325, S-24393 Höör, Sweden. [44]Wageningen Marine Research, 1976CP IJmuiden, Netherlands. [45]Cornell Lab of Ornithology and Department of Natural Resources, Cornell University, Ithaca, NY 14850, USA. [46]Centre for Wildlife Ecology, Simon Fraser University, Burnaby, BC V5A 1S6, Canada. [47]Shorebird Recovery Program, Manomet Inc., P.O. Box 545, Saxtons River, VT 05154, USA. [48]Institute of Vertebrate Biology, Czech Academy of Sciences, 60300 Brno, Czech Republic. [49]Faculty of Science, Charles University, 128 44 Prague, Czech Republic.

*Corresponding author. bulla.mar@gmail.com (M.B.); b.kempenaers@orn.mpg.de (B.K.)

†These authors formed the core team behind this work. The remaining authors are listed alphabetically according to their first name.

Kubelka *et al.* (Reports, 9 November 2018, p. 680) claim that climate change has disrupted patterns of nest predation in shorebirds. They report that predation rates have increased since the 1950s, especially in the Arctic. We describe methodological problems with their analyses and argue that there is no solid statistical support for their claims.

Climate change affects organisms in a variety of ways (*1–4*), including through changes in interactions between species. Kubelka *et al.* (*5*) reported that a specific type of trophic interaction, namely depredation of shorebird nests, has increased globally over the past 70 years. The authors state that their results are "consistent with climate-induced shifts in predator-prey relationships." They also claim that the historical perception of a latitudinal gradient in nest predation, with the highest rates in the tropics, "has been recently reversed in the Northern Hemisphere, most notably in the Arctic." They conclude that "the Arctic now represents an extensive ecological trap for migrating birds, with a predicted negative impact on their global population dynamics." These conclusions have far-reaching implications for evolutionary and population ecology, as well as for shorebird conservation and related policy decisions (*6*). Therefore, such claims require robust evidence, strongly supported by the data. Here, we dispute this evidence.

First, Kubelka *et al.* graphically show nonlinear, spatiotemporal variation in predation rates (their figure 2, A and B, and figure 3) and suggest that in recent years, predation has strongly increased in North temperate and especially Arctic regions, but less so in other areas. However, they only statistically test for linear changes in predation rates over time for all regions combined, and for each geographical region (their table S2) or period (before and after 2000; their table S6) separately. To substantiate their conclusions, they should have presented statistical evidence for an interaction between region/latitude and year/period on predation rate. Moreover, their analyses control for spatial autocorrelation but fail to model non-independence of data from the same site (pseudo-replication).

Using the data of Kubelka *et al.*, we ran a set of mixed-effect models, structurally reflecting their results depicted in their figure 2, A and B, and figure 3, but including location as a random factor (Table 1) (*7*). These analyses show (i) that much of the variation in nest predation rate is explained by study site (>60%, compared to species: <5%), implying a reduced effective sample size; (ii) that all regions—except the South temperate—show similar predation rates; and (iii) that nest predation rates increase over time similarly across all geographical areas (Fig. 1, A to F). Linear models without interaction terms are much better supported than nonlinear models with interactions (Table 1), indicating that predation rates in the Arctic are not increasing any faster than elsewhere (Fig. 1, B, C, E, and F). Thus, these results provide no evidence that the rate at which nest predation increased over time varies geographically.

Second, for the period under study, not only the climate has changed, but also the research methods. Hence, it remains unclear whether nest predation rates have indeed increased over time and if so, why. Kubelka *et al.* used the Mayfield method (*8*, *9*) to calculate daily nest predation rates as the number of depredated nests divided by "exposure" [the total time (in days) all nests were observed]. However, 59% of the 237 populations they used lacked information on exposure. They circumvented this problem by estimating exposure based on the description of nest search intensity in the respective studies (*10*). The key question is when nests were found. Kubelka *et al.* decided that in 114 populations, nests were found such that 60% of the nesting period (egg laying and incubation combined) was "observed" (B = 0.6; nests searched once or twice a week). For 14 populations they used B = 0.9 (nests searched daily or found just after laying), and for 11 populations they used B = 0.5 (assuming nests found midway during the nesting period). However, the choice of B value remains subjective (*7*), and for 38% of the 128 populations where Kubelka *et al.* used $B > 0.5$, we found no information in the reference to suggest that this was appropriate. This issue is not trivial, because using higher B values (i.e., assuming that nests were found earlier than they actually were) overestimates exposure and hence underestimates nest predation rates.

The proportion of populations with estimated exposure declines over time (*7*), particularly after 2000 and especially in the Arctic (Fig. 1G). The timing of the decline coincides with Kubelka *et al.*'s definition of historic and recent data and with the suggested exponential rise of predation in the Arctic (their figure 2, A and B, and figure 3, A and B). Indeed, the results are sensitive to variation in estimated exposure during the "historic period" (Fig. 1H). Although Kubelka *et al.* correctly state that the estimated and true predation rates are highly correlated [using studies with quantitative information on exposure; see supplementary materials of (*5*)], the true rate is typically underestimated for the higher B values they used (Fig. 1I). Given these issues, the main result—the apparent increase in daily nest predation rate over time, especially in the Arctic—may simply be an artifact. To further assess the robustness of the change in predation rate over time, we used only populations where nest predation rates were calculated on the basis of known exposure (N = 98). These analyses reduced the effect of year by ~50% (*7*) and resulted in weak, nonsignificant linear trends (Fig. 1, C and F), which suggests that there is little evidence for changing predation rates.

Finally, we note that nest searching effort and frequency of nest visits likely increased in recent years as researchers learned how best to obtain accurate estimates of nest survival (*11–13*). Researchers also intensified their activities (e.g., capturing adults to band, tag, and collect samples and placing monitoring equipment near nests, which may increase the predation rate) (*14*, *15*). Thus, an increase in the quality of data reporting as well as increased research activity around nests may have further induced a time-dependent bias in estimates with an underestimation of true predation rates in the historic data (see above), and perhaps an overestimation in the contemporary data.

In summary, reanalysis of the data of Kubelka *et al.*, evaluation of the quality and interpretation of the published data used, and considerations about changes in research methods over the past 70 years lead us to conclude that there is no robust evidence for a global disruption of nest predation rates due to climate change. We argue that their claim that the Arctic has become an ecological trap for breeding shorebirds is untenable.

REFERENCES

1. G.-R. Walther, E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J.-M. Fromentin, O. Hoegh-Guldberg, F. Bairlein, Ecological responses to recent climate change. *Nature* **416**, 389–395 (2002). doi:10.1038/416389a Medline
2. N. Jonzén, A. Lindén, T. Ergon, E. Knudsen, J. O. Vik, D. Rubolini, D. Piacentini, C. Brinch, F. Spina, L. Karlsson, M. Stervander, A. Andersson, J. Waldenström, A. Lehikoinen, E. Edvardsen, R. Solvang, N. C. Stenseth, Rapid advance of spring arrival dates in long-distance migratory birds. *Science* **312**, 1959–1961 (2006). doi:10.1126/science.1126119 Medline
3. S. J. Thackeray, P. A. Henrys, D. Hemming, J. R. Bell, M. S. Botham, S. Burthe, P. Helaouet, D. G. Johns, I. D. Jones, D. I. Leech, E. B. Mackay, D. Massimino, S. Atkinson, P. J. Bacon, T. M. Brereton, L. Carvalho, T. H. Clutton-Brock, C. Duck, M. Edwards, J. M. Elliott, S. J. G. Hall, R. Harrington, J. W. Pearce-Higgins, T. T. Høye, L. E. B. Kruuk, J. M. Pemberton, T. H. Sparks, P. M. Thompson, I. White, I. J. Winfield, S. Wanless, Phenological sensitivity to climate across taxa and trophic levels. *Nature* **535**, 241–245 (2016). doi:10.1038/nature18608 Medline
4. D. Zurell, C. H. Graham, L. Gallien, W. Thuiller, N. E. Zimmermann, Long-distance migratory birds threatened by multiple independent risks from global change. *Nat. Clim. Chang.* **8**, 992–996 (2018). doi:10.1038/s41558-018-0312-9 Medline
5. V. Kubelka, M. Šálek, P. Tomkovich, Z. Végvári, R. P. Freckleton, T. Székely, Global pattern of nest predation is disrupted by climate change in shorebirds. *Science* **362**, 680–683 (2018). doi:10.1126/science.aat8695 Medline
6. C. E. Studds, B. E. Kendall, N. J. Murray, H. B. Wilson, D. I. Rogers, R. S. Clemens, K. Gosbell, C. J. Hassell, R. Jessop, D. S. Melville, D. A. Milton, C. D. T. Minton, H. P. Possingham, A. C. Riegen, P. Straw, E. J. Woehler, R. A. Fuller, Rapid population decline in migratory shorebirds relying on Yellow Sea tidal mudflats as stopover sites. *Nat. Commun.* **8**, 14895 (2017). doi:10.1038/ncomms14895 Medline
7. M. Bulla, J. Reneerkens, E. L. Weiser, R. B. Lanctot, B. Kempenaers, Supporting information for Comment on “Global pattern of nest predation is disrupted by climate change in shorebirds.” Open Science Framework, https://osf.io/x8fs6/.
8. H. Mayfield, Nesting success calculated from exposure. *Wilson Bull.* **73**, 255–261 (1961).
9. H. Mayfield, Suggestions for calculating nest success. *Wilson Bull.* **87**, 456–466 (1975).
10. A. J. Beintema, Inferring nest success from old records. *Ibis* **138**, 568–570 (1996). doi:10.1111/j.1474-919X.1996.tb08084.x
11. S. J. Dinsmore, G. C. White, F. L. Knopf, Advanced techniques for modeling avian nest survival. *Ecology* **83**, 3476–3488 (2002). doi:10.1890/0012-9658(2002)083[3476:ATFMAN]2.0.CO;2
12. T. L. Shafer, F. R. Thompson III, Making meaningful estimates of nest survival with model-based methods. *Stud. Avian Biol.* **34**, 84–95 (2007).
13. J. J. Rotella, Modeling nest-survival data: Recent improvements and future directions. *Stud. Avian Biol.* **34**, 145–148 (2007).
14. N. Verboven, B. J. Ens, S. Dechesne, Effect of investigator disturbance on nest attendance and egg predation in Eurasian oystercatchers. *Auk* **118**, 503–508 (2001). doi:10.1642/0004-8038(2001)118[0503:EOIDON]2.0.CO;2
15. B. W. Meixell, P. L. Flint, Effects of industrial and investigator disturbance on Arctic-nesting geese. *J. Wildl. Manage.* **81**, 1372–1385 (2017). doi:10.1002/jwmg.21312

ACKNOWLEDGMENTS

We thank all who contributed to the original studies on predation, shared data, helped to find the original data, or helped in preparing this comment [see (*7*) for details]. **Funding:** Supported by the Max Planck Society (B.K.), an EU Horizon 2020 Marie Curie individual fellowship (4231.1 SocialJetLag; M.B.), the Czech University of Life Sciences (CIGA: 2018421; M.B.), a Netherlands Polar Programme grant (NWO 866.15.207; J.R. and T.P.), and the U.S. Fish and Wildlife Service (R.B.L.). **Author contributions:** M.B., J.R., R.B.L., and B.K. initiated this work; M.B., J.R., E.L.W., D.V.S., R.B.L., and B.K. extracted and evaluated the data; most authors collected data contained in the primary sources; E.L.W. investigated the differences between newly extracted and original data; M.B. conducted the statistical analyses and drew the figure with help from M.V. and E.L.W. and input from J.R., R.B.L., and B.K.; B.K. and M.B. wrote the manuscript with input from J.R., E.L.W., and R.B.L. and finalized it with input from all authors. **Competing interests:** Authors declare no competing interests. **Data and materials availability:** All data, code, methods, results, figures, and tables associated with this comment are freely available from Open Science Framework (*7*).

6 February 2019; accepted 29 May 2019
Published online 14 June 2019
10.1126/science.aaw8529

Table 1. Comparison of models explaining spatiotemporal variation in daily nest predation rate using the original Kubelka *et al.* data. Letters and results in bold refer to panels in Fig. 1; A and D are the models reflecting figures 2A and 3A in (*5*). Each model is fitted with maximum likelihood and controlled for number of nests in a given population (ln-transformed) and for multiple populations at a given site or for a given species, using site and species as random intercepts. Daily predation rate (dependent variable) was ln-transformed after adding 0.01 [following (*5*)]. Predictors are Year (mean year of the study), Hemisphere (Northern versus Southern), Latitude (degrees), Geographical Area (Arctic, North temperate, North tropics, South tropics, South temperate), and Period [historic (1944–1999) versus recent (2000–2016)]. Models that include Period (instead of Year) are not supported by the data [less likely than the best model by factors of 69 to 320, as indicated by the evidence ratio (model weight of the first-ranked model relative to that of the given model, i.e., how many times the first-ranked model is more likely than the given model)]. Models including the interaction between time and geographical region/latitude do not improve the model fit or are much less supported by the data than are models without the interaction. See (*7*) for model output and analyses of total predation rates. Note that we used quadratic or third-order polynomial terms to mimic the relationships depicted in Kubelka *et al*.'s figures (*5*). Number of parameters denotes number of model parameters without the random effects. ΔAIC is the difference in Akaike information criterion between the first-ranked model (AIC = 349.8) and the given model. Model probability refers to Akaike weight (w_i), the weight of evidence (probability) that a given model is the best-approximating model.

Model	Predictors	Number of parameters	ΔAIC	Model probability	Evidence ratio
	Year + Hemisphere + Latitude (absolute)	5	0.00	0.26	1
E	**Year + Latitude (3rd polynomial)**	**6**	**0.05**	**0.25**	**1.02**
	Year + Geographical Area	7	0.51	0.2	1.29
B	**Year (quadratic) + Geographical Area**	**8**	**1.43**	**0.13**	**2.04**
	Year × Hemisphere × Latitude (absolute)	9	2.74	0.07	3.92
	Year × Latitude (3rd polynomial)	9	2.78	0.06	4.08
	Year × Geographical Area	11	6.31	0.01	23.36
A	**Year (quadratic) × Geographical Area**	**16**	**6.43**	**0.01**	**24.89**
D	**Period × Latitude (3rd polynomial)**	**9**	**8.48**	**0**	**69.26**
	Period × Hemisphere × Latitude (absolute)	9	9.66	0	124.9
	Period + Hemisphere + Latitude (absolute)	5	10.30	0	175.3
	Period + Latitude (3rd polynomial)	6	11.50	0	319.7

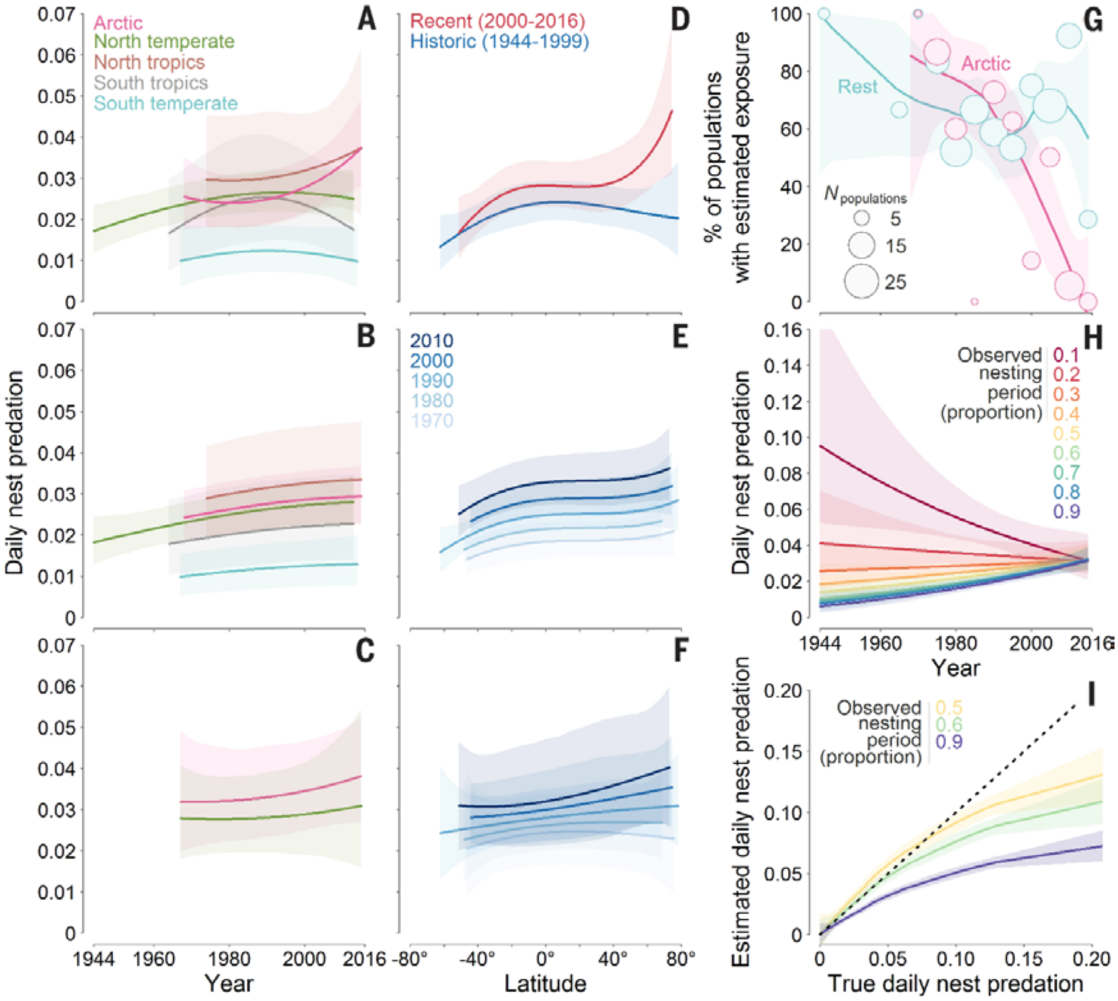

Fig. 1. Spatiotemporal variation in daily nest predation rates of shorebirds. (**A** to **C**) Predation rate in relation to year for different geographical regions: with interaction and using all populations (A), without interaction and using all populations (B), with interaction and using only the 88 populations with known exposure from the Arctic and North temperate region (C). The model behind (A) is less supported by the data than the model behind (B) by a factor of ~18 (Table 1). (**D** to **F**) Predation rate in relation to latitude for different periods: with interaction (period as two-level factor) and using all populations (D), without interaction (year as continuous variable) and using all populations (E), with interaction and using only the 98 populations with known exposure (F). The model behind (D) is less supported than the model behind (E) by a factor of ~70 (Table 1). In (A) to (F), lines and shaded areas represent model predictions with 95% confidence interval (CI) based on posterior distribution of 5000 simulated values. Note the weak ($P > 0.64$) temporal increase in (C) [estimate = 0.08 (95% CI, −0.07 to 0.2) from a linear model without interaction] and (F) [estimate = 0.06 (95% CI, −0.09 to 0.17)]. See Table 1 for model description and comparison and (*7*) for details. (**G**) Temporal change in the percentage of populations in which exposure was estimated [following (*10*)] to calculate predation rate. Note the sharp decline in the Arctic relative to the other regions [see (*7*) for overall and region-specific changes]. Circles represent data for 5-year intervals. (**H**) Modeled changes in predation rate over time assuming different values of *B* (proportion of nesting period observed; higher values indicate nests found sooner after egg laying) for populations with unknown exposure and year <2000 (leaving the original estimates for all remaining populations). This exercise explores the sensitivity of the results to using older studies where the stage at which nests were found is less certain. (**I**) Relation between true and estimated predation rate for different values of *B* [*N* = 65 populations, as in (*5*)]. The dashed line indicates a slope of 1 (i.e., estimated values equaling true values). In (G) and (I), lines and shaded areas represent locally estimated scatterplot smoothing with 95% CI; in (H), lines and shaded areas represent model predictions with 95% CI based on posterior distribution of 5000 simulated values.

Science

Comment on "Global pattern of nest predation is disrupted by climate change in shorebirds"

Martin Bulla, Jeroen Reneerkens, Emily L. Weiser, Aleksandr Sokolov, Audrey R. Taylor, Benoît Sittler, Brian J. McCaffery, Dan R. Ruthrauff, Daniel H. Catlin, David C. Payer, David H. Ward, Diana V. Solovyeva, Eduardo S. A. Santos, Eldar Rakhimberdiev, Erica Nol, Eunbi Kwon, Glen S. Brown, Glenda D. Hevia, H. River Gates, James A. Johnson, Jan A. van Gils, Jannik Hansen, Jean-François Lamarre, Jennie Rausch, Jesse R. Conklin, Joe Liebezeit, Joël Bêty, Johannes Lang, José A. Alves, Juan Fernández-Elipe, Klaus-Michael Exo, Loïc Bollache, Marcelo Bertellotti, Marie-Andrée Giroux, Martijn van de Pol, Matthew Johnson, Megan L. Boldenow, Mihai Valcu, Mikhail Soloviev, Natalya Sokolova, Nathan R. Senner, Nicolas Lecomte, Nicolas Meyer, Niels Martin Schmidt, Olivier Gilg, Paul A. Smith, Paula Machín, Rebecca L. McGuire, Ricardo A. S. Cerboncini, Richard Ottvall, Rob S. A. van Bemmelen, Rose J. Swift, Sarah T. Saalfeld, Sarah E. Jamieson, Stephen Brown, Theunis Piersma, Tomas Albrecht, Verónica D'Amico, Richard B. Lanctot and Bart Kempenaers

Science **364** (6445), eaaw8529.
DOI: 10.1126/science.aaw8529

ARTICLE TOOLS	http://science.sciencemag.org/content/364/6445/eaaw8529
RELATED CONTENT	http://science.sciencemag.org/content/sci/362/6415/680.full
REFERENCES	This article cites 14 articles, 2 of which you can access for free http://science.sciencemag.org/content/364/6445/eaaw8529#BIBL
PERMISSIONS	http://www.sciencemag.org/help/reprints-and-permissions

---

Science (print ISSN 0036-8075; online ISSN 1095-9203) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. The title *Science* is a registered trademark of AAAS.