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1 **Title: Global pattern of nest predation is disrupted by climate change in shorebirds**

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19 **Abstract:** Ongoing climate change is thought to disrupt trophic relationships with consequences for
20 complex interspecific interactions, yet the effects of climate change on species interactions are poorly
21 understood and such effects have not been documented at a global scale. Using a unique database of
22 38,191 nests from 237 populations, we found that shorebirds have experienced a worldwide **increase in**
23 **nest predation over the last 70 years. Historically, there existed a latitudinal gradient in nest predation**

24 with the highest rates in the tropics, however, this pattern has been recently reversed in the Northern
25 hemisphere, most notably in the Arctic. This increased nest predation is consistent with climate-induced
26 shifts in predator-prey relationships.

27 **One Sentence Summary:** Climate change increases offspring mortality in shorebirds globally.

28 **Main Text:** Climate change is impacting organisms at a global scale in several ways (1–4), including
29 directly altering demographic parameters such as adult survival (5) and reproduction (1), or via altered
30 trophic interactions (1, 6, 7). Successful recruitment counters mortality and maintains viable populations,
31 thus disruption of reproductive performance can have detrimental effects on wild populations (8–10).
32 Alterations in demographic parameters have been attributed to recent climate change (1, 5, 11), especially
33 in the Arctic, where the consequences of warming are expected to be more pronounced (6, 12). However,
34 the evidence for impacts of climate change on species interactions is mixed, and to date there is no
35 evidence that such interactions are changing globally (1–3).

36 Offspring mortality due to predation has a pivotal influence on the reproductive performance of
37 wild populations (8, 13–15) and extreme rates of predation can quickly lead to population declines or
38 even species extinction (16). Thus nest predation is a good indicator of the potential for reproductive
39 recruitment in bird populations (10). Disruption to annual productivity through increased nest predation
40 could have a detrimental effect on population dynamics and lead to increased extinction risks (9). To
41 explore changes in spatial patterns of reproduction and potential alterations in trophic interactions due to
42 changes in climate, we use nest predation data from shorebirds, a globally distributed group of ground-
43 nesting birds that exhibit high inter-specific similarity in nest appearance to potential predators and are
44 exceptionally well-studied in the wild including ecology, behaviour and demography (10, 17, 18). We
45 collected data from both published and previously unpublished sources that included 38,191 nests in 237

46 populations of 111 shorebirds species from 149 locations encompassing all continents across a 70-year
47 time span (fig. S1 and table S1).

48 Using our comprehensive dataset in a spatio-phylogenetic framework (19), we show that rates of
49 nest predation increased over the last 70 years. Daily nest predation, as well as total nest predation
50 (reflecting the full incubation period for a given species), have increased overall worldwide since the
51 1950s (Fig. 1, Fig. 2A, Fig. 2B, fig. S2A, fig. S2B and table S2). Thus total nest predation was
52 historically (until 1999) on average $43\% \pm 2\%$ (SEM), and this has increased to $57\% \pm 2\%$ since 2000.
53 However, the extent of change shows considerable geographical variation. In the tropics and South
54 temperate areas, changes in daily and total nest predation were not statistically significant, whereas in the
55 North temperate zone, and especially the Arctic, the increase was pronounced (Fig. 1, Fig. 2A, Fig. 2B,
56 fig. S2A, fig. S2B and table S2). This pattern holds across major clades of shorebirds (Fig. 2C, Fig. 2D,
57 fig. S2C, fig. S2D and table S3) and is also observed within local populations with daily and total nest
58 predation increasing significantly in well-monitored North temperate and Arctic breeding populations
59 (Fig. 2E and Fig. 2F). Thus the total nest predation was historically $35\% \pm 6\%$ that increased to $64\% \pm$
60 5% in recent years for these long-term monitored populations (Fig. 2F, table S4 and table S5).

61 Life-history theory predicts that species that breed close to the Equator should exhibit higher rates
62 of nest predation than species breeding in temperate and polar latitudes, in part owing to the higher
63 diversity of potential nest predators in the tropics, and there is an empirical support for this prediction (14,
64 15, 20, 21). In line with theoretical expectations, historic rates of nest predation in shorebirds follow the
65 parabolic relationship between both daily and total rates of nest predation and latitude (Fig. 3, fig. S3 and
66 table S6).

67 However, in recent years, daily nest predation changed only modestly in the tropics and Southern
68 hemisphere (Fig. 3 and fig. S3), although it increased nearly two-fold in the North temperate zone and
69 three-fold in the Arctic compared with historic values (Fig. 2A, Fig. 3). Thus 70% of nests are now being

70 depredated in the Arctic (Fig. 2B). As a consequence of latitude-dependent changes in nest predation,
71 predation rates now increase from the equator to the Arctic, in contrast to the historic parabolic latitudinal
72 pattern (Fig. 3, fig. S3 and table S6). Although data from Southern hemisphere are scanty, they suggest no
73 major changes in nest predation in southern regions (Fig. 1).

74 It is thought that climate change has influenced trophic interactions (1, 6, 7, 12), therefore to
75 investigate whether altered rates of nest predation are driven by climate, we calculated the changes in
76 ambient temperature in each shorebird population and tested whether the temperature changes predict the
77 shifts in nest predation at a global scale (19). We used two proxies of climate change: the slope of annual
78 mean temperature regressed against time, and the standard deviation of annual mean temperatures
79 measured over 30 years for each shorebird population. Higher rates of both daily and total nest predation
80 were associated with increased ambient temperatures and temperature variations (Fig. 4). Importantly,
81 these results are robust to the choice of climatic variables over periods of 20, 30 or 40 years (table S7).

82 Since predation is the most common cause of breeding failure (13, 14), our results imply declining
83 reproductive success in a widely distributed avian taxon. This decline, unless compensated by higher
84 juvenile or adult survival and/or increased production of clutches, will drive global population declines
85 when recruitment is not sufficient to maintain existing population sizes (9, 10). However, adult survival
86 of long-distance migrants are also decreasing due to recent habitat loss at staging areas (22, 23), and
87 declining chick survival has been reported across Europe (24). Therefore, high latitude breeders are
88 squeezed by both poor breeding performance and reduced adult survival. Whilst tropical shorebirds may
89 increase the number of breeding attempts and thus compensate for low breeding success, such
90 compensation is limited at higher latitudes by short polar summers (6, 12). Since most shorebirds are
91 already declining (18, 23, 25), our results suggest that an important correlate of this decline is the elevated
92 nest predation.

93 Climate change may influence nest predation rates in several ways (1, 6, 12). First, lemmings
94 (*Lemmus* spp., *Dicrostonyx* spp.), small rodents that represent the key component of the Arctic food web,
95 have experienced a crash in their abundances and population cycling due to unsuitable snow cover
96 resulting from ambient temperature increase and fluctuations (26–28). This change was documented over
97 vast Arctic areas around the year 2000 (26–28), and the pattern was similar for temperate voles in Europe
98 (*Microtus* spp., *Myodes* spp., 29, 30). Changes in rodent abundances may have led to alterations in
99 predator-prey interactions in Northern hemisphere, where predators normally consuming mainly rodents
100 increased predation pressure on alternative prey, including shorebird nests (12, 28). Second, the behavior
101 and/or distribution of nest predators may have changed due to climate-change, for instance the
102 distribution or densities of nest predators such as foxes (*Vulpes* spp.) may have increased, or their
103 behavioral activity have changed making them more successful egg-consumers (4, 6, 12). Third,
104 vegetation structure may have changed around shorebird nests leading to increased predation (6, 12, 25).

105 The demographic changes we report here have two major implications. First, migrating birds have
106 been presumed to benefit from breeding in the Arctic as a consequence of lower predation pressure (31).
107 Currently, however, the productivity of Arctic populations is declining due to high rates of nest predation,
108 which suggests that energy demanding long-distance migration to northern breeding grounds is no longer
109 advantageous from a nest predation perspective. Thus the Arctic now represents an extensive ecological
110 trap (32) for migrating birds with a predicted negative impact on their global population dynamics.
111 Second, Arctic birds are likely to decline in the future due to the synergistic effects of the climatically-
112 driven increase of predation pressure at their breeding grounds, a trophic mismatch during chick rearing
113 period due to delayed chick hatching relative to the peak of food abundance (6, 33), predicted shrinkage
114 of suitable habitat (6, 12) and reduced adult survival during migration (22, 23). A future scientific
115 challenge with crucial consequences for species conservation lies in disentangling the effects of these
116 drivers on the overall viability of bird species.

117 We have demonstrated that rapid alterations in species interactions are occurring at a global scale
118 and that these changes are related to altered climate. This underlines the need for understanding the
119 effects of climate change not only for individuals and their populations, but also for interactions in
120 complex ecosystems including prey and predators.

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604 Climatic data are freely available at <http://www.cru.uea.ac.uk/data>. Sources of primary nest predation
605 data are presented in table S1. Data and R codes are available at Dryad at: <http://xxxxxxx>. – we are
606 ready to make these data publicly available just after a possible acceptance and prior publication of our
607 manuscript.

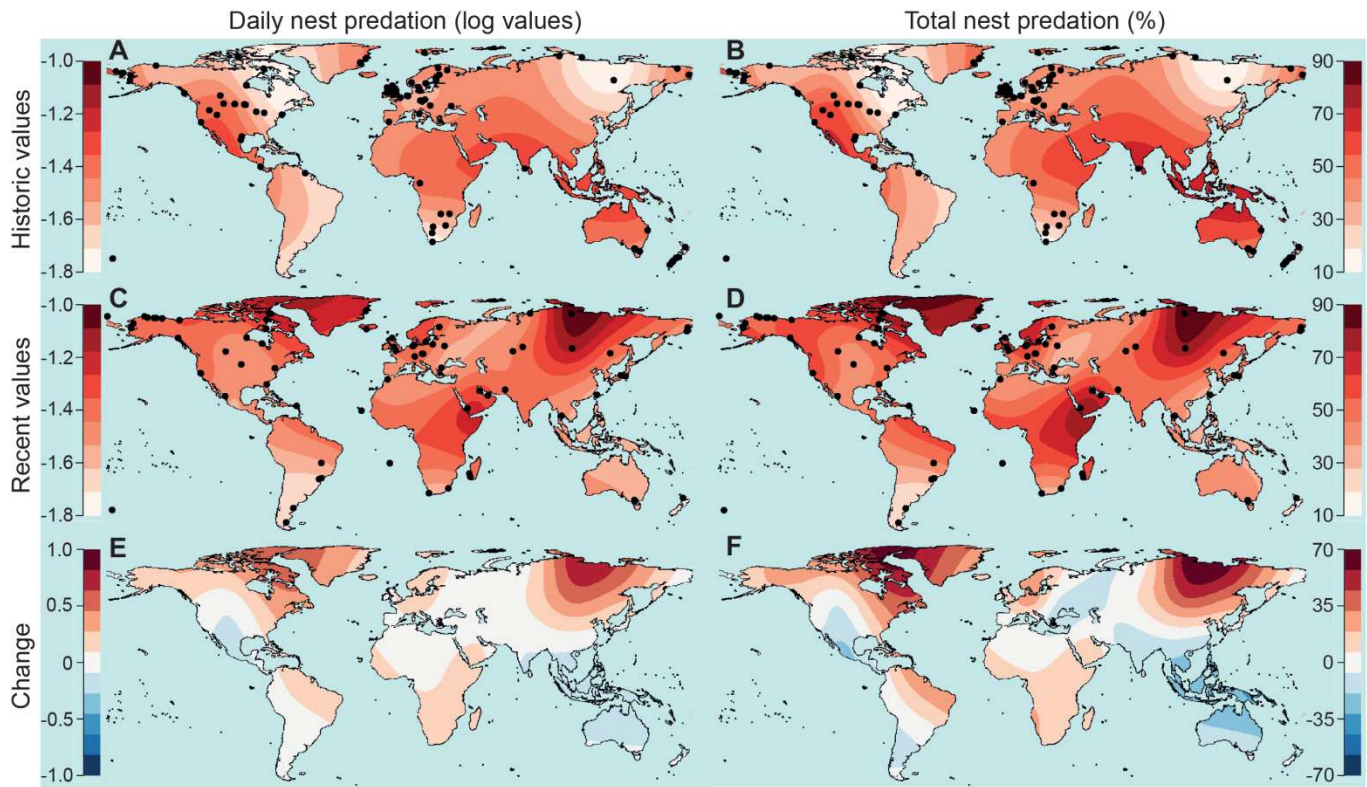
608 **Supplementary materials:**

609 Materials and Methods

610 Figures S1 to S3

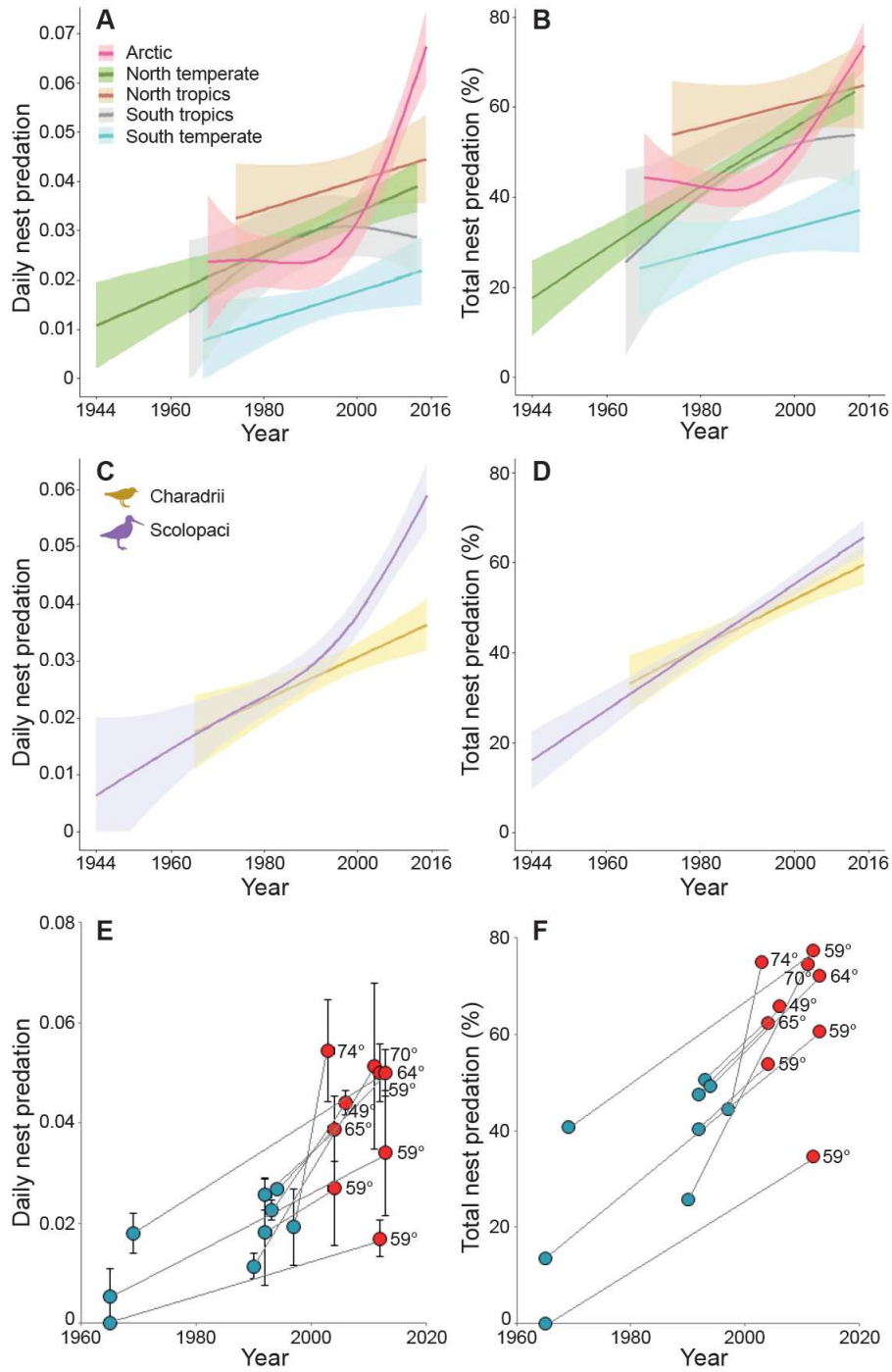
611 Tables S1 to S8

612 References (34–217)



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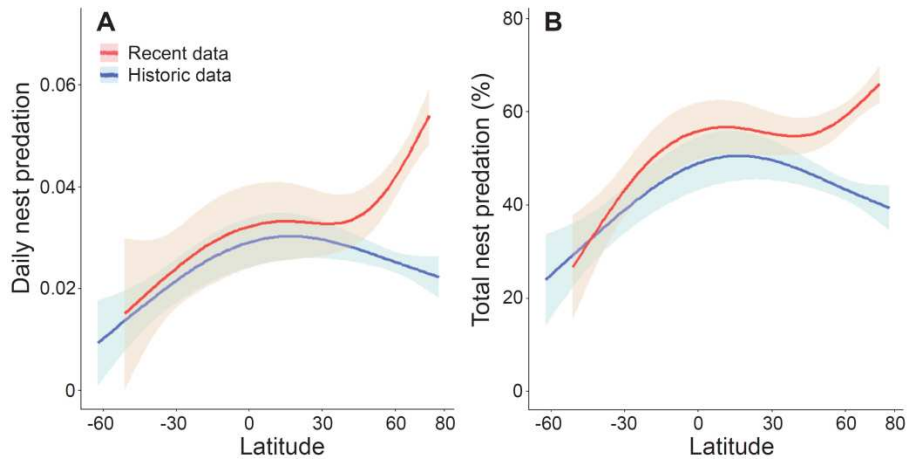
614 **Fig. 1. Nest predation in shorebirds.** (A and B) Historic rates of nest predation (1944–1999, 145
 615 populations). (C and D) Recent rates of nest predation (2000–2016, 102 populations). (E and F) Changes
 616 between historic and recent nest predation rates. Dots show study locations. (A, C, and E) Daily nest
 617 predation; log transformed values after the addition of a small quantity (0.01). (B, D and F) Total nest
 618 predation in %, see (19) for details and fig. S1 for data distribution.



619

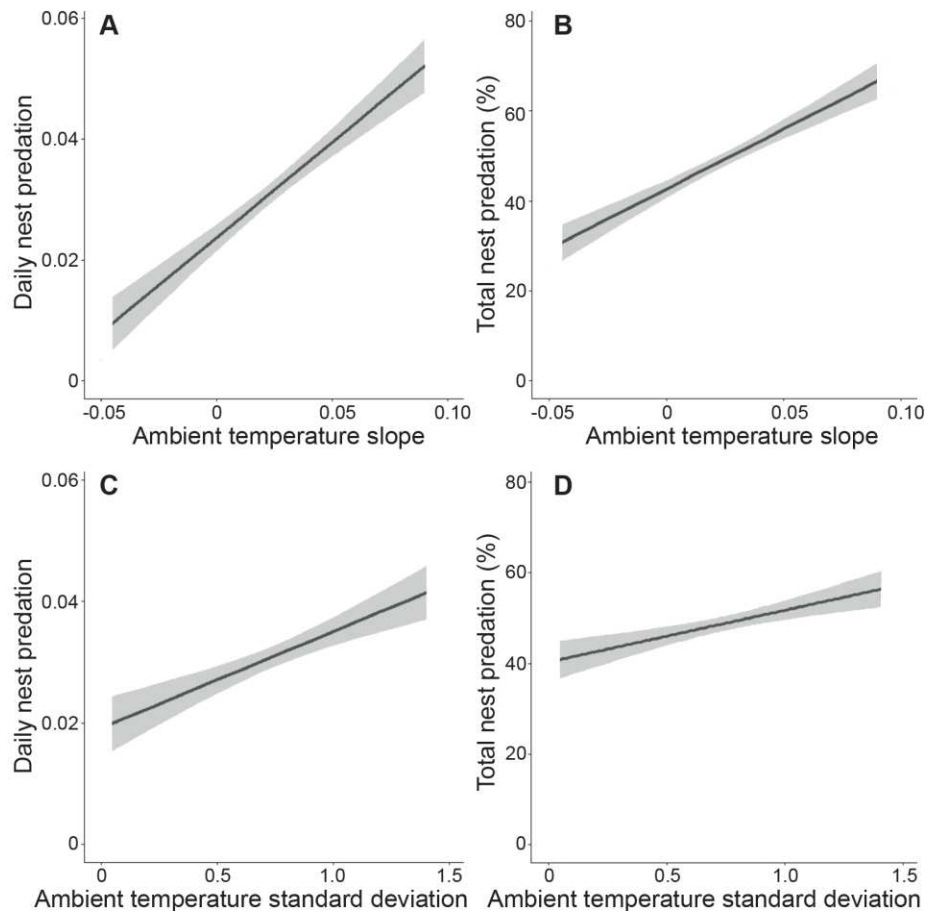
620 **Fig. 2. Temporal changes in nest predation of shorebirds.** (A and B) Nest predation rates for five
 621 latitudinal areas (Arctic n = 86 populations, North temperate n = 96 populations, North tropics n = 17
 622 populations, South tropics n = 14 populations, South temperate n = 24 populations), see (19) for areas
 623 definition and model description in table S2. (C and D) Nest predation rates for plovers and allies

624 (Charadrii = 110 populations) and sandpipers and allies (Scolopaci = 127 populations), see (19) for clades
625 definition and models description in table S3. (E and F) Local changes in nest predation rates for nine
626 populations, each dot represents mean \pm SEM (E) over 2–19 breeding seasons for historic data (blue) and
627 recent data (red), latitude of the population is given next to the recent data, see table S4 and models
628 description in table S5. (A–D) Generalized additive model fits with 95% confidence intervals. (A, C and
629 E) Daily nest predation. (B, D and F) Total nest predation.



630

631 **Fig. 3. Latitudinal gradient in historic versus recent nest predation of shorebirds.** Daily (A) and total
 632 (B) nest predation rates (historic data 1944–1999, n = 145 populations; recent data 2000–2016, n = 102
 633 populations), generalized additive model fits with 95% confidence intervals, see (19) for details and
 634 models description in table S6.



635

636 **Fig. 4. Climate change predicts nest predation rates in shorebirds.** (A and B) Relationship between
 637 daily (A) or total (B) nest predation rates and the slope of mean year temperatures. (C and D)
 638 Relationship between daily (C) or total (D) nest predation rates and the standard deviation of mean year
 639 temperatures. (A–D) Climatic data over 30 years prior to the last year of data collection, $n = 247$ values,
 640 generalized additive model fits with 95% confidence intervals, see (19) for details and table S7 for
 641 models description.

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Supplementary Materials for

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

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Materials and Methods

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Figs. S1 to S3

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657 **Materials and methods**

658 Data collection

659 We targeted our search for data on nest predation in 245 shorebird species (17, 34, 35). We searched
660 articles using keywords (species Latin name + „breeding" or „breeding success" or „nest predation") in
661 electronic databases including Web of Science, Searchable Ornithological Research Archive and Google
662 Scholar, reference books (36–42), and reviews (24, 43). We either downloaded articles from electronic
663 databases or photocopied the printed version in the ornithological Alexander Library in Oxford (UK).
664 Additionally, we asked members of International Wader Study Group for published grey literature and
665 previously unpublished datasets concerning shorebirds nest predation. In total, these searches provided
666 over 12,000 articles. From these, we chose more than 900 papers for closer investigation and out of them,
667 143 publications held information on nest predation or additional variables used in this study. Altogether,
668 the final dataset contains nest predation for 38,191 nests (with continuous exposure of 503,120 days) in
669 237 populations of 111 shorebird species at 149 localities worldwide (fig. S1 and table S1).

670 For each shorebird population, we extracted 12 additional variables. We estimated latitude and
671 longitude at the centre of the study area via a GPS coordinates converter ([www.gps-coordinates.net/gps-](http://www.gps-coordinates.net/gps-coordinates-converter)
672 [coordinates-converter](http://www.gps-coordinates.net/gps-coordinates-converter)) in decimal degrees format (three decimal spaces) with use of World Geodetic
673 System 84 (WGS 84). We also recorded the year of the study (if the research was carried over more
674 seasons, we used the mean) and the number of nests. The last eight variables represent a set of climatic
675 factors addressing the climate change impact on species demographic parameters (1, 6, 12). Although it is
676 possible that there is a small short-term advantage of warmer temperatures for the breeding productivity
677 of birds at northern locations during particular breeding season (12, 44), the larger the climate change
678 over the years at a given location, the bigger negative impact on species and biotic interactions is
679 expected (3, 6, 45).

680 Climatic variables

681 We extracted ambient temperature data from the University of East Anglia Climate Research Unit
682 database (CRU; <http://www.cru.uea.ac.uk/>, version 3.10.01) (46). The CRU database is a freely available
683 global dataset containing interpolated monthly average temperatures from 1901 onward in a grid of
684 spatial coordinates ($0.5^\circ \times 0.5^\circ$). For each population, we selected temperatures from 40 years prior to the
685 last year of data collection, inclusive and calculated mean year temperatures. We computed two main
686 indices of climate change from those data: 1) the slope of the regression of mean year temperatures over
687 30 years prior to the last year of data collection, the higher positive slope, the more pronounced effect of
688 climate change (global warming) was supposed; 2) the standard deviation of mean year temperatures over
689 30 years prior to the last year of data collection, the higher standard deviation, the more pronounced
690 effect of climate change (climatic instability) was supposed. For the sensitivity control of the chosen
691 period of 30 years, we prepared the same temperature slope and temperature standard deviation variables
692 also for 40, 20 and 10 years prior to the last year of data collection, resulting in eight climatic variables
693 for each population in total (table S7).

694 Data processing

695 We used two response variables in the study. Daily nest predation rate of nests, according to Mayfield
696 defined as the number of depredated nests divided by the exposure of all nests in days (47, 48) or follow-
697 up methods (49–51), was the target variable for the nest predation rate, standardized among species and
698 locations (14). We calculated the standard error (SEM) for each data point following Johnson (51). We
699 computed total nest predation rate of the nests as $1 - ((1 - \text{daily nest predation rate})^{\text{incubation period}})$, where

700 incubation period means the egg-laying and incubation period in days together for particular species (47,
701 48). Because the egg-laying and incubation periods represent the interval for which the successful nest
702 with eggs is exposed to potential predators, the total nest predation rate provides a species-specific nest
703 predation rate (mean percentage of nests being depredated in particular population) with respect to
704 species life-history strategies (20, 52). Total nest predation rate can be well used for inspecting spatial
705 patterns because species are geographically restricted and their incubation period is also connected with
706 the particular location. However, we must interpret temporal patterns in total nest predation rate with
707 increased caution, because changes in species composition in our dataset (with various incubation periods
708 among species) over the years has no ecologically relevant nature. Albeit having probably only limited
709 influence, species composition could affect average total nest predation rate for a particular period. Egg-
710 laying and incubation period was the same for every population of a particular species, data obtained
711 from Myhrvold (53) or from primary articles. Where not available (six cases), we assumed egg-laying
712 periods to be identical with those of closely related species. We refer to these variables through the article
713 as daily nest predation and total nest predation, the later expressed between 0–100%.

714 For 97 populations (41%), daily nest predation or exposure in days and number of depredated
715 nests were given in the source data. In any given article, daily nest predation may have been: 1) directly
716 given; 2) computed from the given exposure and number of predated nests; 3) computed as a mean
717 weighted by sample size (number of nests) from daily nest predation values available for particular
718 habitats or other data subsets; 4) back-calculated from total nest predation provided by authors with the
719 period for which the total nest predation was extrapolated; or 5) obtained by combination of
720 aforementioned approaches. Options 1–4 are equivalent to each other and reflect several ways in which
721 authors may present the same data. Therefore when used to calculate daily nest predation, obtained values
722 were directly comparable.

723 The procedure for computing the exposure for daily nest predation was as follows. The exposure
724 for hatched nests is from a day of finding until known or predicted hatching (e.g. 11 April and 28 April
725 means $28-11 = 17$ days of exposure). The exposure of depredated nests is from day of finding until
726 midpoint assumption between last positive and first negative visits of the particular nest, the exposure of
727 failed nests due to any other reason than predation (agriculture machinery, flooding, trampling etc.) or for
728 nest with an unidentified fate is from day of finding until the last positive visits (not midpoint assumption
729 between last positive and first negative visits of the nest).

730 For 140 populations (59%), daily nest predation and the total exposure were not provided but
731 numbers of nests hatched, predated or failed for other reasons were reported instead for “apparent
732 predation” or “apparent survival” computation (47, 48, 54). Therefore we used the Beintema’s method
733 (55) for estimating the exposure for these nests to subsequently convert “apparent predation” to daily nest
734 predation values. The logic of the method is that a successful nest is on average found halfway from
735 laying to hatching (e.g. 15 days in case of 30 days incubation period) and a depredated nest is on average
736 lost halfway from this 15-days period. However, if most nests were found earlier after egg-laying, mean
737 observation time set up on 0.5 of egg-laying and incubation period needs to be adjusted (55). We applied
738 two additional options of mean observation time (0.9 and 0.6) to account for this. The first option was
739 used for studies, where authors were checking the study plot for new nests every day and where most
740 nests were found during the egg-laying period. The second option was applied for the majority of cases,
741 where study plots were checked for new nests once or twice per week and most of the nests were found
742 before reaching the half of incubation stage. The default 0.5 option was employed when data from nest
743 card schemes were analysed or visits of the locality were very scarce and thus the incubation stage of
744 found nest was random.

745 To check the accuracy of our approach, we compared computed daily nest predation rates with
746 given values in 56 shorebird populations for which both approaches were available. The computed daily

747 nest predation highly correlated with given values: Pearson's correlation coefficient, $r_s = 0.96$, $P < 0.001$,
748 mean daily nest predation computed value = 0.042 ± 0.004 (SEM), given value = 0.046 ± 0.005 (SEM),
749 pairs of values did not differ (paired t-test, $t = 1.70$, $df = 55$, $P = 0.094$) and temporal trends were
750 consistent between groups of data with directly given daily nest predation and data where daily nest
751 predation was derived from "apparent predation" (table S3), therefore all data were treated together. We
752 excluded all studies which violated the aforementioned consistent methodologies from all comparative
753 analyses.

754 Every nest where at least one chick hatched was regarded as successful. Only complete nest
755 depredations were included in the predated nests category (partial egg loss were omitted). Clutches with
756 infertile eggs with present parents which had not been depredated over expected egg-laying and
757 incubation period were regarded as successful ones for the purpose of predation analyses. Nests with
758 unclear fate (without any certainly survived period between two visits) were totally excluded from further
759 computations and they are not included in sample sizes. In two cases, a single study from Antarctica (56)
760 and a single study from Alaska (57), we presumed all failed nests to be depredated, although it was not
761 explicitly stated in the article. Potential small overestimation of predation in these cases should not
762 present an issue because it is contrary to our expectation of lower nest predation in polar regions (14, 20,
763 58).

764 Different populations of one species were defined as localities at least 40 km from each other.
765 Southern hemisphere breeding season over two calendar years was attributed only to one year (the first
766 one) to be comparable with the Northern hemisphere. When data were available for more seasons in
767 particular population, the sum of depredated nests and overall exposure were pooled over years to obtain
768 mean predation values with presenting the mean year of data collection.

769 The number of seasons involved in each data point ($n = 237$) varied from one to 44 years, mean =
770 5.3 ± 5.8 (SD), median = 3 years. Total exposure per data point varied between 77–70,000 days, mean =
771 $2,123 \pm 6,508$ (SD), median = 631 days. Number of nests varied between 12–5,000 nests, mean = $161 \pm$
772 479 (SD), median = 51 nests. Studies with fewer than 12 nests with known fate were omitted from all
773 analyses as well as nests covered with cages in predator control management. We accounted for the
774 number of nests per population in modelling (see Statistical analyses for details). The variation for daily
775 nest predation values was as follows: 0–0.209, mean = 0.031 ± 0.028 (SD), median = 0.025 and for total
776 nest predation values was 0–99.77%, mean = $48.91\% \pm 25.23$ (SD), median = 50.89%.

777 Where the fate was given for individual eggs only but not for whole nests and authors were not
778 able to provide us with additional information, we omitted these data because such data are not possible
779 to use for correct calculation of daily nest predation values for nests as the unit.

780 Data division

781 For the purpose of more detailed analyses of temporal trend in nest predation, we divided the
782 whole data set into 1) five latitudinal areas: South temperate (from -62° to -30°) – 24 populations, South
783 tropics (from -30° to 0°) – 14 populations, North tropics (from 0° to 30°) – 17 populations, North
784 temperate (from 30° to 60°) – 96 populations and the Arctic (from 60° to 78°) – 86 populations; 2) two
785 clades of shorebirds i) Charadrii – 110 populations (families: Charadriidae, Haematopodidae,
786 Recurvirostridae, Burhinidae, Chionidae) and ii) Scolopaci and allies – 127 populations (families:
787 Scolopacidae, Jacanidae, Glareolidae, Rostratulidae). Generally, there is an obvious lack of available
788 demographic data for shorebirds from the tropics and South America (59), even after 20 years of research
789 and therefore we encourage further targeted investigation of shorebirds in these regions.

790 Apart from possible latitudinal variations in the impact of climate change (1, 6), nest predation
791 rates could be affected by different predator communities in different geographical areas as it was
792 hypothesized that higher diversity of nest predators in the tropics (14), particularly snakes (15, 60, 61) or

793 small mammals (62), is primarily responsible for higher nest predation rate near the Equator (14, 20, 58,
794 63, 64). Indeed, communities of shorebirds nest predators vary latitudinally (17, 21). The Arctic Fox
795 (*Vulpes lagopus*), four species of skuas (Stercorariidae) and gulls (*Larus* spp.) are the main predators in
796 the Arctic (10, 12, 17). Red Fox (*Vulpes vulpes*), several mustelids species (Mustelidae), hedgehogs
797 (*Erinaceus* spp.) and gulls are perceived as predominant predators of shorebird nests in temperate regions
798 (17, 21, 37, 43, 65). Members of the family Corvidae, especially *Corvus* spp., are effective avian
799 predators of shorebird nests from the Arctic to temperate and tropical regions (17, 21, 37, 43). Our
800 knowledge of predators on shorebird clutches in the tropics is based mainly on accidental observations or
801 assumptions (17) which is in line with the general lack of studies from tropical regions (Fig S1). Despite
802 this data deficiency, highly diverse taxa such as coyotes and jackals (*Canis* spp.), domestic cats and dogs,
803 mongooses and suricates (Herpestidae), rats (*Rattus* spp.), various raptor species, coots and gallinules
804 (Rallidae), monitor lizards (Varanidae), several species of snakes, Atlantic Ghost Crab (*Ocypode*
805 *quadrata*) but also foxes, mustelids and gulls have been repeatedly reported as shorebird nest predators in
806 the tropics (17, 66, 67). Despite recent improvement with camera monitoring technology (68), our better
807 understanding of tropical predator communities and their relative relevance as ground nesting birds
808 predators still remains an obvious challenge for next decades of research.

809 For more detailed investigation of spatial pattern in nest predation, we divided our dataset into the
810 two subsets of historic and recent data (before and after the year 2000 – the year 2000 is in the latter
811 period). The extensive change of Arctic and North temperate ecosystem food-webs, the crash of small
812 rodent, the lemmings (*Lemmus* spp., *Dicrostonyx* spp.) and voles (*Microtus* spp., *Myodes* spp.) population
813 cycles and abundances dated around the year 2000 (26–30) led us to the assumption that this change
814 could cause the increase in shorebirds nest predation via altered trophic interactions (1, 6), because
815 shorebirds nests are known as alternative prey instead rodents (12, 69). Furthermore, climate-induced
816 changes in the Arctic nest predation rates could account also for spreading of new predators to the North
817 (4, 6, 12), namely Red Fox (70) or alterations in vegetation structures changing the nest visibility for
818 potential predators (6, 12, 25).

819 Ten populations with long surveillance over decades and over the year 2000 were divided into two
820 subsets. Nine of them with data from two and more seasons in a given period are described in table S4
821 and were used for pairwise comparison of historic and recent nest predation values at same localities for
822 the same species (Fig. 2E, Fig. 2F, table S5). Otherwise, every population was classified into the historic
823 (1944–1999) or recent (2000–2016) period according to the mean year of data collection, altogether
824 accounting for 145 populations before 2000 and 102 populations after 2000 (Fig. 3). Further division
825 according to shorebirds clades was not possible due to insufficient samples in some latitudinal areas and
826 the total lack of Scolopaci clade nest predation values from Southern hemisphere after the year 2000.

827 Maps and figures preparation

828 Values of daily nest predation which were log transformed after the addition of a small quantity (0.01)
829 and original total nest predation values were used for extrapolation of nest predation over the globe (Fig.
830 1). A single data point from Antarctica (56) from the mean year 1988, daily nest predation = 0.0098, total
831 nest predation = 27%, although included in all analyses, was not included in all maps (Fig. 1), to avoid
832 non-appropriate extrapolation of nest predation over the whole continent of Antarctica. For all
833 populations and their localities see fig. S1. Mapped nest predation rates were generated by generalized
834 additive models (maximum dimension of the basis $k = 50$), with Gaussian error family (71–73) in R (ver.
835 3.3.3) (74) for each point on the globe using latitude/longitude and known daily and total nest predation
836 values separately. Daily nest predation values, as well as total nest predation values in maps, were
837 presented in nine colour categories. The scale was the same for historic and recent values. Differences
838 between historic and recent values were plotted for the figures of change in daily and total nest predation

839 at the scale of 11 colour categories (Fig. 1E and Fig. 1F) with use of R (ver. 3.3.3) (74). Note that nest
 840 predation extrapolation over the globe is more precise in North temperate and the Arctic with more data
 841 points (Fig. 1). Figures 2A–D, 3A, 3B and 4A–4D were generated by the generalized additive model of
 842 the given relationship with 95% confidence intervals, the dimension of the basis (k) = 5, Gaussian error
 843 family (71). Figures were plotted with ‘ggplot’ function in ‘ggplot2’ R package (75). Original daily nest
 844 predation values and total nest predation values (in %) were plotted in figures 2, 3, 4, S2 and S3.

845 Statistical analysis

846 All statistical analyses were performed with R (ver. 3.3.3) (74). To assure normality of response
 847 variables, all daily nest predation values were adjusted to original value + 0.01 and log-transformed
 848 before entering analyses; total nest predation values were left in their original form. We used
 849 phylogenetically and spatially controlled generalized linear models. Specifically, we control for 1)
 850 phylogeny – we obtained species level of phylogeny from current avian tree (76) with manual addition of
 851 two recently recognized species: Snowy Plover (*Charadrius nivosus*) (77) and Wilson’s Snipe (*Gallinago*
 852 *delicata*) (17, 35). We created a variance–covariance matrix (\mathbf{V}) to model the expected similarity among
 853 species that is defined by the phylogeny (78–80), and incorporated it into each model. Because data were
 854 analysed at the population level, we accounted for this by incorporating the random effect of the species
 855 into each model; 2) spatial autocorrelation – we created a spatial matrix (\mathbf{D}) from GPS coordinates of
 856 each locality for each population following an established approach (80, 81) and incorporated it into each
 857 model; 3) number of nests – due to the fact that nest predation values obtained from smaller sample of
 858 nests could be less precise (55), we accounted for this in two ways: i) incorporating a control variable, the
 859 logarithm of number of nests into each model and ii) creating a diagonal matrix from reciprocal of the
 860 number of nests (\mathbf{H}) (71) and incorporating it into each model.

861 Overall, the model for the predation rate of population i in species j (p_{ij}), transformed by the
 862 addition of a small amount in the case of DPR, included: an intercept term estimated as a random effect,
 863 grouped by species (α_j with variance σ_α^2); an effect of time (the mean year of study y_i for the population);
 864 the number of nests measured in population i (N_i) as well as additional modelled covariates measured at
 865 the population level (x_{ik}):

$$\log(p_{ij}) = \alpha_j + b_y y_i + b_N \log(N_i) + \sum_{k=1}^n b_k x_{ik} + \varepsilon_i; \alpha_j \sim \mathcal{N}(0, \sigma_\alpha^2) \varepsilon_i \sim \mathcal{N}(0, \mathbf{J} \otimes \mathbf{W})$$

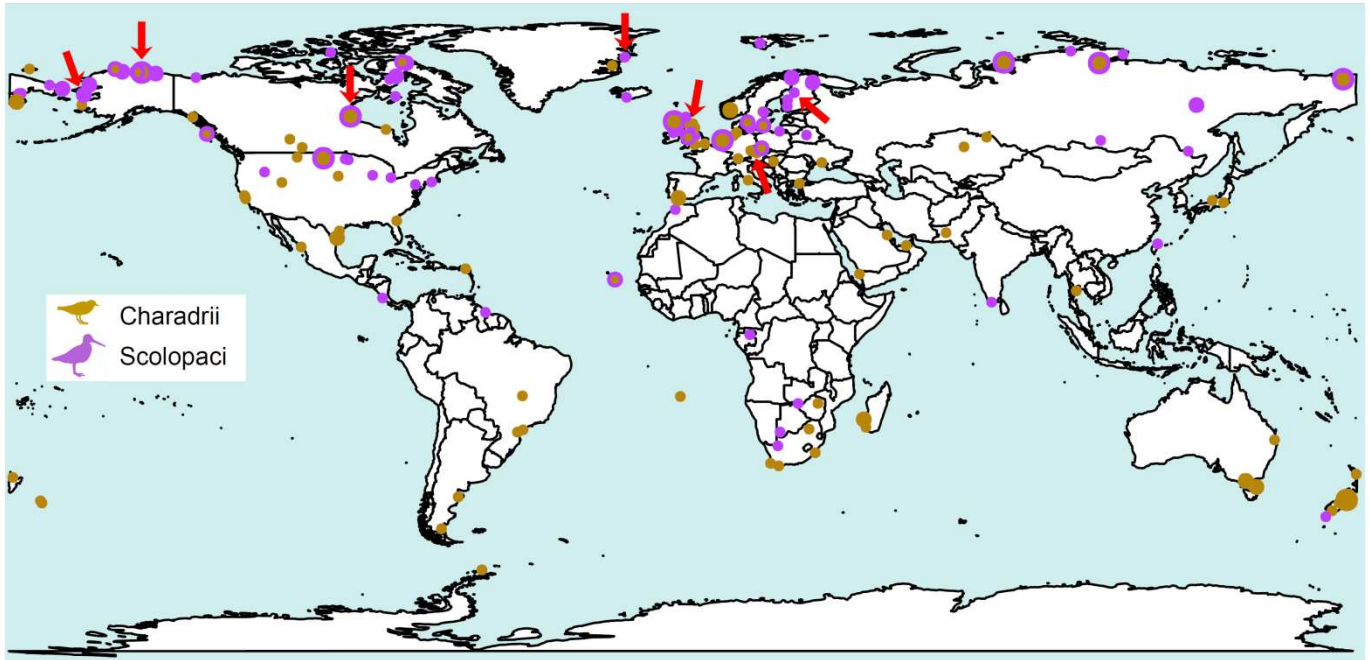
$$\mathbf{W} = \phi \mathbf{D} + \lambda(1 - \phi) \mathbf{V} + (1 - \phi)(1 - \lambda) \mathbf{H}$$

866 The errors (ε_i) are distributed according to a multivariate normal distribution with covariance
 867 matrix $\mathbf{J} \otimes \mathbf{W}$ where \mathbf{J} indicates which species each population belongs to, and the matrix \mathbf{W} is a species-
 868 level matrix that combines the matrices of geographic distances (\mathbf{D}), phylogenetic similarity (\mathbf{V}) and
 869 variation resulting from measured numbers of nests (\mathbf{H}), with estimated variance components (ϕ, λ)
 870 weighting the contribution of each, see (81). ϕ, λ are estimated by restricted maximum likelihood along
 871 with the rest of the model parameters. To address the issue of uncertainty resulting from phylogenetic
 872 error, we ran the analyses described above for 1000 randomly sampled trees. We found that the variance
 873 in parameters and model outputs was low (see supplementary code for an example) therefore we did not
 874 explore this further.

875 Because explanatory variables were potentially inter-correlated (see correlation matrix in table
 876 S8), we performed the climatic modelling in the sequence of simple linear mixed-effects models (table
 877 S7) with control for phylogeny, spatial autocorrelation and sample size (see above). Only for within-
 878 population temporal variation in predation (table S5), we used linear mixed-effect models (71) with

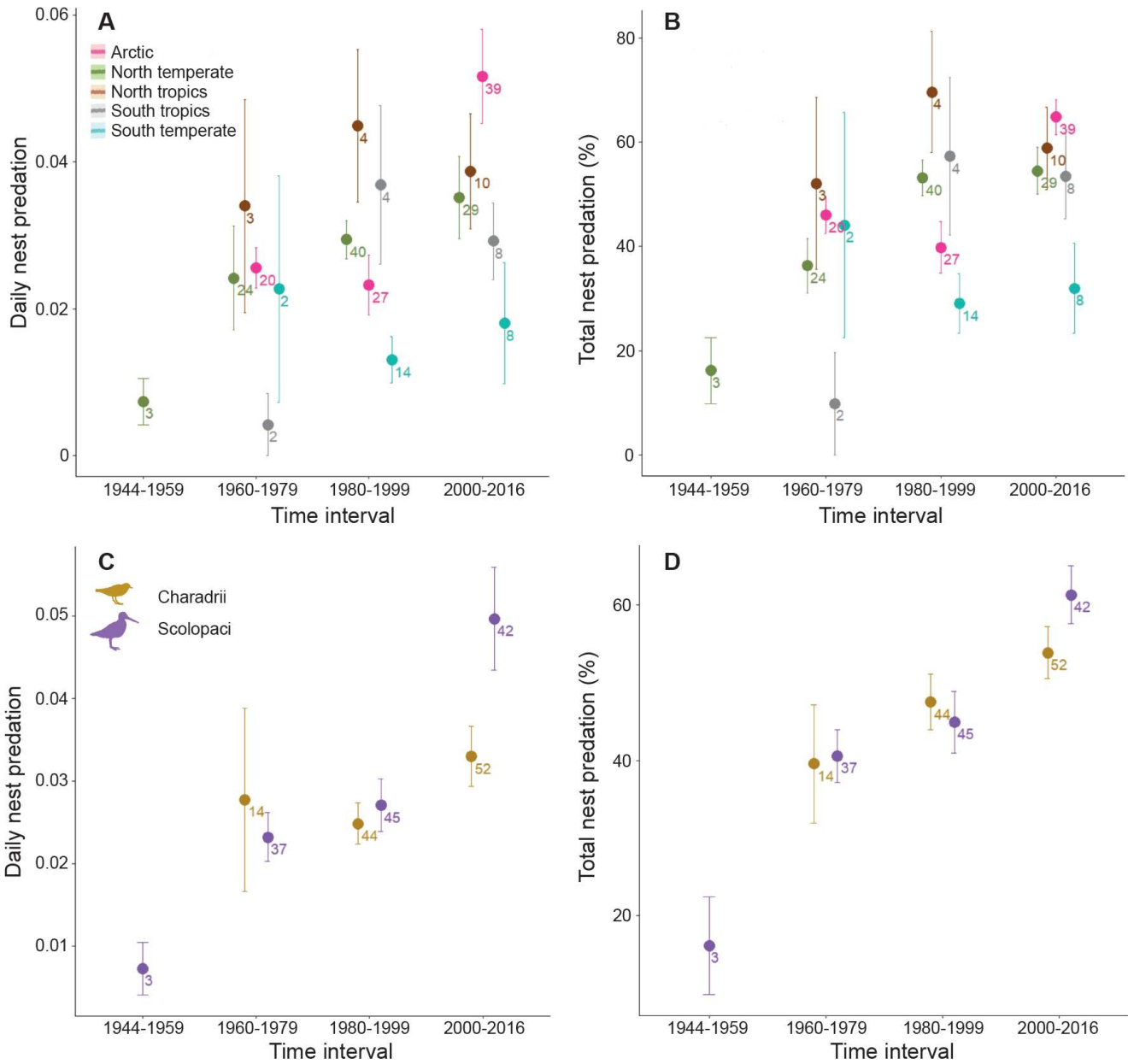
879 random effects of species and locality. We ran individual models including all predictors (table S2, table
880 S3, table S5 and table S7). Additionally separate models for possible interaction effects were fitted, then
881 non-significant interactions deleted (table S6). Phylo-spatial models were fitted using the package
882 ‘coxme’ (82). Linear mixed-effects models were fitted with the ‘lme4’ package (83). Residuals from all
883 tests were checked for normality in quantile-quantile plot (71). All statistical tests were two-tailed.

884



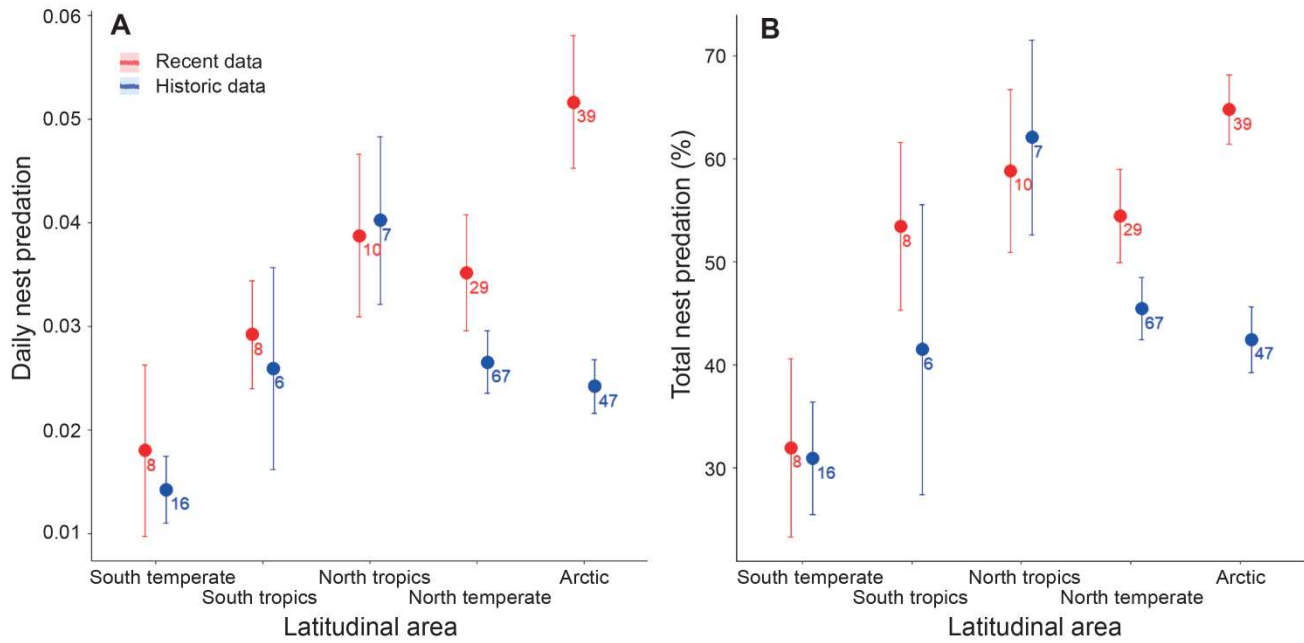
885

886 **Fig. S1. Geographical distribution of the analysed data on nest predation in shorebirds.** Altogether,
887 237 populations of 111 shorebirds species at 149 localities were used in analyses. Dots of locations are
888 divided into three size categories (small = 1 population only, medium = 2–3 populations, big = 4 and
889 more populations per locality). Where shorebirds from both clades were studied, dots are presented in
890 both colours. Red arrows denote seven locations with long-term monitoring of nine shorebird populations
891 presented in the Fig. 2E, Fig. 2F and table S4.



892

893 **Fig. S2. Temporal changes in nest predation of shorebirds in 20 years intervals.** (A and B) Nest
 894 predation rates for five latitudinal areas, see (19) for areas definition. (C and D) Nest predation rates for
 895 plovers and allies (Charadrii) and sandpipers and allies (Scolopaci), see (19) for clades definition. (A–D)
 896 Mean \pm SEM, number of populations is given next to the relevant data point. (A and C) Daily nest
 897 predation. (B and D) Total nest predation.



898

899 **Fig. S3. Latitudinal gradient in historic versus recent nest predation of shorebirds.** Daily (A) and
 900 total (B) nest predation rates (historic data 1944–1999; recent data 2000–2016), Mean \pm SEM for five
 901 latitudinal areas separately, see (19) for areas definition. Number of populations is given next to the
 902 relevant data point.

Table S1. Shorebird species used in the study with number of populations and relevant data sources.

Species order	Species	N populations	Data sources
1	Eurasian Thick-knee (<i>Burhinus oedicnemus</i>)	2	(Taylor 2006) (84), (Nadeem <i>et al.</i> 2014) (85), Nadeem in litt.
2	Water Thick-knee (<i>Burhinus vermiculatus</i>)	1	(Dobson 2004) (86)
3	Snowy Shearwater (<i>Chionis albus</i>)	1	(Favero 1993) (56)
4	Magellanic Plover (<i>Pluvianellus socialis</i>)	1	(Lishman & Nol 2012) (87), C. Lishman in litt.
5	American Black Oystercatcher (<i>Haematopus bachmani</i>)	1	(Tessler & Garding 2006) (88)
6	American Oystercatcher (<i>Haematopus palliatus</i>)	2	(Sabine <i>et al.</i> 2005) (89), (Barbieri & Delchiaro 2009) (90)
7	African Oystercatcher (<i>Haematopus moquini</i>)	2	(Calf & Underhill 2002) (91), (Scott <i>et al.</i> 2011) (92)
8	Eurasian Oystercatcher (<i>Haematopus ostralegus</i>)	5	(Hughey 1985) (93), (Beintema & Müskens 1987) (94), (Rudenko 1998) (95), (Jackson & Green 2000) (96), (Otwall 2005) (97)
9	Pied Oystercatcher (<i>Haematopus longirostris</i>)	1	(Lauro & Nol 1995) (98)
10	Variable Oystercatcher (<i>Haematopus unicolor</i>)	1	(Michaux 2013) (99)
11	Chatham Oystercatcher (<i>Haematopus chathamensis</i>)	1	(Moore & Reid 2009) (100)
12	Sooty Oystercatcher (<i>Haematopus fuliginosus</i>)	1	(Lauro & Nol 1995) (98)
13	Black-winged Stilt (<i>Himantopus himantopus</i>)	2	(Hughey 1985) (93), (Cuervo 2003) (101)
14	Black Stilt (<i>Himantopus novaezelandiae</i>)	1	(Pierce 1986) (102)
15	Pied Avocet (<i>Recurvirostra avosetta</i>)	2	(Beintema & Müskens 1987) (94), (Cuervo 2003) (101)
16	American Avocet (<i>Recurvirostra americana</i>)	1	(Herring <i>et al.</i> 2011) (103)
17	Northern Lapwing (<i>Vanellus vanellus</i>)	16	(Bain 1987) (104), (Beintema & Müskens 1987) (94), (Galbraith 1988) (105), (Baines 1990) (106), (Berg <i>et al.</i> 1992) (107), (Blomqvist & Johansson 1995) (108), (Flodin <i>et al.</i> 1995) (109), (Jackson & Green 2000) (96), (Hart <i>et al.</i> 2002) (110), (Schröpfer 2002) (111), (Šálek & Šmilauer 2002) (112), (Köster & Bruns 2003) (113), (Otwall 2005) (97), (Junker <i>et al.</i> 2006) (114), (Sharpe 2006) (115), (Kragten & De Snoo 2007) (116), (Pucha <i>et al.</i> 2009) (117), (Zámečník <i>et al.</i> 2017) (118), V. Kubelka unpublished data, M. Šálek unpublished data, V. Štorek in litt.
18	Spur-winged Lapwing (<i>Vanellus spinosus</i>)	1	(Makrigianni <i>et al.</i> 2008) (119), E. Makrigianni in litt.
19	Crowned Lapwing (<i>Vanellus coronatus</i>)	1	(Ade 1979) (120)
20	Grey-headed Lapwing (<i>Vanellus cinereus</i>)	1	(Takahashi & Ohkawara 2007) (121)
21	Black-shouldered Lapwing (<i>Vanellus novaehollandiae</i>)	3	(Barlow <i>et al.</i> 1972) (122), (Giese & Jones 1996) (123), (Cardilini <i>et al.</i> 2013) (124)
22	Sociable Lapwing (<i>Vanellus gregarius</i>)	2	(Watson <i>et al.</i> 2006) (125), (Shedon <i>et al.</i> 2013) (126), P. Donald & I. Fisher in litt.
23	Southern Lapwing (<i>Vanellus chilensis</i>)	2	(Cerbocini <i>et al.</i> 2015) (127), (Santos & Macedo 2017) (128), R. A. Cerbocini in litt., E. S. A. Santos & R. H. Macedo in litt.
24	Wrybill (<i>Anarhynchus frontalis</i>)	1	(Hughey 1985) (93)
25	Golden Plover (<i>Pluvialis apricaria</i>)	1	(Byrkjedal 1987) (129)
26	Pacific Golden Plover (<i>Pluvialis fulva</i>)	3	(Schekkerman <i>et al.</i> 2004) (130), (Arctic Shorebird Demographics Network 2016) (131), P. Tomkovich unpublished data
27	American Golden Plover (<i>Pluvialis dominica</i>)	3	(Moitoret <i>et al.</i> 1996) (57), (Arctic Shorebird Demographics Network 2016) (131)
28	Grey Plover (<i>Pluvialis squatarola</i>)	4	(Kondratyev 1982) (132), (Moitoret <i>et al.</i> 1996) (57), (Tomkovich & Dondua 2011) (133), (Arctic Shorebird Demographics Network 2016) (131)
29	Northern Red-breasted Plover (<i>Charadrius aquilonius</i>)	1	(Wills <i>et al.</i> 2003) (134)
30	Common Ringed Plover (<i>Charadrius hiaticula</i>)	5	(Kondratyev 1982) (132), (Pienkowski 1984) (135), (Jackson & Green 2000) (96)
31	Semipalmated Plover (<i>Charadrius semipalmatus</i>)	2	(Jehl 1971) (136), (Cooper & Miller 1997) (137)
32	Long-billed Plover (<i>Charadrius placidus</i>)	1	(Katayama <i>et al.</i> 2010) (138)
33	Little Ringed Plover (<i>Charadrius dubius</i>)	2	(Dolanský & Žďárek 2001) (139), (Cepáková <i>et al.</i> 2007) (140), Cepáková <i>et al.</i> in litt.
34	Wilson's Plover (<i>Charadrius wilsonia</i>)	3	(Bergstrom 1982) (141), (Brown & Brindock 2011) (142)
35	Killdeer (<i>Charadrius vociferus</i>)	1	(Kantrud & Higgins 1992) (143)
36	Piping Plover (<i>Charadrius melodus</i>)	3	(Catlin <i>et al.</i> 2011) (144), (Richardson 1999) (145), (White 2005) (146)
37	Black-banded Plover (<i>Charadrius thoracicus</i>)	2	(Zefania <i>et al.</i> 2008) (147), C. Carmona <i>et al.</i> in litt., L. Eberhart-Phillips <i>et al.</i> in litt.
38	Kittlitz's Plover (<i>Charadrius pecuarius</i>)	1	C. Carmona <i>et al.</i> in litt., L. Eberhart-Phillips <i>et al.</i> in litt.
39	St Helena Plover (<i>Charadrius sanctaehelenae</i>)	1	(Burns <i>et al.</i> 2013) (148)
40	White-fronted Plover (<i>Charadrius marginatus</i>)	1	C. Carmona <i>et al.</i> in litt., L. Eberhart-Phillips <i>et al.</i> in litt.

Table continued on next page. Species are taxonomically ordered according to IOC World Bird List (ver. 6.3, 2016) (35). Complete references from this table are presented in the list of references.

Table S1. Shorebird species used in the study with number of populations and relevant data sources.
– table continued from the previous page.

Species order	Species	N populations	Data sources
41	Kentish Plover (<i>Charadrius alexandrinus</i>)	6	(Székely <i>et al.</i> 1994) (149), (Pietrelli <i>et al.</i> 2001) (150), (Kozstolány <i>et al.</i> 2009) (151), (Al Rashidi <i>et al.</i> 2011) (152), (Carmona-Isunza <i>et al.</i> 2015) (153), (Al Rashidi 2016) (154), M. C. Carmona-Isunza <i>et al.</i> in litt.
42	Snowy Plover (<i>Charadrius nivosus</i>)	5	(Paton 1994) (155), (Rupert 1997) (156), (Neuman 2003) (157), (Demers & Robinson-Nilsen 2012) (158), M. C. López in litt.
43	Red-capped Plover (<i>Charadrius ruficapillus</i>)	1	(Tan <i>et al.</i> 2015) (159)
44	Malay Plover (<i>Charadrius peronii</i>)	1	(Yasué <i>et al.</i> 2007) (160)
45	Two-banded Plover (<i>Charadrius falklandicus</i>)	1	G. D. Hevia & V. L. D'Amico in litt.
46	Double-banded Plover (<i>Charadrius bicinctus</i>)	2	(Hughey 1985) (93), (Keedwell & Sanders 2002) (161)
47	Lesser Sandplover (<i>Charadrius mongolus</i>)	1	P. Tomkovich unpublished data
48	Eurasian Dotterel (<i>Eudromias morinellus</i>)	1	(Byrkjedal 1987) (129)
49	Mountain Plover (<i>Charadrius montanus</i>)	1	(Dinsmore <i>et al.</i> 2002) (49)
50	Hooded Plover (<i>Thinornis cucullatus</i>)	2	(Dowling & Weston 1999) (162), (Baird & Daan 2003) (163)
51	Shore Plover (<i>Thinornis novaeseelandiae</i>)	1	(Davis 1994) (164)
52	Greater Painted-snipe (<i>Rostratula benghalensis</i>)	1	(Hsu & Severinghaus 2011) (165)
53	African Jacana (<i>Actophilornis africanus</i>)	1	(Tarboton 1992) (166)
54	Bronze-winged Jacana (<i>Metopidius indicus</i>)	1	(Butchart 2000) (167)
55	Northern Jacana (<i>Jacana spinosa</i>)	1	(Stephens 1984) (67), M. L. Stephens in litt.
56	Wattled Jacana (<i>Jacana jacana</i>)	1	(Osborne 1982) (168)
57	Eurasian Woodcock (<i>Scolopax rusticola</i>)	1	(Hoodles & Coulson 1998) (169)
58	American Woodcock (<i>Scolopax minor</i>)	1	(Miller & Jordan 2011) (170)
59	Auckland Snipe (<i>Coenocorypha aucklandica</i>)	1	(Miskelly 1990) (171)
60	Common Snipe (<i>Gallinago gallinago</i>)	3	(Beintema & Müskens 1987) (94), (Mongin 2002) (172), (Yarovikova 2003) (173)
61	Wilson's Snipe (<i>Gallinago delicata</i>)	1	(Kantrud & Higgins 1992) (143)
62	Short-billed Dowitcher (<i>Limnodromus griseus</i>)	1	(Arctic Shorebird Demographics Network 2016) (131)
63	Long-billed Dowitcher (<i>Limnodromus scolopaceus</i>)	4	(Kondratyev 1982) (132), (Moitoret <i>et al.</i> 1996) (57), (Arctic Shorebird Demographics Network 2016) (131)
64	Black-tailed Godwit (<i>Limosa limosa</i>)	3	(Beintema & Müskens 1987) (94), (Groen & Hemerik 2002) (174), (Groen <i>et al.</i> 2006) (175)
65	Hudsonian Godwit (<i>Limosa haemastica</i>)	1	(Jehl 1971) (136), (Arctic Shorebird Demographics Network 2016) (131)
66	Bar-tailed Godwit (<i>Limosa lapponica</i>)	1	(Larsen & Moldsvor 1992) (176)
67	Marbled Godwit (<i>Limosa fedoa</i>)	1	(Kantrud & Higgins 1992) (143)
68	Whimbrel (<i>Numenius phaeopus</i>)	5	(Jehl 1971) (136), (Skeel 1983) (177), (Larsen & Moldsvor 1992) (176), (Pulliainen & Saari 1993) (178), (Katrínardóttir <i>et al.</i> 2015) (179), (Arctic Shorebird Demographics Network 2016) (131), B. Katrínardóttir in litt.
69	Eurasian Curlew (<i>Numenius arquata</i>)	6	(Bain 1987) (104), (Berg 1992) (180), (Grant <i>et al.</i> 1999) (181), (Valkama <i>et al.</i> 1999) (182)
70	Far Eastern Curlew (<i>Numenius madagascariensis</i>)	1	(Antonov 2010) (183), A. I. Antonov in litt.
71	Long-billed Curlew (<i>Numenius americanus</i>)	1	(Redmond & Jenni 1986) (184)
72	Upland Sandpiper (<i>Bartramia longicauda</i>)	1	(Kantrud & Higgins 1992) (143)
73	Spotted Redshank (<i>Tringa erythropus</i>)	1	(Kondratyev 1982) (132)
74	Common Redshank (<i>Tringa totanus</i>)	4	(Beintema & Müskens 1987) (94), (Flodin <i>et al.</i> 1995) (109), (Jackson & Green 2000) (96), (Otwall 2005) (97)
75	Marsh Sandpiper (<i>Tringa stagnatilis</i>)	1	(Larionov 2015) (185)
76	Common Greenshank (<i>Tringa nebularia</i>)	1	(Christian & Hancock 2009) (186), M. Hancock in litt.
77	Wood Sandpiper (<i>Tringa glareola</i>)	2	(Pulliainen & Saari 1991) (187), (Larionov 2015) (185)
78	Willet (<i>Tringa semipalmata</i>)	1	(Kantrud & Higgins 1992) (143)
79	Terek Sandpiper (<i>Xenus cinereus</i>)	1	(Larionov 2015) (185)
80	Common Sandpiper (<i>Actitis hypoleucos</i>)	3	(Cuthbertson <i>et al.</i> 1952) (188), (Holland <i>et al.</i> 1982) (189), (Dolanský & Zdárek 2001) (139)

Table continued on next page. Species are taxonomically ordered according to IOC Word Bird List (ver. 6.3, 2016) (35). Complete references from this table are presented in the list of references.

Table S1. Shorebird species used in the study with number of populations and relevant data sources.
– table continued from the previous page.

Species order	Species	N populations	Data sources
81	Spotted Sandpiper (<i>Actitis macularius</i>)	5	(Cialdini & Orians 1944) (190), (Miller & Miller 1948) (191), (Hays 1972) (192), (Oring & Knudson 1972) (193), (Alberico <i>et al.</i> 1991) (194)
82	Turnstone (<i>Arenaria interpres</i>)	2	(Kondratyev 1982) (132), (Perkins <i>et al.</i> 2007) (195)
83	Great Knot (<i>Calidris tenuirostris</i>)	1	(Tomkovich 2001) (196), P. Tomkovich unpublished data
84	Red Knot (<i>Calidris canutus</i>)	1	P. Tomkovich unpublished data
85	Sanderling (<i>Calidris alba</i>)	2	(Parmelee 1970) (197), (Hansen <i>et al.</i> 2010) (198), H. J. Hansen in litt.
86	Semipalmated Sandpiper (<i>Calidris pusilla</i>)	4	(Gratto <i>et al.</i> 1983) (199), (Moitoret <i>et al.</i> 1996) (57), (Sandercock 1997) (200), (Arctic Shorebird Demographics Network 2016) (131)
87	Western Sandpiper (<i>Calidris mauri</i>)	4	(Holmes 1972) (201), (Kondratyev 1982) (132), (Morozov & Tomkovich 1988) (202), (Sandercock 1997) (200)
88	Red-necked Stint (<i>Calidris ruficollis</i>)	1	(Morozov & Tomkovich 1988) (202)
89	Little Stint (<i>Calidris minuta</i>)	2	(Schekkerman <i>et al.</i> 2004) (130), (Arctic Shorebird Demographics Network 2016) (131)
90	Temminck's Stint (<i>Calidris temminckii</i>)	3	(Kondratyev 1982) (132), (Rönkä <i>et al.</i> 2003) (203), (Thompson <i>et al.</i> 2014) (204), P. Tomkovich unpublished data
91	Least Sandpiper (<i>Calidris minutilla</i>)	2	(Jehl 1971) (136), (Cooper and Miller 1997) (137)
92	White-rumped Sandpiper (<i>Calidris fuscicollis</i>)	2	(McKinnon & Bêty 2009) (205), (Arctic Shorebird Demographics Network 2016) (131)
93	Baird's Sandpiper (<i>Calidris bairdii</i>)	3	(Reid & Montgomerie 1985) (206), (McKinnon & Bêty 2009) (205), (Arctic Shorebird Demographics Network 2016) (131)
94	Pectoral Sandpiper (<i>Calidris melanotos</i>)	3	(Kondratyev 1982) (132), (Moitoret <i>et al.</i> 1996) (57), (Arctic Shorebird Demographics Network 2016) (131)
95	Sharp-tailed Sandpiper (<i>Calidris acuminata</i>)	1	(Soloviev <i>et al.</i> 2010) (207), (Arctic Shorebird Demographics Network 2016) (131), M. Soloviev in litt.
96	Curlew Sandpiper (<i>Calidris ferruginea</i>)	2	(Schekkerman <i>et al.</i> 1998) (208), (Schekkerman <i>et al.</i> 2004) (130)
97	Purple Sandpiper (<i>Calidris maritima</i>)	1	(Pierce <i>et al.</i> 2010) (209)
98	Rock Sandpiper (<i>Calidris ptilocnemis</i>)	1	P. Tomkovich unpublished data
99	Dunlin (<i>Calidris alpina</i>)	6	(Jehl 1971) (136), (Kondratyev 1982) (132), (Jönsson 1991) (210), (Moitoret <i>et al.</i> 1996) (57), (Jackson and Green 2000) (96), (Schekkerman <i>et al.</i> 2004) (130), (Arctic Shorebird Demographics Network 2016) (131)
100	Stilt Sandpiper (<i>Calidris himantopus</i>)	3	(Jehl 1971) (136), (Moitoret <i>et al.</i> 1996) (57), (Arctic Shorebird Demographics Network 2016) (131)
101	Spoon-billed Sandpiper (<i>Eurynorhynchus pygmeus</i>)	1	(Kondratyev 1982) (132)
102	Broad-billed Sandpiper (<i>Limicola falcinellus</i>)	1	(Soloviev <i>et al.</i> 2010) (207), (Arctic Shorebird Demographics Network 2016) (131), M. Soloviev & V. V. Golovnyuk in litt.
103	Buff-breasted Sandpiper (<i>Tryngites subruficollis</i>)	3	(Moitoret <i>et al.</i> 1996) (57), (Arctic Shorebird Demographics Network 2016) (131)
104	Ruff (<i>Philomachus pugnax</i>)	3	(Kondratyev 1982) (132), (Beintema & Müskens 1987) (94), (Arctic Shorebird Demographics Network 2016) (131)
105	Wilson's Phalarope (<i>Phalaropus tricolor</i>)	2	(Kagarise 1979) (211), (Kantrud & Higgins 1992) (143)
106	Red-necked Phalarope (<i>Phalaropus lobatus</i>)	5	(Moitoret <i>et al.</i> 1996) (57), (Walpole <i>et al.</i> 2008) (212), (Arctic Shorebird Demographics Network 2016) (131), M. Sládeček <i>et al.</i> in litt.
107	Red Phalarope (<i>Phalaropus fulicarius</i>)	2	(Moitoret <i>et al.</i> 1996) (57), (Arctic Shorebird Demographics Network 2016) (131)
108	Cream-coloured Courser (<i>Cursorius cursor</i>)	1	(Gonçalves 2014) (213), (Seymour <i>et al.</i> 2015) (214), Gonçalves in litt., K. Seymour in litt.
109	Double-banded Courser (<i>Rhinoptilus africanus</i>)	2	(Lloyd 2004) (66)
110	Collared Pratincole (<i>Glareola pratincola</i>)	1	(Hanane <i>et al.</i> 2010) (215)
111	Rock Pratincole (<i>Glareola nuchalis</i>)	2	(Brosset 1979) (216), (Williams <i>et al.</i> 1989) (217)

Species are taxonomically ordered according to IOC Word Bird List (ver. 6.3, 2016) (35). Complete references from this table are presented in the list of references.

Table S2. Nest predation in respect to time at different latitudes.

	Response variable	Daily predation rate				Total predation rate			
		Explanatory variable	Estimate	SEM	<i>z</i> -value	<i>P</i> -value	Estimate	SEM	<i>z</i> -value
A, All data	(Intercept)	-32.7721	5.023			-12.1412	2.121		
n = 237 populations	Mean year	0.0148	0.003	5.87	< 0.001	0.0063	0.001	5.96	< 0.001
	log(Number of nests)	-0.0159	0.031	-0.51	0.610	-0.0027	0.013	-0.21	0.840
B, Subset of data – South temperate	(Intercept)	-17.1626	14.348			-4.4434	6.182		
latitudes from -62° to -30°	Mean year	0.0065	0.007	0.90	0.370	0.0023	0.003	0.74	0.460
n = 24 populations	log(Number of nests)	0.1159	0.107	1.08	0.280	0.0550	0.046	1.20	0.230
C, Subset of data – South tropics	(Intercept)	-11.2928	24.046			-4.7132	10.269		
latitudes from -30° to 0°	Mean year	0.0036	0.012	0.30	0.770	0.0025	0.005	0.48	0.630
n = 14 populations	log(Number of nests)	0.1494	0.135	1.11	0.270	0.0627	0.057	1.09	0.280
D, Subset of data – North tropics	(Intercept)	-19.1330	18.785			-5.6102	8.585		
latitudes from 0° to 30°	Mean year	0.0083	0.009	0.88	0.380	0.0032	0.004	0.74	0.460
n = 17 populations	log(Number of nests)	-0.1071	0.093	-1.16	0.250	-0.0401	0.042	-0.94	0.350
E, Subset of data – North temperate	(Intercept)	-28.1316	7.203			-11.2914	3.067		
latitudes from 30° to 60°	Mean year	0.0125	0.004	3.47	< 0.001	0.006	0.002	3.87	< 0.001
n = 96 populations	log(Number of nests)	-0.0475	0.043	-1.11	0.270	-0.0183	0.018	-1.01	0.310
F, Subset of data – Arctic	(Intercept)	-40.3296	8.232			-14.3587	3.394		
latitudes from 60° to 78°	Mean year	0.0187	0.004	4.49	< 0.001	0.0075	0.002	4.38	< 0.001
n = 86 populations	log(Number of nests)	-0.0371	0.064	-0.58	0.560	-0.0171	0.027	-0.64	0.520

Linear mixed-effects kinship models with control for phylogeny (species level of phylogeny + random effect of the species), spatial autocorrelation and number of nests per population, see (19) for details. Mean year = the mean year of the data collection, log(N number of nests) = logarithm of the number of nests.

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Table S3. Robustness of temporal trend in nest predation to shorebird clades and daily nest predation computation method.

	Response variable	Daily predation rate				Total predation rate			
	Explanatory variable	Estimate	SEM	<i>z</i> -value	<i>P</i> -value	Estimate	SEM	<i>z</i> -value	<i>P</i> -value
A, All data n = 237 populations	(Intercept)	-32.7721	5.023			-12.1412	2.121		
	Mean year	0.0148	0.003	5.87	< 0.001	0.0063	0.001	5.96	< 0.001
	log(Number of nests)	-0.0159	0.031	-0.51	0.610	-0.0027	0.013	-0.21	0.840
B, Subset of data – Charadrii n = 110 populations	(Intercept)	-28.7906	8.643			-10.3532	3.704		
	Mean year	0.0127	0.004	2.94	0.003	0.0054	0.002	2.93	0.003
	log(Number of nests)	0.0045	0.045	0.10	0.920	0.0026	0.019	0.14	0.890
C, Subset of data – Scolopaci n = 127 populations	(Intercept)	-36.7972	6.176			-12.9052	2.608		
	Mean year	0.0168	0.003	5.43	< 0.001	0.0067	0.001	5.15	< 0.001
	log(Number of nests)	-0.0180	0.044	-0.41	0.680	-0.0057	0.018	-0.31	0.760
D, Subset of data – given DPR n = 97 populations	(Intercept)	-27.8570	9.197			-9.1005	3.737		
	Mean year	0.0125	0.005	2.73	0.006	0.0049	0.002	2.63	0.009
	log(Number of nests)	-0.0851	0.047	-1.80	0.071	-0.0280	0.019	-1.46	0.140
E, Subset of data – computed DPR n = 140 populations	(Intercept)	-26.4563	6.347			-10.1864	2.792		
	Mean year	0.0114	0.003	3.56	< 0.001	0.0053	0.001	3.74	< 0.001
	log(Number of nests)	0.0594	0.042	1.42	0.160	0.0301	0.018	1.63	0.100

Linear mixed-effects kinship models with control for phylogeny (species level of phylogeny + random effect of the species), spatial autocorrelation and number of nests per population, see (19) for details. Mean year = the mean year of the data collection, log(N number of nests) = logarithm of the number of nests.

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Table S4. Within-population variation in historic and recent nest predation.

Species	Location	Latitude	Longitude	Period	DPR	SEM	TPR (%)	Years	Mean year	N nests	Exposure
Northern Lapwing	Czech Rep.	49.115	14.268	historic	0.023	0.002	50.64	10	1993	375	6883
<i>Vanellus vanellus</i>				recent	0.044	0.002	65.84	8	2006	505	6694.8
Hudsonian Godwit	Canada	58.701	-93.802	historic	0.005	0.005	13.53	4	1965	12	186.3
<i>Limosa haemastica</i>				recent	0.034	0.012	60.67	3	2013	21	235.5
Whimbrel	Canada	58.701	-93.802	historic	0.018	0.004	40.78	6	1969	80	1172.8
<i>Numenius phaeopus</i>				recent	0.050	0.006	77.37	4	2012	138	1481.5
Common Greenshank	Scotland	58.533	-4.232	historic	0.018	0.011	40.40	18	1992	24	275.925
<i>Tringa nebularia</i>				recent	0.027	0.011	53.81	7	2004	27	297.15
Sanderling	Greenland	74.478	-20.555	historic	0.019	0.008	44.53	4	1997	36	365.8
<i>Calidris alba</i>				recent	0.054	0.010	74.95	6	2003	38	405.7
Western Sandpiper	Alaska	64.449	-164.977	historic	0.027	NA	49.20	3	1994	126	1071
<i>Calidris mauri</i>				recent	0.050	0.005	72.26	3	2013	196	2280
Temminck's Stint	Finland	65.021	24.72	historic	0.026	0.003	47.60	19	1992	424	4642.56
<i>Calidris temminckii</i>				recent	0.039	0.007	62.45	4	2004	76	877.92
Pectoral Sandpiper	Alaska	70.380	-149.534	historic	0.011	0.003	25.67	4	1990	123	1762.8
<i>Calidris melanotos</i>				recent	0.051	0.017	74.56	2	2011	18	195
Dunlin	Canada	58.701	-93.802	historic	0.000	NA	0.00	4	1965	13	195
<i>Calidris alpina</i>				recent	0.017	0.004	34.62	4	2012	114	1483.5

Historic values are prior 2000 and recent after the year 2000, DPR = daily nest predation, TPR % = total nest predation values, Years refer to the number of breeding seasons involved, exposure is given in days. Standard error computation follows Johnson (51); it was impossible to compute it in the historic period for Western Sandpiper because the number of all failed nests was not given and for the Dunlin due to zero nest predation. For data sources see table S1. Species are taxonomically ordered according to IOC World Bird List (ver. 6.3, 2016) (35).

925 **Table S5. Within-population variation in historic and recent nest predation – statistics.**

Response variable	Daily nest predation				Total nest predation			
Explanatory variable	Estimate	SEM	<i>t-value</i>	<i>P-value</i>	Estimate	SEM	<i>t-value</i>	<i>P-value</i>
(Intercept)	-3.8687	1.033			0.3572	0.457		
Period	0.5475	0.216	2.54	< 0.001	0.2698	0.092	2.93	< 0.001
Latitude	0.0115	0.016	0.71	0.414	0.0042	0.007	0.58	0.508

926 Linear mixed effect model with the random effect of species, n = 9 populations, for details see table S4.

Table S6. Effect of latitude (A, B and C) and time (A) on nest predation.

	Response variable Explanatory variable	Daily predation rate				Total predation rate			
		Estimate	SEM	<i>z</i> -value	<i>P</i> -value	Estimate	SEM	<i>z</i> -value	<i>P</i> -value
A, All data	(Intercept)	-34.0867	4.883			12.6453	2.076		
n = 237 populations	Mean year	0.0153	0.002	6.24	< 0.001	0.0065	0.001	6.28	< 0.001
	Hemisphere	0.4058	0.111	3.66	< 0.001	0.1655	0.047	3.42	< 0.001
	abs(Latitude)	-0.0013	0.002	-0.52	0.610	-0.0009	0.001	-0.93	0.350
	log(Number of nests)	-0.0161	0.030	-0.53	0.600	-0.0024	0.013	-0.19	0.850
separate model for interaction effect	Mean year : Hemisphere	0.0031	0.008	0.38	0.700	0.0019	0.003	0.55	0.580
separate model for interaction effect	Hemisphere : abs(Latitude)	0.0160	0.008	1.90	0.057	0.0067	0.004	1.88	0.060
separate model for interaction effect	Mean year : abs(Latitude)	0.0003	< 0.001	1.84	0.066	0.0001	< 0.001	1.67	0.095
B, Subset of historic data	(Intercept)	-3.5763	0.244			0.4477	0.108		
(before year 2000)	Hemisphere	0.3929	0.144	2.74	0.006	0.1607	0.063	2.54	0.011
n = 145 populations	abs(Latitude)	-0.0064	0.003	-1.86	0.063	-0.0034	0.002	-2.25	0.025
	log(Number of nests)	0.0137	0.039	0.35	0.730	0.0049	0.017	0.29	0.770
separate model for interaction effect	Hemisphere : abs(Latitude)	0.0087	0.012	0.73	0.460	0.0032	0.005	0.61	0.540
C, Subset of recent data	(Intercept)	-3.7969	0.310			0.3199	0.129		
(after year 2000)	Hemisphere	0.3511	0.172	2.04	0.041	0.1476	0.071	2.07	0.038
n = 102 populations	abs(Latitude)	0.0049	0.004	1.35	0.180	0.0014	0.002	0.96	0.340
	log(Number of nests)	0.0208	0.052	0.40	0.690	0.0135	0.021	0.63	0.530
separate model for interaction effect	Hemisphere : abs(Latitude)	0.0301	0.013	2.25	0.025	0.0138	0.006	2.52	0.012

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Linear mixed-effects kinship models with control for phylogeny (species level of phylogeny + random effect of the species), spatial autocorrelation and number of nests per population. The sum of historic and recent nest predation values is 247 data points because 10 populations were divided into two subsets. We ran individual models including all predictors, additionally separate models for possible interaction effects were fitted, then non-significant interactions deleted. See (19) for details. Mean year = the mean year of the data collection, Hemisphere = Northern and Southern hemisphere, abs(Latitude) = absolute value of latitude, log(N number of nests) = logarithm of the number of nests.

933 **Table S7. Climate change in relation to nest predation.**

Response variable Explanatory variable	Daily predation rate				Total predation rate			
	Estimate	SEM	<i>z-value</i>	<i>P-value</i>	Estimate	SEM	<i>z-value</i>	<i>P-value</i>
(Intercept)	-3.4586	0.147			0.4441	0.065		
Temperature slope 30	6.8118	1.272	5.36	< 0.001	2.7528	0.540	5.10	< 0.001
log(Number of nests)	-0.0160	0.032	-0.51	0.610	-0.0500	0.013	-0.37	0.710
(Intercept)	-3.5177	0.149			0.4192	0.065		
Temperature slope 40	8.5660	1.625	5.27	< 0.001	3.4748	0.690	5.03	< 0.001
log(Number of nests)	-0.0030	0.032	-0.10	0.920	0.0005	0.013	0.04	0.970
(Intercept)	-3.4189	0.149			0.4587	0.065		
Temperature slope 20	4.3937	0.986	4.53	< 0.001	1.7097	0.412	4.15	< 0.001
log(Number of nests)	-0.0111	0.032	-0.35	0.730	-0.0023	0.014	-0.17	0.870
(Intercept)	-3.3508	0.152			0.4854	0.065		
Temperature slope 10	0.4753	0.413	1.15	0.250	0.1551	0.175	0.89	0.370
log(Number of nests)	-0.0060	0.033	-0.18	0.860	< 0.0001	0.014	0.00	1.000
(Intercept)	-3.754	0.182			0.3634	0.081		
Temperature sd 30	0.3903	0.133	2.93	0.003	0.1251	0.058	2.17	0.030
log(Number of nests)	0.0176	0.033	0.53	0.590	0.0070	0.014	0.49	0.620
(Intercept)	-3.8077	0.182			0.3407	0.082		
Temperature sd 40	0.4379	0.130	3.36	< 0.001	0.1463	0.057	2.59	0.010
log(Number of nests)	0.0196	0.033	0.59	0.550	0.0077	0.014	0.55	0.580
(Intercept)	-3.6842	0.180			0.3910	0.082		
Temperature sd 20	0.3117	0.129	2.42	0.016	0.0898	0.056	1.62	0.110
log(Number of nests)	0.0165	0.033	0.49	0.620	0.0056	0.014	0.39	0.700
(Intercept)	-3.5598	0.166			0.4410	0.076		
Temperature sd 10	0.2072	0.123	1.69	0.091	0.0569	0.052	1.09	0.280
log(Number of nests)	0.0079	0.033	0.24	0.810	0.0027	0.014	0.19	0.850

934 N = 247 population measurements (10 populations were divided into two subsets), see (19) for details and climatic variables preparation.

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Table S8. Correlation matrix of four potential predictors of nest predation.

Correlation matrix (Spearman's rank correlation)				
Variable	Latitude	Year	Temperature slope 30	Temperature sd 30
Latitude	1			
Mean year	-0.003	1		
Temperature slope 30	0.230	0.672	1	
Temperature sd 30	0.701	0.202	0.484	1
Correlation matrix with Spearman's correlation test P-values				
Variable	Latitude	Year	Temperature slope 30	Temperature sd 30
Latitude				
Mean year	0.115			
Temperature slope 30	< 0.000	< 0.001		
Temperature sd 30	< 0.001	0.001	< 0.001	

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N = 247 population measurements (10 populations were divided into two subsets), see (19) for details.