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**Title: Ecological insights from three decades of animal movement tracking across a changing Arctic**

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**Abstract:** The Arctic is entering a new ecological state, with alarming consequences for humanity. Animal-borne sensors offer a unique window into these changes. Although substantial animal tracking data from the Arctic and Subarctic exist, most are difficult to discover and access. Here we utilize the new Arctic Animal Movement Archive (AAMA), a growing collection of 201 standardized terrestrial and marine animal tracking studies from 1991–present. The AAMA supports public data discovery, preserves fundamental baseline data for the future, and facilitates efficient, collaborative data analysis. With AAMA-based case studies, we document climatic influences on the migration phenology of eagles, geographic differences in adaptive response of caribou reproductive phenology to climate change, and species-specific changes in terrestrial mammal movement rates in response to increasing temperature.

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**One Sentence Summary:** The Arctic Animal Movement Archive facilitates long-term and large-scale ecological studies of the Arctic and reveals the timing and extent of changes to animal behavior patterns.

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### Main Text

The Arctic and adjacent regions are experiencing the most rapid climate and environmental changes on Earth, caused primarily by anthropogenic greenhouse gas emissions (1). Striking trends include warming winter temperatures, ice loss, and earlier spring snowmelt. These changes profoundly affect conditions experienced by animals, including food availability, interspecific competition, predation and increased human disturbances (2). Impacts of climate change on Arctic vertebrates include rapid poleward range shifts (3, 4), phenological trophic mismatches (5), and changes in migration (6), foraging, and predator-prey dynamics (7). Because rapid environmental change in the Arctic challenges the ability of the region's fauna to adapt, a primary response will likely occur through phenotypic plasticity in the patterns, locations, and timing of their movements (2). Documenting and understanding these changes requires multi-decadal, pan-Arctic data at multiple trophic levels.

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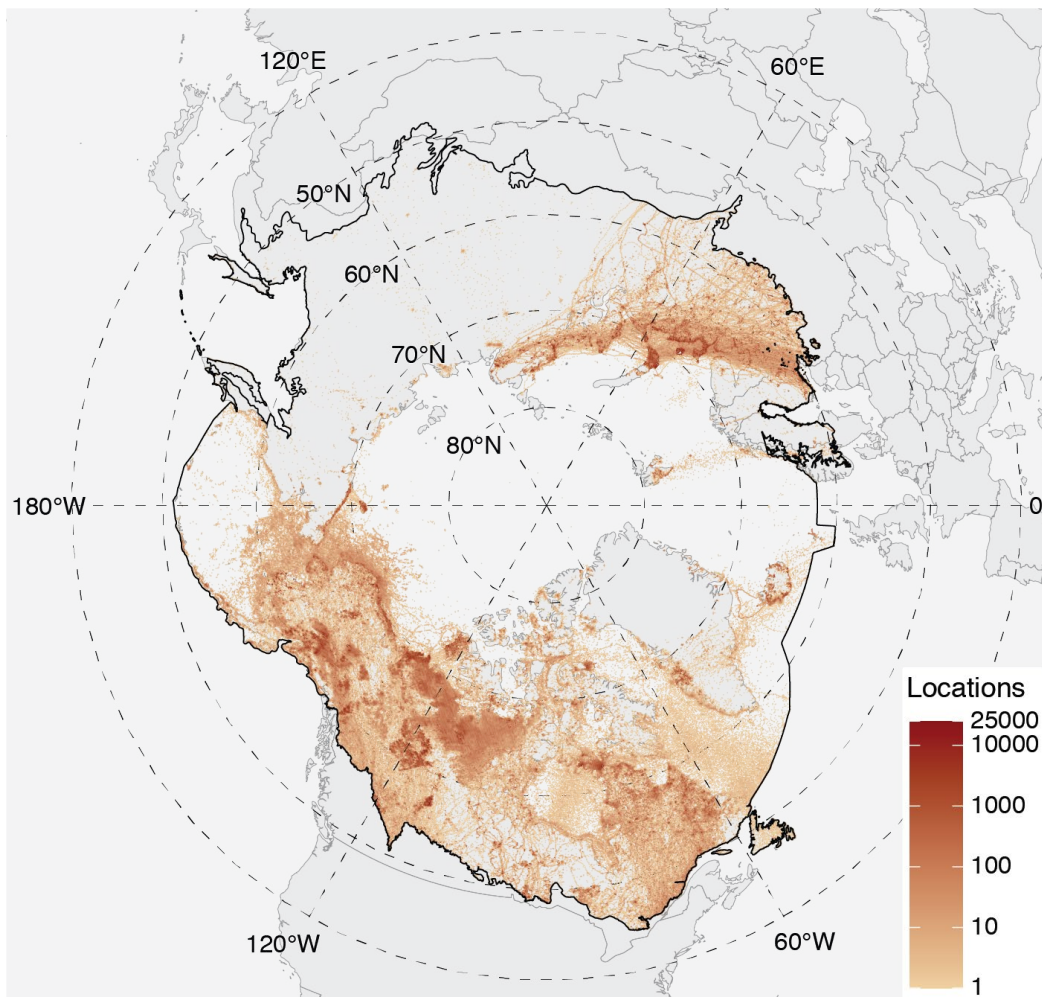
We demonstrate the ecological utility of the Arctic Animal Movement Archive (AAMA), an active, collaborative collection of animal tracking datasets (S.M). Marine ecology archives, such as IOOS-ATN, IMOS, OBIS-SEAMAP, and (8), provide insight regarding space use, movement and connectivity (e.g., 9, 10, 11). Terrestrial animal movement archives are rare and

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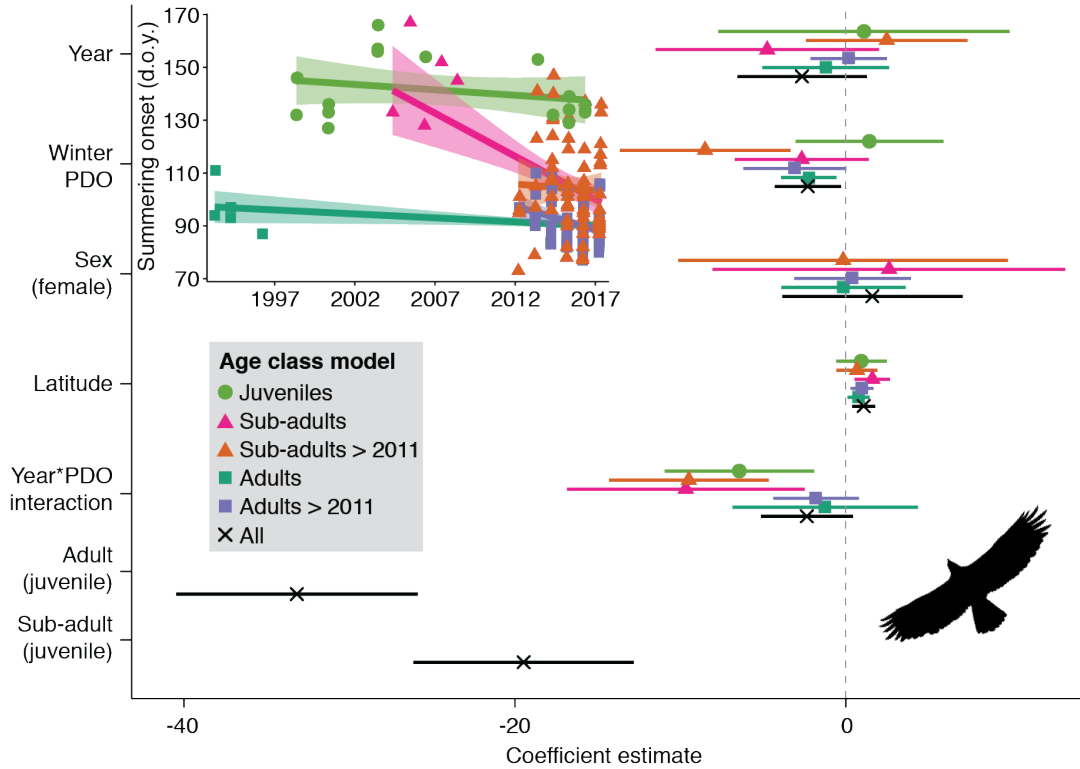


tend to have a regional or taxonomic focus (e.g., 12). AAMA is the first Arctic-focused archive with both terrestrial and marine data and is hosted on the global Movebank database. The geographic scope of the AAMA (Fig. 1) includes the Arctic, Arctic-marine, and Subarctic 'boreal forests/taiga' regions defined by (13) and (14) (S.M.). The dataset contains over 15,000,000 occurrences of 8,000 individuals representing 96 species, from 1991–present (Fig. S.1–S.2, Tables S.1–S.4). Combining data from multiple AAMA studies, we show evidence of (1) climate drivers of golden eagle migration phenology, (2) climate adaptation of parturition by caribou, and (3) consequences of increased temperature and precipitation on movements of mammalian predators and herbivores.

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15 **Fig. 1. Map of the AAMA boundary and data.** Density of animal locations at logarithmic scale characterizes data availability, not animal density or utilization.



**Fig. 2. Changes in the onset date of golden eagles' summering.** Coefficient estimates ( $\pm 95\%$  CI) reflecting age-specific changes in response to year, previous winter PDO, sex (reference: females), latitude, the interaction of year and PDO, and age class (reference: juveniles; Tables S.8–S.9). Inset: time series of model-estimated summering.

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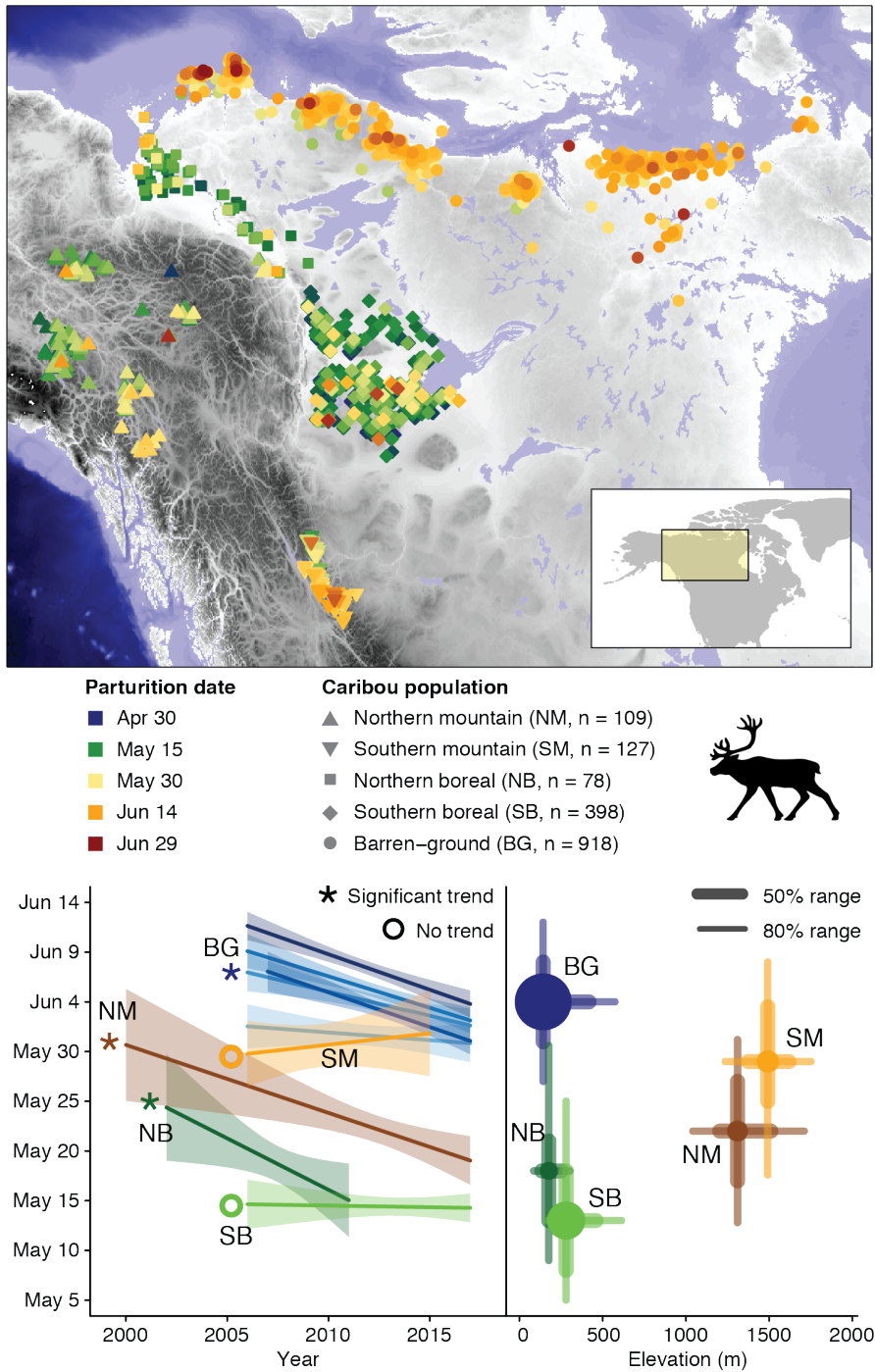
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Behavioral flexibility enables migrants to optimize energy expenditure during migration and adjust arrival at summering grounds (15, 16). We used tracking data from 103 individuals during 1993–2017 (S.M., Table S.5) to examine arrival timing to breeding grounds of northward migrating golden eagles (‘summering’), modeling it with predictors for age, sex, summering onset latitude, year, and preceding-winter mean Pacific Decadal Oscillation index (PDO).

Mean summering date changed slowly over 25 years (-0.5 days/year). The long-term trend differed among age classes, with adults arriving earliest, followed by sub-adults and then juveniles, and was influenced by winter climate (PDO, Fig. 2; Tables S.8–S.9). Eagles of all age classes began summering later at northern latitudes (1.08 days/degree). The significant interaction of year and previous “warm-phase” PDO explains earlier summering dates for sub-adults and juveniles, highlighting their known responsiveness to environmental conditions (16). These warm-phase winters cause warmer and drier climate with reduced snowpack and an earlier snow-free date. Earlier adult arrival to summering grounds should result from selection and competition for territories, yet local climatic variables affect eagle condition prior to, and energy expenditure during, northward migration (16). For sub-adults sampled after 2011, the direct effect of PDO is significant, whereas in the full dataset the direct effect of year replaces PDO (Fig. 2). This period-related difference in inference of climatic drivers highlights the importance of compiling long-term, multi-generational observations. Given the importance of the winter PDO and known impacts of global climate change, golden eagles could face age-specific challenges during migration and at their warming Arctic summering grounds.

The timing of parturition is a key to the demography of wildlife populations, and can be an adaptive response to climate shifts (17). For many mammals, the period from late pregnancy through weaning has the highest energetic demands, and thus is timed to occur when vegetation productivity is highest (18). Caribou occur in five different ecotypes (Fig. 3) across Boreal and Arctic North America, and are facing global declines (19). Using data from 928 individuals during 2000–2017 in northern Canada, we used characteristic patterns of low movement during the calving season to estimate 1647 parturition dates in five populations of barren-ground, boreal, and mountain caribou (S.M., Table S.6).

We found differences in parturition timing and trends among five populations. The southern and northern-boreal populations calved earliest, followed by northern and southern mountain populations (Table S.10). Barren-ground caribou calved later despite occupying a similar latitudinal range as the northern-boreal caribou (Fig. 3). Most importantly, only northern boreal caribou exhibited significant trends towards earlier parturition (0.4–1.1 days/year, Table S.10). This is the first continental-scale retrospective evidence of potential adaptive responses to climate trends by caribou.



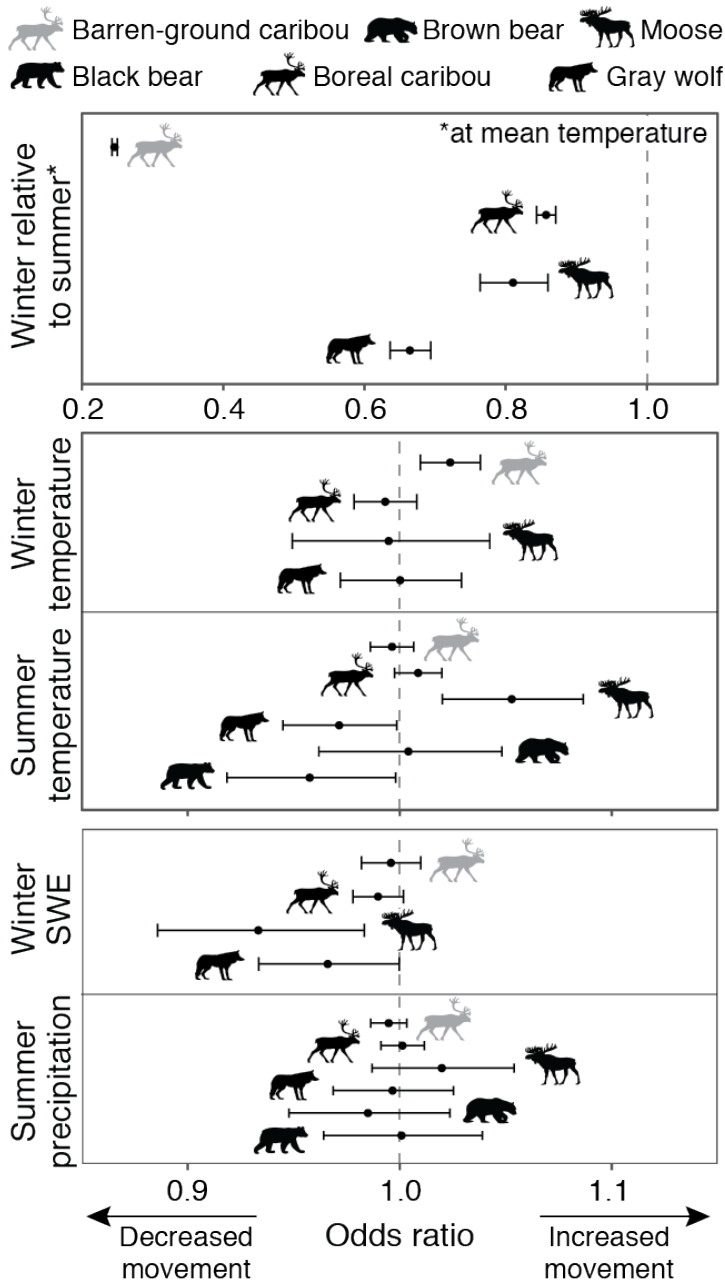
**Fig. 3. Climate-change adaptation of parturition times (PT) of caribou.** Top (map): PT by population. Bottom left: PT trends by population, including five BG subpopulations. Bottom right: PT dates by elevation.

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5 Animals conserve energy by modifying their behavior in response to weather conditions,  
with important implications for individual fitness and species resilience under climate change  
(20). We tested for effects of temperature and precipitation on seasonal movement rates (m/min)  
using records from 1,720 individuals of two herbivore and three predator species (black bear,  
grizzly bear, caribou, moose, and wolf) during 1998–2019 (S.M., Table S.7). We predicted that  
winter movement rates would decline relative to summer, when energetic costs of self-  
maintenance would be highest. Rate would also decline within seasons, during weather  
10 conditions that increase the energetic cost of movement (snow that increases energy  
requirements for movement, higher ambient temperatures during the summer that accelerate  
metabolism).

15 All species exhibited lower movement rates during winter relative to summer (Fig. 4). As  
temperatures increased in summer, wolves and black bears slowed their movement rates, while  
moose increased their movement rates. In winter, only barren-ground caribou increased  
movement rates as temperature increased. Snow impeded wolves, boreal caribou, and moose,  
whereas all species were generally insensitive to summer precipitation. These patterns may  
reflect asynchronous responses to climate change within and across trophic levels. Climate-  
driven variation in animal activity is likely to affect species interactions, altering energy  
expenditure, encounter rates, and foraging success with demographic implications for both  
predators and prey.

20 As we demonstrate, the AAMA provides a solution to Arctic data collection and sharing  
challenges. It serves as a critical baseline and resource to identify early signals of local or large-  
scale changes in animal distribution, movement responses, and adaptive traits. Continued shifts  
in phenology in the Arctic pose challenges to migratory species that encounter changing seasonal  
fluctuations along migration routes, and at Arctic summering and southern wintering grounds  
25 (21). Key drivers of population responses, such as migration, parturition, and foraging  
movement, are undergoing rapid changes, suggesting that climate change is affecting animals in  
ways that will shape the future of the Arctic.



**Fig. 4. Changes in species-specific movement rates in response to daily maximum temperature, summer precipitation and winter snow-water equivalent (SWE).** Odds ratios for continuous covariates represent the positive or negative change in movement rates per one unit change in temperature or precipitation, respectively. Ratios were identified as neutral if credible intervals overlapped one.

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### Supplementary Materials:

Methods

Figures S.1-S.2

40 Tables S.1-S.10

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## Supplementary Materials for

### Ecological insights from three decades of animal movement tracking across a changing Arctic

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#### Materials and Methods:

##### Arctic Animal Movement Archive (AAMA)

The AAMA enables the discovery and use of Arctic and Subarctic animal movement data. The AAMA is hosted on Movebank ([movebank.org](http://movebank.org)), a global research platform for animal tracking and bio-logging data. We defined the geographic scope of the AAMA to include marine and terrestrial Arctic areas defined by the Arctic Monitoring and

Assessment Programme (13) (shapefile available from <https://www.amap.no/about/geographical-coverage>) and Subarctic land regions represented as ‘boreal forests/taiga’ as classified by the Nature Conservancy (14) (shapefile available from <http://maps.tnc.org/files/metadata/TerrEcos.xml>). The AAMA boundary and the observation density within it are shown in Fig. 1. We calculated the density of animal occurrences shown in Fig. 1 as location counts within 10-km hexagonal grid cells (spacing 9.68 km, area 95.98 km<sup>2</sup>) in equal area projection in R using the *dggridR* package (22).

The AAMA is a living archive. Many ongoing studies continuously add data, and new participants and studies can join. Data in the AAMA are organized into studies, with each study (i.e. dataset) managed by one or more data owners. Studies participating in the AAMA as of November 2019 are listed in Table S.1. Participating studies include data within the geographic area described above and can include additional data from other regions, thus supporting inclusion of species that spend substantial portions of their annual life cycle in temperate or tropical regions, and future inclusion of species that enter the region due to northward range shifts. The AAMA preserves the data, harmonizes it, and makes it discoverable by publishing the metadata. All data are curated to ensure they are accurately stored and include sufficient descriptive detail. AAMA Participants retain ownership of their data, with the option to allow public download or limit access to approved users. Study-level information including species, tagging method, number of animals and locations, time period covered, project description and available citations, and owner contact information are publicly available, searchable online, and by API. In all cases, data owners can be contacted directly to discuss data access and proposed uses. Location and other sensor data from the majority of participating studies are available for public download from the AAMA (currently 56% of the data), and many represent datasets formally published through the Movebank Data Repository. The AAMA offers assistance for potential users in negotiating data sharing and maintains current contact information for study owners. Reasons for access-controlled sharing include (i) data are still being actively collected and are not yet quality controlled, (ii) public knowledge of animal locations could compromise conservation efforts, and (iii) legal or contractual restrictions prohibit uncontrolled public data access. The AAMA’s support for public and controlled-access sharing provides a solution that preserves and allows collaboration using data that would otherwise remain undiscoverable, and in many cases would eventually be lost (e.g., after the data owner retires). All data in the AAMA were collected using appropriate animal care permissions (Table S.3). Funding sources for data collection are provided in Table S.4. Current information about participating studies, how to download or request data, and how to join the archive and provide new datasets is available at the AAMA landing page (<https://www.movebank.org/cms/movebank-content/arctic-animal-movement-archive>).

The organization of studies in the AAMA on the Movebank platform represents significant efforts to document and organize data using a consistent format, vocabulary, and set of quality-control procedures. This reduces the time needed to prepare data for sharing and integration in combined analyses, and provides a single access point, thus minimizing logistical efforts needed for construction of data ensembles to address large-scale research questions in meaningful meta-analyses. Furthermore, automated data feeds and management tools promote further participation by allowing data owners to efficiently add and maintain studies over time. We solicit additional participation in the AAMA, both by data owners and those conducting new analyses. As the archive and period of record grow, it will allow increasingly rigorous testing of hypotheses about human-driven, climate-induced, or other natural effects on animal movement, distribution and behavior.

### Case Study 1. Long-term data reveal influence of decadal climate patterns on summering behavior in a migratory raptor

We used 569,720 location estimates collected from 146 golden eagles (*Aquila chrysaetos*) in 12 AAMA studies across western North America (Table S.5). Records were imported into R via the *move* package (23). We assigned all individuals to one of three age categories: juvenile (survived up to the onset of its 2<sup>nd</sup> southbound migration), sub-adult (surviving up to the onset of its 4<sup>th</sup> southbound migration), or adult (surviving past the onset of its 4<sup>th</sup> southbound migration) (16, 24). We incorporated into analyses instances where individuals were observed during an age-class transition. Breeding status was not considered in analyses because it was not determined for all individuals. We identified the onset of golden eagle summering behavior via a mechanistic range shift analysis (MRSAs (25)) in R with the *marcher* package (26). The model was fit with the maximum likelihood method, and we used the Ornstein-Uhlenbeck model option to estimate ranging behavior. We modified the MRSAs slightly by forcing the model to fail if a data gap of >30 days occurred. We inspected start dates and locations to remove

spurious model results due to tag deployments that ended during spring migration or began during summer. This process yielded 179 summering onset estimates with modelled start and end dates made by 103 eagles (Table S.5).

We used linear mixed-effects models in R via the *lme4* package (version 1.1-17) (27), fit by restricted maximum likelihood to assess the significance of year (fixed, continuous, scaled), eagle sex and age during migration (both fixed, categorical), latitude (fixed, continuous), and PDO (fixed, continuous) in explaining golden eagle summering onset date. For adults and subadults, we included eagle individuals as a random term to account for repeated measures for some individuals (n = 49), but not for juveniles, due to a lack of repeated measures. We mean-centered year and included an interaction between year and PDO. We averaged the monthly mean PDO (28, 29) of the preceding winter (November to March) to explore the influence of this large-scale climate indicator on golden eagle behavioral phenology. Multi-collinearity between predictor variables did not exceed recommended variance-inflation levels (30). We performed model selection in R using the *dredge* function of the *MuMIn* package (31) and report results from the conditional averaged models. We first ran a model including eagles of all age classes to explore differences in age classes. We then analyzed each age class separately to facilitate interpretation. Because few summering onsets before 2011 were available for adults and sub-adults, we also compared model-averaged results for the full sets of adult and subadult observations (n = 89, n = 72, respectively) to those for the post-2011 adult and subadult observations (n = 83, n = 67, respectively).

### Case Study 2. Large-scale geographic differences in parturition timing of caribou

We used caribou movement data in 13 AAMA studies (Table S.6). Among the caribou in our study, woodland caribou (*Rangifer tarandus caribou*) are considered a separate subspecies from barren-ground caribou (*R. t. groenlandicus*), which are known for their long-distance calving migrations. Woodland caribou are further classified as belonging to different ecotypes, including boreal and mountain, which differ by habitat and behavioral phenotype. Following exploratory analysis, we further partitioned woodland caribou by geographic area into northern and southern mountain and boreal caribou. Barren-ground caribou data were partitioned into their largely coherent reproductive subpopulations (herds).

Parturition dates were estimated by adapting methods described in (32) for each of the two subspecies. For *R. t. caribou*, we analyzed movements between April 28 and June 30 and found times when movement activity decreased suddenly and persistently below 5 threshold speeds (10, 15, 20, 25, and 30 m/h), and conservatively retained those parturitions where three of five thresholds agreed within a day of each other. For barren-ground caribou, which calve significantly later and shortly after completing a long-distance migration, we adapted the individual-based method (32), which fits a non-calving model, in which movement rates remain constant throughout the study period, and a calving model, where there is a sudden drop in movement rate followed by a progressive increase. The models were fit using maximum likelihood, and AIC was used as a criterion to determine which model was selected. Tests for the effects of latitude, longitude, elevation, and year on parturition dates were conducted using a combination of linear models, generalized additive models, and mixed effects models, with individuals as a random effect. The *R. t. groenlandicus* (barren-ground) population is subdivided into five subpopulations (herds), which were also modeled as a random effect. Results are summarized in Table S.10.

### Case Study 3: Temperature and precipitation response in movement rates of terrestrial mammals

We compiled movement paths for 1,720 individuals representing five mammalian species from 22 AAMA studies: black bear, *Ursus americanus*; grizzly bear, *U. arctos*; caribou, *R. tarandus ssp.*; moose, *Alces alces*; and wolf, *Canis lupus* (Table S.7). We calculated step lengths (m) and location sampling interval (min) along each movement time series, excluding locations with sampling intervals longer than 24 hours. We annotated movement data with daily maximum temperatures (°C) and summertime precipitation or winter snow water equivalent (SWE) estimates using the Daymet data product (33). To match the temporal scale of Daymet, we aggregated movements by estimating daily mean step lengths and sampling intervals for each day within an individual's time series. In order to reduce the influence of seasonally dependent behaviors (e.g., migration or parturition), we partitioned data into January-only (peak winter) and July-only (peak summer) datasets. As in case study 2, we treated the two subspecies of caribou (*R. t. groenlandicus* and *R. t. caribou*) as distinct groups within our analysis due to anticipated differences in daily movement rates. We also excluded bears from the winter analyses due to lack of data; however, the very nature of their hibernation represents a reduced overwinter movement rate..

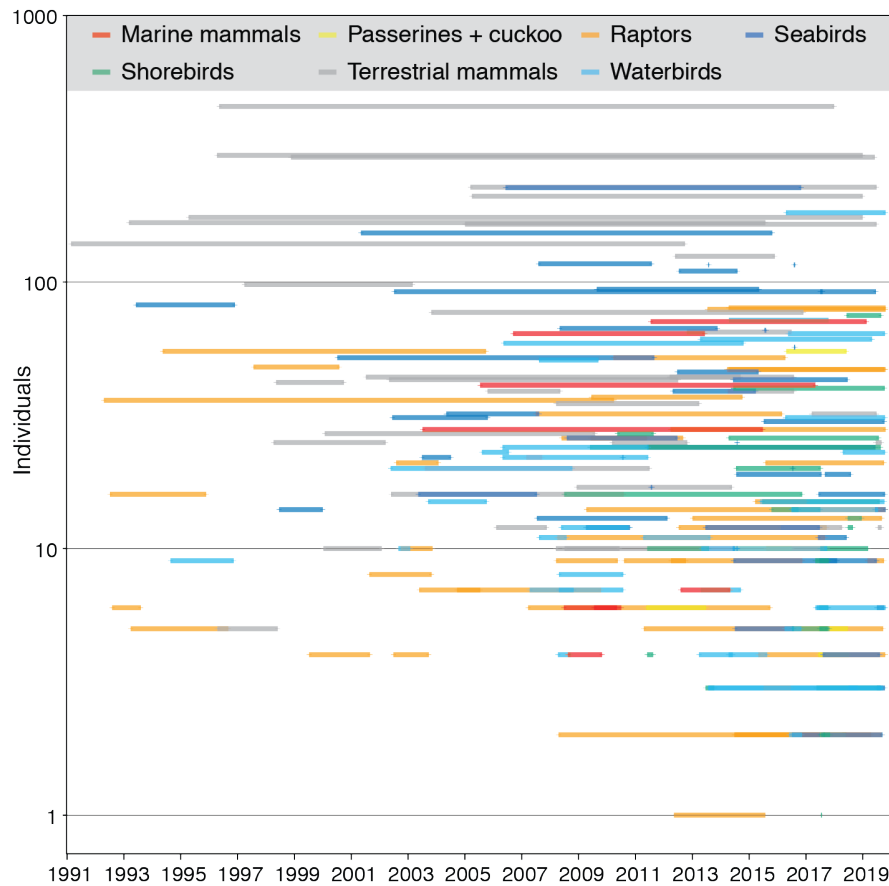
5 We assessed the influence of daily maximum temperature and cumulative precipitation on daily movement  
 rates ( $\text{m}\cdot\text{min}^{-1}$ ) using a generalized linear mixed model (GLMM) framework with the *lme4* R package (27). Because  
 movement rates are positive continuous, we used discretized step lengths (rounded to the nearest meter) as the  
 response and location sampling interval as an offset in a GLMM with negative binomial errors. Prior to modeling,  
 we standardized daily temperature and precipitation estimates by subtracting means and dividing by one standard  
 deviation, each estimated at the study level by season in an effort to account for regional differences in exposure to  
 weather conditions. We evaluated two models for each species represented by an interaction between season  
 (January or July) and a single climate metric: season  $\times$  temperature and season  $\times$  precipitation. However, we used  
 10 SWE ( $\text{kg}\cdot\text{m}^2$ ) as a measure of snow cover during the winter and daily total precipitation (mm) during the summer.  
 We included random intercepts for individual nested within study crossed within year to account for variation in  
 individual movement rates and sample sizes within and across studies. As there was a single study for bears, we  
 included random intercepts for individual and year only. Variable effectiveness was determined by coefficient  
 confidence interval overlap with zero, where an overlap indicating the effect is neutral (i.e., no change).

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**Fig. S1.**

**Summary of the content of studies participating in the AAMA as of November 2019.** Temporal range and number of individuals in each study (Table S.1) colored by species group (Table S.2). Note logarithmic scale on y-axis.

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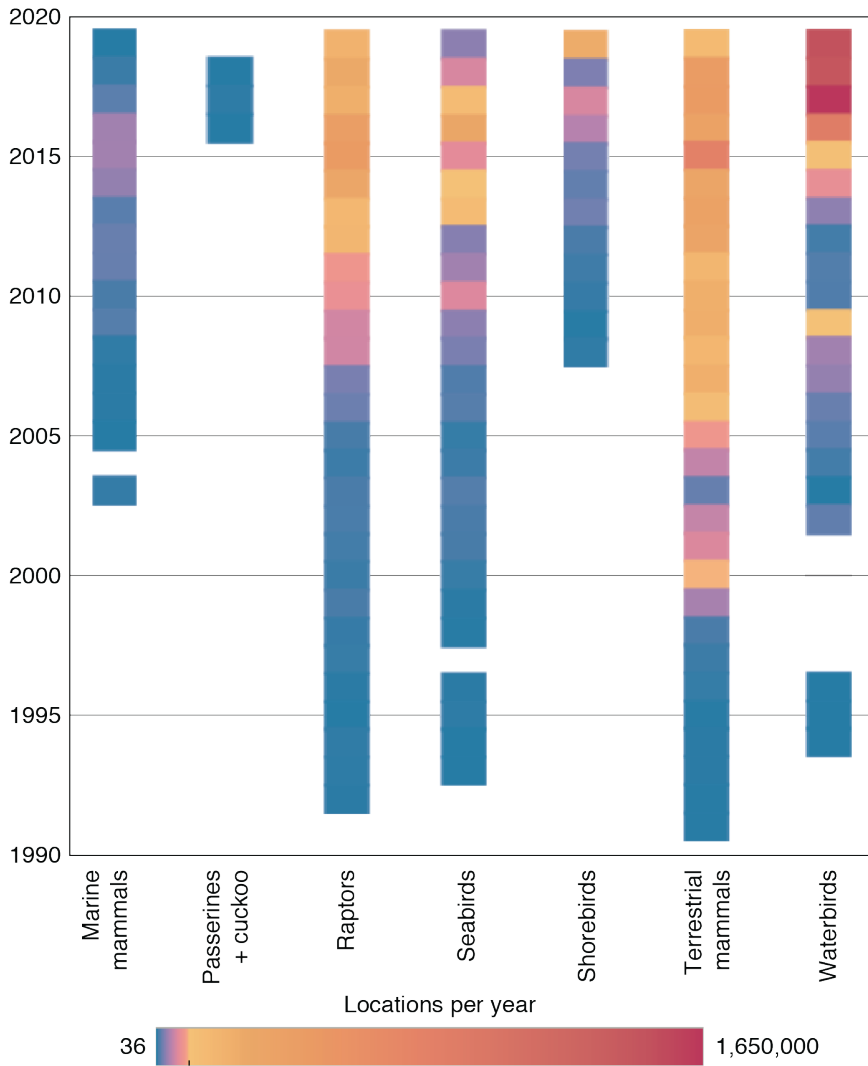


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**Figure S.2.**

**The number of locations per year per species group for data participating the AAMA as of November 2019.**  
The number of locations includes only those with locations within the AAMA boundary. See Table S.2 for species assigned to each species group.

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**Table S1.**

Studies participating in the AAMA as of November 2019. ‘Study name’ and ‘Study ID’ refer to the dataset as stored in a study on Movebank. ‘Species’ and ‘Years’ are based on locations within the AAMA boundary. ‘Animals’ shows the number of individuals with locations within the AAMA boundary, followed in parentheses, by the total number of animal individuals that were tracked in the study, regardless of location. Superscript ‘CSx’ in ‘Study name’ indicates studies used in the case studies where x is the case study number (Tables S.5–S.7). ‘Data ref’ lists the citation for published study datasets. Current information about participating studies, and information about how to join, is available at the AAMA landing page.

| Study name  | Study ID  | Location sensors       | Species                   | Animals   | Years     | Data ref. |
|---|-----------|------------------------|---------------------------|-----------|-----------|-----------|
| ABOVE: ADFG Fortymile River Brown Bears                         | 199248940 | GPS                    | <i>Ursus arctos</i>       | 10 (10)   | 2008–2014 |           |
| ABOVE: ADFG Mulchatna Caribou                                   | 194796273 | GPS                    | <i>Rangifer tarandus</i>  | 39 (39)   | 2014–2016 |           |
| ABOVE: BC Atlin Caribou CS2, CS3                                | 238680850 | GPS                    | <i>Rangifer tarandus</i>  | 10 (10)   | 2000–2002 |           |
| ABOVE: Boelman Alberta American Robins                          | 136953438 | GPS, Argos Doppler     | <i>Turdus migratorius</i> | 55 (55)   | 2016–2018 |           |
| ABOVE: Boutin Alberta Grey Wolf CS3                             | 492444603 | GPS                    | <i>Canis lupus</i>        | 44 (44)   | 2012–2014 |           |
| ABOVE: Boutin Alberta Moose CS3                                 | 302664172 | GPS                    | <i>Alces alces</i>        | 25 (25)   | 2010–2012 |           |
| ABOVE: Hebblewhite Alberta-BC Wolves CS3                        | 209824313 | GPS                    | <i>Canis lupus</i>        | 27 (68)   | 2000–2009 |           |
| ABOVE: NPS Dall Sheep Lake Clark                                | 240650779 | GPS                    | <i>Ovis dalli</i>         | 39 (39)   | 2005–2008 |           |
| ABOVE: NPS Denali Bears   | 197244288 | Radio Transmitter      | <i>Ursus arctos</i>       | 139 (139) | 1991–2012 |           |
| ABOVE: NPS Denali Wolves CS3                                    | 223402683 | GPS                    | <i>Canis lupus</i>        | 77 (77)   | 2003–2016 |           |
| ABOVE: NPS Lake Clark Wolves                                    | 164639210 | GPS                    | <i>Canis lupus</i>        | 17 (17)   | 2008–2014 |           |
| ABOVE: NPS Moose in the Upper Koyukuk Alaska                    | 143848765 | GPS                    | <i>Alces alces</i>        | 35 (35)   | 2008–2013 |           |
| ABOVE: NPS Wolves in Yukon-Charley Rivers National Preserve CS3 | 183074887 | GPS, Radio Transmitter | <i>Canis lupus</i>        | 167 (167) | 1993–2015 |           |
| ABOVE: NWT Dehcho Boreal Woodland Caribou CS2, CS3              | 384182382 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>  | 165 (165) | 2005–2019 |           |
| ABOVE: NWT Inuvik Barren Ground Caribou CS2, CS3                | 579621649 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>  | 456 (456) | 1996–2017 |           |
| ABOVE: NWT Inuvik Boreal Woodland Caribou CS2, CS3              | 532613794 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>  | 43 (43)   | 2002–2012 |           |
| ABOVE: NWT North Slave Barren Ground Caribou: Bathurst CS2, CS3 | 140788890 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>  | 299 (299) | 1996–2018 |           |



|   |           |                        |   |           |           |
|---|-----------|------------------------|---|-----------|-----------|
| ABOVE: NWT North Slave Boreal Caribou <sup>CS2, CS3</sup>                           | 469002388 | GPS                    | <i>Rangifer tarandus</i>                                      | 32 (32)   | 2017–2019 |
| ABOVE: NWT Sahtu Barren Ground Caribou: Bluenose-East <sup>CS2, CS3</sup>           | 148449793 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>                                      | 210 (210) | 2005–2018 |
| ABOVE: NWT Sahtu Boreal Woodland Caribou <sup>CS2, CS3</sup>                        | 151021631 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>                                      | 20 (20)   | 2003–2011 |
| ABOVE: NWT Sahtu Mountain Woodland Caribou <sup>CS2, CS3</sup>                      | 151041376 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>                                      | 16 (16)   | 2002–2010 |
| ABOVE: NWT South Slave Barren Ground Caribou: Beverly and Ahiak <sup>CS2, CS3</sup> | 242950074 | GPS, Radio Transmitter | <i>Rangifer tarandus</i>                                      | 175 (175) | 1995–2018 |
| ABOVE: NWT South Slave Barren Ground Caribou: Queen Maud Gulf                       | 149369862 | Argos Doppler          | <i>Rangifer tarandus</i>                                      | 5 (5)     | 1996–1998 |
| ABOVE: NWT South Slave Boreal Woodland Caribou <sup>CS2, CS3</sup>                  | 149370498 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>                                      | 227 (227) | 2005–2019 |
| ABOVE: Peters Hebblewhite Alberta-BC Moose <sup>CS3</sup>                           | 178994931 | GPS                    | <i>Alces alces</i>  | 10 (19)   | 2008–2010 |
| ABOVE: USFWS R6 Golden Eagles <sup>CS1</sup>  | 240931758 | GPS                    | <i>Aquila chrysaetos</i>                                      | 2 (2)     | 2014–2019 |
| ABOVE: USGS/WVU Raptors <sup>CS1</sup>  | 182803629 | GPS                    | <i>Aquila chrysaetos</i> ,<br><i>Haliaeetus leucocephalus</i> | 9 (9)     | 2012–2016 |
| ABOVE: Yukon Caribou <sup>CS2, CS3</sup>  | 168279948 | GPS, Argos Doppler     | <i>Rangifer tarandus</i>                                      | 294 (294) | 1998–2019 |
| ADACLIM   | 365245962 | Solar Geolocator       | <i>Alle alle</i>  | 94 (94)   | 2009–2015 |
| ADF&G Nelchina Caribou  | 171485485 | GPS                    | <i>Rangifer tarandus</i>                                      | 125 (125) | 2012–2015 |
| ADF&G Susitna Valley Moose  | 205534405 | GPS                    | <i>Alces alces</i>  | 65 (65)   | 2012–2016 |
| Adult Golden Eagle Satellite Tracking <sup>CS1</sup>                                | 5009273   | GPS, Argos Doppler     | <i>Aquila chrysaetos</i>                                      | 14 (25)   | 2009–2019 |
| Alaska Golden Eagles <sup>CS1</sup>   | 17680093  | GPS, Argos Doppler     | <i>Aquila chrysaetos</i>                                      | 47 (47)   | 2014–2019 |
| <i>Aquila chrysaetos</i> interior west N. America, Craigs, Fuller <sup>CS1</sup>    | 38866222  | Argos Doppler          | <i>Aquila chrysaetos</i>                                      | 5 (21)    | 1993–1996 |
| <i>Aquila chrysaetos</i> Mark Fuller North America                                  | 1111541   | Argos Doppler          | <i>Aquila chrysaetos</i>                                      | 6 (6)     | 1992–1993 |
| Arctic breeding shorebirds; Rausch; various Canadian arctic locations               | 22390461  | Argos Doppler          | <i>Pluvialis squatarola</i> ,<br><i>Numenius phaeopus</i>     | 40 (40)   | 2014–2019 |
| Arctic fox Bylot - Argos tracking   | 942774711 | Argos Doppler          | <i>Vulpes lagopus</i>   | 12 (12)   | 2019–2019 |
| Arctic hare Alert - Argos tracking  | 887332716 | Argos Doppler          | <i>Lepus arcticus</i>   | 25 (25)   | 2019–2019 |
| Arctic Raptors - <a href="http://www.ArcticRaptors.ca">www.ArcticRaptors.ca</a>     | 1924571   | GPS                    | <i>Falco peregrinus</i>                                       | 26 (26)   | 2008–2012 |

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|---|-----------|----------------------|--|-----------|-----------|
| Arctic shorebird migration tracking study - American Golden-Plover                      | 565443493 | GPS                  | <i>Pluvialis dominica</i>                                      | 13 (13)   | 2018–2018 |
| Arctic shorebird migration tracking study - Dunlin                                      | 565467203 | GPS                  | <i>Calidris alpina</i>   | 6 (6)     | 2017–2017 |
| Arctic shorebird migration tracking study - Pectoral Sandpiper                          | 560144617 | GPS                  | <i>Calidris melanotos</i>                                      | 12 (12)   | 2018–2018 |
| Arctic shorebird migration tracking study - Semipalmated Sandpiper                      | 606508137 | GPS                  | <i>Calidris pusilla</i>  | 1 (1)     | 2017–2017 |
| Arctic Skua, Faroe Islands, GPS   | 922875688 | GPS                  | <i>Stercorarius parasiticus</i>                                | 11 (11)   | 2017–2018 |
| Arctic Skua, van Bemmelen, Norway   | 968984187 | Solar Geolocator Raw | <i>Stercorarius parasiticus</i>                                | 43 (43)   | 2014–2018 |
| Arctic Skua, van Bemmelen, Tobseda  | 976692287 | Solar Geolocator Raw | <i>Stercorarius parasiticus</i>                                | 5 (5)     | 2014–2016 |
| Arctic Tern Alaska  | 727170503 | Solar Geolocator Raw | <i>Sterna paradisaea</i>                                       | 9 (9)     | 2017–2019 |
| Atlantic puffin in Iceland (Petersen)   | 943122207 | Solar Geolocator     | <i>Fratercula arctica</i>                                      | 13 (13)   | 2007–2012 |
| Atlantic Seabird Study (Red-Throated Loons)   | 37025629  | Argos Doppler        | <i>Gavia stellata</i>  | 39 (62)   | 2012–2015 |
| Atlantic Seabird Study (Surf Scoters)   | 1508766   | Argos Doppler        | <i>Melanitta perspicillata</i>                                 | 153 (192) | 2001–2015 |
| Azores Great Whales Satellite Telemetry Program   | 72289508  | Argos Doppler        | <i>Balaenoptera physalus</i> ,<br><i>Balaenoptera borealis</i> | 6 (36)    | 2008–2010 |
| Bald Eagle <i>Haliaeetus leucocephalus</i> Mojica/Watts                                 | 7917413   | GPS, Argos Doppler   | <i>Haliaeetus leucocephalus</i>                                | 11 (72)   | 2008–2017 |
| Bald Eagles in coastal Alaska; Lewis  | 105181396 | GPS                  | <i>Haliaeetus leucocephalus</i>                                | 5 (13)    | 2011–2019 |
| Barnacle goose (Greenland) Larry Griffin/David Cabot                                    | 6946314   | GPS                  | <i>Branta leucopsis</i>  | 8 (9)     | 2008–2010 |
| Barnacle goose (Svalbard) Larry Griffin   | 6956518   | GPS, Argos Doppler   | <i>Branta leucopsis</i>  | 24 (31)   | 2006–2011 |
| Bean Goose <i>Anser fabalis</i> Finnmark.   | 11223924  | GPS                  | <i>Anser fabalis</i>   | 3 (3)     | 2013–2019 |
| Beringia Dunlin   | 939826359 | Solar Geolocator Raw | <i>Calidris alpina</i>   | 27 (27)   | 2010–2011 |
| Beringia South Migrant Golden Eagle <sup>CS1</sup>                                      | 212420825 | GPS                  | <i>Aquila chrysaetos</i>                                       | 1 (1)     | 2012–2015 |
| Black-bellied Plover Alaska   | 77248725  | Argos Doppler        | <i>Pluvialis squatarola</i>                                    | 15 (15)   | 2015–2019 |
| Black-legged Kittiwakes; Mallory/Gaston/Akearok, Prince Leopold Island, Nunavut, Canada | 40008075  | GPS                  | <i>Rissa tridactyla</i>  | 10 (10)   | 2014–2014 |

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|---|-----------|--|---|---------|-----------|------|
| Bowhead whale Admiralty Inlet   | 920007556 | Argos Doppler                          | <i>Balaena mysticetus</i>                                     | 4 (4)   | 2008–2009 |      |
| Bowhead whale Cumberland Sound  | 467034665 | Argos Doppler                          | <i>Balaena mysticetus</i>                                     | 41 (41) | 2005–2017 |      |
| Bowhead whale Foxe Basin  | 467031755 | Argos Doppler                          | <i>Balaena mysticetus</i>                                     | 28 (28) | 2003–2015 |      |
| Brant Geese Sean Boyd 2002  | 1495582   | Argos Doppler                          | <i>Branta bernicla</i>  | 10 (10) | 2002–2003 |      |
| Brant Geese Sean Boyd 2005  | 1518377   | Argos Doppler                          | <i>Branta bernicla</i>  | 23 (23) | 2005–2006 |      |
| Broad-winged Hawk Alberta Boreal  | 77253173  | Argos Doppler                          | <i>Buteo platypterus</i>                                      | 3 (3)   | 2015–2016 |      |
| Brown and Black bear ( <i>Ursus</i> spp.), Jerry Belant, Alaska CS3                                       | 1574786   | GPS                                    | <i>Ursus americanus</i> ,<br><i>Ursus arctos</i>              | 42 (42) | 1998–2000 |      |
| Canadian Ringed Plover geolocation tracking, Bylot Island, Canada (data from Léandrii-Breton et al. 2019) | 849807214 | Solar Geolocator, Solar Geolocator Raw | <i>Charadrius hiaticula</i>                                   | 20 (20) | 2014–2017 | (34) |
| Common cuckoo, Kamchatka  | 290504591 | Argos Doppler                          | <i>Cuculus canorus</i>  | 4 (4)   | 2017–2018 |      |
| Common cuckoo, Khakassia  | 532621861 | GPS, Argos Doppler                     | <i>Cuculus canorus</i>  | 1 (4)   | 2018–2018 |      |
| Common Eiders; Love/Gilchrist; East Bay Island, Canada  | 40163576  | GPS                                    | <i>Somateria mollissima</i>                                   | 10 (10) | 2014–2014 |      |
| Common Nighthawk  | 399353330 | GPS                                    | <i>Chordeiles minor</i>                                       | 10 (48) | 2015–2017 |      |
| Common/King Eiders; East Bay Island, Nunavut; Gilchrist 2012 and 2013                                     | 8560764   | Argos Doppler                          | <i>Somateria spectabilis</i> ,<br><i>Somateria mollissima</i> | 46 (46) | 2012–2015 |      |
| Common/King Eiders; East Bay Island, Nunavut; Gilchrist/Mosbech 2001 and 2003                             | 43747715  | Argos Doppler                          | <i>Somateria spectabilis</i> ,<br><i>Somateria mollissima</i> | 22 (22) | 2003–2004 |      |
| Common/King Eiders; Nuuk/Disko Bay/Upervik, Greenland; Gilchrist/Mosbech; 2002 and 2003                   | 8317873   | Argos Doppler                          | <i>Somateria spectabilis</i> ,<br><i>Somateria mollissima</i> | 31 (31) | 2002–2005 |      |
| Connecticut Warbler Alberta Boreal  | 613824346 | Solar Geolocator, Solar Geolocator Raw | <i>Oporornis agilis</i>                                       | 5 (5)   | 2017–2018 |      |
| Distribution of spectacled eiders in Russia and Alaska 1993-1996 (data from Petersen et al. 1999)         | 177841261 | Argos Doppler                          | <i>Somateria fischeri</i>                                     | 82 (82) | 1993–1996 | (35) |
| Disturbance of BG by IFV and IWR  | 137654491 | GPS                                    | <i>Branta leucopsis</i>                                       | 64 (85) | 2016–2019 |      |
| Disturbance of GWFG by IFV and IWR  | 127892189 | GPS                                    | <i>Anser albifrons</i>  | 31 (37) | 2016–2019 |      |
| Disturbance of GWFG by IFV and IWR 2017-2018  | 408961322 | GPS                                    | <i>Anser albifrons</i>  | 23 (26) | 2018–2019 |      |

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|---|-----------|--------------------|---|-----------|-----------|------|
| Dolphin_Union_Caribou_UA V  | 416289710 | GPS                | <i>Rangifer tarandus</i>                                      | 776 (776) | 2015–2015 |      |
| Eagles Wintering in Bitterroot Valley <sup>CS1</sup>  | 17707607  | GPS                | <i>Aquila chrysaetos</i> ,<br><i>Haliaeetus leucocephalus</i> | 28 (43)   | 2012–2019 |      |
| Earthspan Peregrines  | 619061097 | Argos Doppler      | <i>Falco peregrinus</i>                                       | 55 (69)   | 1994–2005 |      |
| Eastern Montana Golden Eagles <sup>CS1</sup>  | 6853103   | GPS, Argos Doppler | <i>Aquila chrysaetos</i>                                      | 12 (40)   | 2012–2017 |      |
| Eastern North America Golden Eagles   | 166509889 | GPS                | <i>Aquila chrysaetos</i>                                      | 52 (76)   | 2010–2016 |      |
| Eastern Washington Lesser Canada Goose - Delineating the breeding grounds of small Canada geese wintering in the Columbia Basin | 18105431  | Argos Doppler      | <i>Branta canadensis</i>                                      | 4 (5)     | 2014–2015 |      |
| Fall Migrant Raptors - U.S. Atlantic Flyway - Biodiversity Research Institute   | 45525232  | GPS, Argos Doppler | <i>Falco columbarius</i> ,<br><i>Falco peregrinus</i>         | 13 (57)   | 2013–2019 |      |
| Foraging behaviour and fuel accumulation of pink-footed geese (data from Chudzińska et al. 2016)                                | 49535504  | GPS, Argos Doppler | <i>Anser brachyrhynchus</i>                                   | 11 (11)   | 2011–2013 | (36) |
| FTZ Curlew  | 74810223  | GPS                | <i>Numenius arquata</i>                                       | 26 (37)   | 2014–2019 |      |
| FTZ Geese Wadden Sea  | 69724677  | GPS                | <i>Branta leucopsis</i> ,<br><i>Branta bernicla</i>           | 15 (19)   | 2015–2019 |      |
| Glaucous Gull Barrow Alaska   | 116817431 | GPS, Argos Doppler | <i>Larus hyperboreus</i>                                      | 14 (14)   | 2015–2017 |      |
| Glaucous Gull BPN KoEco Chaun 2017  | 958179188 | GPS                | <i>Larus hyperboreus</i>                                      | 2 (2)     | 2017–2017 |      |
| Golden Eagle ( <i>Aquila chrysaetos</i> ) Eastern N. America Mojica/Watts   | 7917980   | GPS, Argos Doppler | <i>Aquila chrysaetos</i>                                      | 2 (3)     | 2008–2018 |      |
| Golden Eagle Migration, Denali, Alaska, McIntyre <sup>CS1</sup>   | 1916886   | Argos Doppler      | <i>Aquila chrysaetos</i>                                      | 48 (48)   | 1997–2000 |      |
| Golden Eagle Satellite Telemetry Data   | 166529112 | GPS                | <i>Aquila chrysaetos</i>                                      | 6 (13)    | 2007–2015 |      |
| Golden Eagles of Interior Alaska; Lewis <sup>CS1</sup>  | 19389828  | GPS                | <i>Aquila chrysaetos</i>                                      | 47 (47)   | 2014–2019 |      |
| Greenland White-fronted Goose tracking  | 947818172 | GPS                | <i>Anser albifrons</i>  | 61 (89)   | 2013–2019 |      |
| Gyr Falcon, High Arctic Institute, central-west Greenland   | 917901503 | Argos Doppler      | <i>Falco rusticolus</i>                                       | 4 (4)     | 2002–2003 | (37) |
| Gyr Falcon, High Arctic Institute, east Greenland trapping station  | 915166703 | Argos Doppler      | <i>Falco rusticolus</i>                                       | 7 (7)     | 2004–2005 | (38) |
| Gyr Falcon, High Arctic Institute, Maniitsoq trapping station   | 917906795 | Argos Doppler      | <i>Falco rusticolus</i>                                       | 10 (10)   | 2002–2003 | (39) |
| Gyr Falcon, High Arctic Institute, northwest Greenland  | 915037836 | Argos Doppler      | <i>Falco rusticolus</i>                                       | 21 (21)   | 2002–2004 | (40) |

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| Gyrfalcons Alaska McIntyre   | 4846927   | Argos<br>Doppler                                  | <i>Falco rusticolus</i>  | 16 (16)  | 1992–1995 |      |
| HawkWatch International<br>Golden Eagles <sup>CS1</sup>                    | 171287018 | GPS,<br>Argos<br>Doppler                          | <i>Aquila chrysaetos</i>   | 7 (33)   | 2003–2009 | (41) |
| Herring Gull QIA KoEco<br>Korea 2017                                       | 395440520 | GPS   | <i>Larus vegae</i>   | 9 (16)   | 2017–2017 |      |
| Herring Gulls (Larus<br>Argentatus); Gilchrist; East<br>Bay Island, Canada | 11815535  | Argos<br>Doppler                                  | <i>Larus argentatus</i>  | 16 (16)  | 2008–2016 | (42) |
| Hudsonian Godwit (Limosa<br>haemastica) Canada<br>Smith/Watts              | 11327614  | Argos<br>Doppler                                  | <i>Limosa haemastica</i>   | 3 (3)    | 2013–2013 |      |
| iceSeals_NSB_Alaska_vonD<br>uyke   | 732321226 | Argos<br>Doppler                                  | <i>Pusa hispida</i> ,<br><i>Erignathus barbatus</i> ,<br><i>Phoca largha</i> | 71 (71)  | 2011–2019 |      |
| Kidd et al. Rough-legged<br>Hawk Movements in North<br>America             | 109335608 | GPS,<br>Argos<br>Doppler,<br>Radio<br>Transmitter | <i>Buteo lagopus</i>   | 80 (104) | 2014–2019 |      |
| Kittiwake, Brides & Petersen,<br>Iceland                                   | 916687231 | GPS   | <i>Rissa tridactyla</i>  | 19 (19)  | 2014–2017 |      |
| Latham Alberta Wolves <sup>CS3</sup>                                       | 178979729 | GPS   | <i>Canis lupus</i>   | 12 (12)  | 2006–2007 | (43) |
| Lesser White-fronted Goose<br><i>Anser erythropus</i> Finnmark             | 11185254  | GPS   | <i>Anser erythropus</i>  | 3 (3)    | 2013–2019 |      |
| Lesser Yellowlegs (Tringa<br>flavipes) Migratory<br>Connectivity           | 543061768 | GPS,<br>Argos<br>Doppler                          | <i>Tringa flavipes</i>   | 75 (80)  | 2018–2019 |      |
| LifeTrack Peregrine falcon   | 103426553 | GPS   | <i>Falco peregrinus</i>  | 21 (29)  | 2015–2019 |      |
| LifeTrack Rough-legged<br>buzzards   | 9493874   | GPS,<br>Argos<br>Doppler                          | <i>Buteo lagopus</i>   | 79 (80)  | 2013–2019 |      |
| LifeTrack Whooper Swan<br>Latvia   | 92261778  | GPS   | <i>Cygnus cygnus</i>   | 5 (9)    | 2016–2016 |      |
| Light-bellied brent goose<br>(Canadian High Arctic)<br>Kendrew Colhoun     | 2235650   | GPS,<br>Argos<br>Doppler                          | <i>Branta bernicla</i>   | 20 (20)  | 2002–2008 |      |
| Long-tailed ducks ARGOS<br>2019  | 872134463 | Argos<br>Doppler                                  | <i>Clangula hyemalis</i>   | 14 (14)  | 2019–2019 |      |
| Long-tailed ducks GLS 2018   | 714362126 | Solar<br>Geolocator                               | <i>Clangula hyemalis</i>   | 19 (19)  | 2017–2018 |      |
| Long-tailed Jaeger Alaska  | 300812056 | Argos<br>Doppler                                  | <i>Stercorarius<br/>longicaudus</i>  | 16 (17)  | 2017–2019 |      |
| Long-tailed Skua, van<br>Bemmelen, Sweden                                  | 968980842 | Solar<br>Geolocator<br>Raw                        | <i>Stercorarius<br/>longicaudus</i>  | 24 (24)  | 2011–2019 |      |
| Lower 48 GOEA Migration  | 577947076 | GPS,<br>Argos<br>Doppler                          | <i>Aquila chrysaetos</i>   | 9 (14)   | 2019–2019 |      |
| LTDU   | 137245750 | Argos<br>Doppler                                  | <i>Clangula hyemalis</i>   | 67 (118) | 2008–2013 |      |
| Migration of Sabine's gulls<br>from the Canadian High<br>Arctic            | 208672795 | Solar<br>Geolocator                               | <i>Xema sabini</i>   | 26 (26)  | 2008–2012 | (44) |

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|--|-----------|------------------------|---|-----------|-----------|------|
| Migration Patterns of Pacific Sea Ducks  | 6506971   | Argos Doppler          | <i>Histrionicus histrionicus</i> ,<br><i>Melanitta perspicillata</i> ,<br><i>Bucephala islandica</i>              | 226 (375) | 2006–2016 |      |
| Migration timing in barnacle geese (Barents Sea) (data from Kölzsch et al. and Shariatinajafabadi et al. 2014)       | 29799425  |                        | <i>Branta leucopsis</i>   | 12 (15)   | 2008–2010 | (45) |
| Migration timing in barnacle geese (Greenland) (data from Kölzsch et al. and Shariatinajafabadi et al. 2014)         | 31987083  | GPS                    | <i>Branta leucopsis</i>   | 7 (7)     | 2008–2010 | (46) |
| Migration timing in barnacle geese (Svalbard) (data from Kölzsch et al. and Shariatinajafabadi et al. 2014)          | 31888520  | GPS                    | <i>Branta leucopsis</i>   | 22 (22)   | 2006–2011 | (47) |
| Migration timing in white-fronted geese (data from Kölzsch et al. 2016)  | 133992043 | GPS, Argos Doppler     | <i>Anser albifrons</i>  | 59 (65)   | 2006–2014 | (48) |
| Mountain caribou in British Columbia <sup>CS2, CS3</sup>   | 216040785 | GPS, Radio Transmitter | <i>Rangifer tarandus</i>  | 44 (260)  | 2001–2016 | (49) |
| Movement of long-tailed ducks marked on the Yukon-Kuskokwim Delta, Alaska 1998-2000 (data from Petersen et al. 2003) | 140391801 | Argos Doppler          | <i>Clangula hyemalis</i>  | 14 (14)   | 1998–2000 | (50) |
| North Sea population tracks of greater white-fronted geese 2014-2017 (data from Kölzsch et al. 2019)                 | 657674643 | GPS                    | <i>Anser albifrons</i>  | 72 (81)   | 2014–2017 | (51) |
| North Slope Cackling Geese   | 588214579 | GPS                    | <i>Branta hutchinsii</i>  | 3 (3)     | 2018–2018 |      |
| NPS Dall Sheep Gates of the Arctic   | 942509734 | Radio Transmitter      | <i>Ovis dalli</i>   | 25 (25)   | 1998–2002 |      |
| NPS Dall Sheep in Yukon-Charley Rivers National Preserve   | 673728219 | GPS, Radio Transmitter | <i>Ovis dalli</i>   | 98 (98)   | 1997–2003 |      |
| NPS Denali Dall Sheep  | 666644968 | GPS, Radio Transmitter | <i>Ovis dalli</i>   | 22 (22)   | 2007–2007 |      |
| NWT South Slave Boreal Wolves <sup>CS3</sup>   | 625331087 | GPS                    | <i>Canis lupus</i>  | 12 (12)   | 2016–2018 |      |
| NYSDEC Raptor Tracking   | 2943485   | GPS, Argos Doppler     | <i>Aquila chrysaetos</i> ,<br><i>Asio flammeus</i> ,<br><i>Haliaeetus leucocephalus</i> , <i>Falco peregrinus</i> | 36 (78)   | 1992–2010 | (52) |
| Oystercatcher 2016 Alves Iceland   | 163339641 | GPS                    | <i>Haematopus ostralegus</i>  | 14 (14)   | 2016–2016 |      |
| Oystercatcher 2017 Alves Iceland   | 292990053 | GPS                    | <i>Haematopus ostralegus</i>  | 10 (10)   | 2017–2019 |      |
| Pacific Loons Alaska Colville River Delta  | 77252092  | Argos Doppler          | <i>Gavia pacifica</i>   | 30 (30)   | 2015–2019 | (53) |

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|---|-----------|----------------------|---|---------|-----------|------|
| Pannonic population tracks of greater white-fronted geese 2013-2017 (data from Kölzsch et al. 2019) | 657965212 | GPS                  | <i>Anser albifrons</i>  | 10 (10) | 2013–2017 | (54) |
| Parasitic Jaeger/Arctic Skua North America  | 630339095 | Argos Doppler        | <i>Stercorarius parasiticus</i>   | 6 (8)   | 2019–2019 |      |
| Peregrine Falcon, High Arctic Institute, northwest Greenland  | 7249090   | Argos Doppler        | <i>Falco peregrinus</i>   | 8 (8)   | 2001–2003 |      |
| Pomarine Jaeger North America   | 973570814 | Argos Doppler        | <i>Stercorarius pomarinus</i>   | 3 (3)   | 2019–2019 |      |
| Pre-breeding prospecting behaviour of snowy owls (data from Therrien et al. 2015)                   | 54108884  | Argos Doppler        | <i>Bubo scandiacus</i>  | 9 (9)   | 2008–2010 | (55) |
| Red-necked Phalarope southern Chukotka (data from Mu et al. 2018)                                   | 411155573 | Solar Geolocator Raw | <i>Phalaropus lobatus</i>   | 2 (2)   | 2016–2017 | (56) |
| Red-necked Phalarope, van Bemmelen, Norway  | 968983708 | Solar Geolocator Raw | <i>Phalaropus lobatus</i>   | 9 (9)   | 2014–2018 |      |
| Red-necked Phalarope, van Bemmelen, Sweden  | 99570338  | Solar Geolocator Raw | <i>Phalaropus lobatus</i>   | 12 (12) | 2013–2017 |      |
| redThroatedLoon_USGS_AS C_argos   | 506722909 | Argos Doppler        | <i>Gavia stellata</i>   | 52 (52) | 2000–2011 | (57) |
| Ringed seals Igloolik   | 920008781 | Argos Doppler        | <i>Pusa hispida</i>   | 6 (6)   | 2009–2010 |      |
| Ringed Seals Resolute   | 467038889 | Argos Doppler        | <i>Pusa hispida</i>   | 7 (7)   | 2012–2014 |      |
| Ringed seals Sanikiluaq   | 467037497 | Argos Doppler        | <i>Pusa hispida</i>   | 64 (66) | 2006–2013 |      |
| Rough-legged Buzzard in variable environment  | 944655375 | Argos Doppler        | <i>Buteo lagopus</i>  | 2 (2)   | 2014–2017 |      |
| Rusty Blackbird Alberta   | 613825248 | GPS                  | <i>Euphagus carolinus</i>   | 2 (2)   | 2017–2018 |      |
| Sabine's Gulls in the Juan de Fuca Eddy   | 304527187 | Argos Doppler        | <i>Xema sabini</i>  | 2 (2)   | 2017–2019 |      |
| Seaducks in the Fehmarn Belt (southern Baltic)  | 1962595   | Argos Doppler        | <i>Clangula hyemalis</i> ,<br><i>Aythya fuligula</i> ,<br><i>Somateria mollissima</i> ,<br><i>Melanitta nigra</i> | 12 (27) | 2009–2010 |      |
| Short-eared Owl, North America  | 7423317   | Argos Doppler        | <i>Asio flammeus</i>  | 26 (26) | 2009–2011 |      |
| Skagit County Washington Western High Arctic Brant  | 150569357 | Argos Doppler        | <i>Branta bernicla</i>  | 2 (3)   | 2016–2016 |      |
| Skagit Valley / Wrangel Island Snow Goose   | 14050108  | Argos Doppler        | <i>Chen caerulescens</i>  | 7 (7)   | 2013–2014 |      |
| Skagit Valley / Wrangel Island Snow Goose 2016-17 GSM   | 156118432 | GPS                  | <i>Chen caerulescens</i>  | 14 (14) | 2016–2019 |      |
| Snow Bunting Migration Phenology  | 959128259 | Solar Geolocator Raw | <i>Plectrophenax nivalis</i>  | 6 (6)   | 2011–2013 |      |

|  |           |                      |  |           |                |
|--|-----------|----------------------|--|-----------|----------------|
| Snow bunting, Svalbard   | 540289187 | Solar Geolocator Raw | <i>Plectrophenax nivalis</i>                         | 10 (10)   | 2014–2016      |
| Snowy owl - North America  | 12112706  | Argos Doppler        | <i>Bubo scandiacus</i>                               | 32 (32)   | 2007–2016      |
| Snowy owls from Barrow Alaska 1999-2001 (Fuller)   | 944461692 | Argos Doppler        | <i>Bubo scandiacus</i>                               | 4 (4)     | 1999–2001      |
| Solovki Larus Track  | 312267867 | GPS                  | <i>Larus fuscus, Larus argentatus, Larus marinus</i> | 6 (6)     | 2017–2019      |
| Taiga Bean Geese Larry Griffin   | 35342375  | GPS                  | <i>Anser fabalis</i>                                 | 4 (6)     | 2013–2014      |
| TBMUCOMU.GastonMonte vecchi.NWAtlantic   | 14381504  | Solar Geolocator     | <i>Uria lomvia, Uria aalge</i>                       | 117 (122) | 2007–2011      |
| Thayer's Gulls from the Canadian High Arctic   | 176466071 | Argos Doppler        | <i>Larus thayeri</i>                                 | 5 (5)     | 2016–2017      |
| Thick-billed murre Elliott Coats 2010  | 248994009 | GPS                  | <i>Uria lomvia</i>                                   | 22 (22)   | 2010–2010      |
| Thick-billed murre Elliott Coats 2011  | 249266943 | GPS                  | <i>Uria lomvia</i>                                   | 17 (17)   | 2011–2011      |
| Thick-billed murre Elliott Coats 2013  | 376145741 | GPS                  | <i>Uria lomvia</i>                                   | 116 (116) | 2013–2013      |
| Thick-billed murre Gaston PLI 2014   | 394802766 | GPS                  | <i>Uria lomvia</i>                                   | 10 (10)   | 2014–2014      |
| Thick-billed murre Gilchrist and Elliott Coats 2016  | 287187244 | GPS                  | <i>Uria lomvia</i>                                   | 20 (20)   | 2016–2016      |
| Thick-billed murre Gilchrist and Elliott Coats 2017  | 318843635 | GPS                  | <i>Uria lomvia</i>                                   | 92 (92)   | 2017–2017 (58) |
| Thick-billed murre Gilchrist and Elliott Digges 2015   | 358865092 | GPS                  | <i>Uria lomvia</i>                                   | 66 (66)   | 2015–2015      |
| Thick-billed murre Gilchrist and Elliott Digges 2016   | 249737372 | GPS                  | <i>Uria lomvia</i>                                   | 116 (116) | 2016–2016      |
| Thick-billed murre Gilchrist Cape Graham Moore 2016  | 11815535  | GPS                  | <i>Uria lomvia</i>                                   | 57 (57)   | 2016–2016      |
| Thick-billed Murres; Gaston/Akearok, Prince Leopold Island, Nunavut, Canada                                    | 40012605  | GPS                  | <i>Uria lomvia</i>                                   | 10 (10)   | 2014–2014      |
| Thick-billed Murres; Gilchrist; Cape Graham Moore, Canada  | 33622846  | GPS                  | <i>Uria lomvia</i>                                   | 25 (25)   | 2014–2014      |
| Thick-billed Murres; Gilchrist; Digges Island, Canada  | 10006517  | GPS                  | <i>Uria lomvia</i>                                   | 110 (110) | 2012–2014      |
| Tobseda Barnacle Goose   | 2231619   | Argos Doppler        | <i>Branta leucopsis</i>                              | 15 (15)   | 2003–2005      |
| Tracking movements of Peregrine Falcons Falco peregrinus from breeding populations in Arctic Eurasia           | 934079034 | Argos Doppler        | <i>Falco peregrinus</i>                              | 37 (37)   | 2009–2016      |
| Tracking post-fledging dispersal and migration of juvenile Peregrine Falcons Falco peregrinus in Arctic Russia | 922820594 | Argos Doppler        | <i>Falco peregrinus</i>                              | 9 (9)     | 2010–2012      |



|   |           |                    |   |            |                |
|---|-----------|--------------------|---|------------|----------------|
| Upper Midwest Bald Eagle Project                            | 166277154 | GPS                | <i>Haliaeetus leucocephalus</i>   | 15 (37)    | 2015–2017      |
| USGS WERC Dixon Field Station Compiled Avian Telemetry      | 619097045 | GPS                | <i>Anas acuta, Anas americana, Anas clypeata, Anas discors, Anser albifrons, Chen caerulescens, Chen rossii, Circus cyaneus</i> | 184 (1020) | 2016–2019      |
| Vega Gull BPN KoEco Russia Chaun 2017                       | 407469571 | GPS                | <i>Larus vegae</i>  | 5 (5)      | 2017–2017      |
| Wader migration German Wadden Sea: bar-tailed godwits       | 5666500   | Argos Doppler      | <i>Limosa lapponica</i>   | 4 (8)      | 2011–2011      |
| Wader migration German Wadden Sea: grey plovers             | 533575900 | Argos Doppler      | <i>Pluvialis squatarola</i>   | 10 (14)    | 2011–2013 (59) |
| Washington State Surf Scoter                                | 41656517  | Argos Doppler      | <i>Melanitta perspicillata</i>  | 32 (34)    | 2004–2007      |
| Washington State White-winged Scoter                        | 949577211 | Argos Doppler      | <i>Melanitta fusca</i>  | 16 (19)    | 2003–2007      |
| Western GOEA Conservation cs1                               | 20050095  | GPS, Argos Doppler | <i>Aquila chrysaetos</i>  | 4 (80)     | 2015–2019      |
| Whimbrel Numenius phaeopus Acadian Peninsula                | 161439311 | Argos Doppler      | <i>Numenius phaeopus</i>  | 3 (6)      | 2017–2019      |
| Whimbrel Numenius phaeopus North America Smith/Watts/Winn   | 7073245   | Argos Doppler      | <i>Numenius phaeopus</i>  | 24 (36)    | 2009–2019      |
| White fronted Goose QIA KoEco Korea 2017                    | 402496791 | GPS                | <i>Anser albifrons</i>  | 6 (11)     | 2017–2017      |
| White-fronted goose (Greenland) Larry Griffin               | 2235641   | GPS                | <i>Anser albifrons</i>  | 4 (4)      | 2008–2008      |
| White-fronted goose full year tracks 2006-2010 Alterra IWWR | 467107447 | GPS, Argos Doppler | <i>Anser albifrons</i>  | 7 (7)      | 2007–2008 (60) |
| Whooper swan (Icelandic) Larry Griffin II                   | 2279366   | GPS                | <i>Cygnus cygnus</i>  | 51 (57)    | 2007–2009      |
| Whooper swan (Icelandic) Larry Griffin/Colin Pennycuick     | 2235656   | Argos Doppler      | <i>Cygnus cygnus</i>  | 9 (9)      | 1994–1996      |
| Whooper swan (Icelandic) Larry Griffin/Kendrew Colhoun      | 2235659   | GPS, Argos Doppler | <i>Cygnus cygnus</i>  | 11 (11)    | 2007–2008      |
| Whooper swans in Latvia 2016                                | 182459847 | GPS                | <i>Cygnus cygnus</i>  | 6 (11)     | 2017–2019 (61) |
| yellowBilledloon_USGS_AS C_argos                            | 506737915 | Argos Doppler      | <i>Gavia adamsii</i>  | 92 (92)    | 2002–2019 (62) |

**Table S2.**

Species-level and species group summary of data from studies participating in the AAMA as of November 2019.

| Species                      | Species group       | Studies | Location sensors                      |
|------------------------------|---------------------|---------|---------------------------------------|
| <i>Alces alces</i>           | Terrestrial mammals | 4       | GPS                                   |
| <i>Alle alle</i>             | Seabirds            | 1       | Geolocator                            |
| <i>Anas acuta</i>            | Waterbirds          | 1       | GPS                                   |
| <i>Anas Americana</i>        | Waterbirds          | 1       | GPS                                   |
| <i>Anas clypeata</i>         | Waterbirds          | 1       | GPS                                   |
| <i>Anas discors</i>          | Waterbirds          | 1       | GPS                                   |
| <i>Anser albifrons</i>       | Waterbirds          | 10      | GPS, Argos Doppler                    |
| <i>Anser brachyrhynchus</i>  | Waterbirds          | 1       | GPS, Argos Doppler                    |
| <i>Anser erythropus</i>      | Waterbirds          | 1       | GPS                                   |
| <i>Anser fabalis</i>         | Waterbirds          | 2       | GPS                                   |
| <i>Aquila chrysaetos</i>     | Raptors             | 18      | GPS, Argos Doppler                    |
| <i>Asio flammeus</i>         | Raptors             | 2       | Argos Doppler                         |
| <i>Balaena mysticetus</i>    | Marine mammals      | 3       | Argos Doppler                         |
| <i>Balaenoptera borealis</i> | Marine mammals      | 1       | Argos Doppler                         |
| <i>Balaenoptera physalus</i> | Marine mammals      | 1       | Argos Doppler                         |
| <i>Branta bernicla</i>       | Waterbirds          | 5       | GPS, Argos Doppler                    |
| <i>Branta canadensis</i>     | Waterbirds          | 1       | Argos Doppler                         |
| <i>Branta hutchinsii</i>     | Waterbirds          | 1       | GPS                                   |
| <i>Branta leucopsis</i>      | Waterbirds          | 8       | GPS, Argos Doppler                    |
| <i>Bubo scandiacus</i>       | Raptors             | 3       | Argos Doppler                         |
| <i>Bucephala islandica</i>   | Seabirds            | 1       | Argos Doppler                         |
| <i>Buteo lagopus</i>         | Raptors             | 3       | GPS, Argos Doppler, Radio transmitter |
| <i>Buteo platypterus</i>     | Raptors             | 1       | Argos Doppler                         |
| <i>Calidris alpina</i>       | Shorebirds          | 2       | GPS, Geolocator                       |
| <i>Calidris melanotos</i>    | Shorebirds          | 1       | GPS                                   |
| <i>Calidris pusilla</i>      | Shorebirds          | 1       | GPS                                   |
| <i>Canis lupus</i>           | Terrestrial mammals | 7       | GPS, Radio transmitter                |
| <i>Charadrius hiaticula</i>  | Shorebirds          | 1       | Geolocator                            |
| <i>Chen caerulescens</i>     | Waterbirds          | 3       | GPS, Argos Doppler                    |
| <i>Chen rossii</i>           | Waterbirds          | 1       | GPS                                   |
| <i>Chordeiles minor</i>      | Raptors             | 1       | GPS                                   |
| <i>Circus cyaneus</i>        | Raptors             | 2       | GPS                                   |
| <i>Clangula hyemalis</i>     | Seabirds            | 5       | Argos Doppler, Geolocator             |
| <i>Cuculus canorus</i>       | Passerines+cuckoo   | 2       | GPS, Argos Doppler                    |
| <i>Cygnus cygnus</i>         | Waterbirds          | 5       | GPS, Argos Doppler                    |
| <i>Erignathus barbatus</i>   | Marine mammals      | 1       | Argos Doppler                         |
| <i>Euphagus carolinus</i>    | Passerines+cuckoo   | 1       | GPS                                   |
| <i>Falco columbarius</i>     | Raptors             | 1       | Argos Doppler                         |
| <i>Falco peregrinus</i>      | Raptors             | 8       | GPS, Argos Doppler                    |
| <i>Falco rusticolus</i>      | Raptors             | 5       | Argos Doppler                         |
| <i>Fratercula arctica</i>    | Seabirds            | 1       | Geolocator                            |
| <i>Gavia adamsii</i>         | Seabirds            | 1       | Argos Doppler                         |
| <i>Gavia pacifica</i>        | Seabirds            | 1       | Argos Doppler                         |

|                                  |                     |    |                                       |
|----------------------------------|---------------------|----|---------------------------------------|
| <i>Gavia stellata</i>            | Seabirds            | 2  | Argos Doppler                         |
| <i>Haematopus ostralegus</i>     | Shorebirds          | 2  | GPS                                   |
| <i>Haliaeetus leucocephalus</i>  | Raptors             | 6  | GPS, Argos Doppler                    |
| <i>Histrionicus histrionicus</i> | Seabirds            | 1  | Argos Doppler                         |
| <i>Larus argentatus</i>          | Shorebirds          | 2  | GPS, Argos Doppler                    |
| <i>Larus fuscus</i>              | Seabirds            | 1  | GPS                                   |
| <i>Larus hyperboreus</i>         | Shorebirds          | 2  | GPS, Argos Doppler                    |
| <i>Larus marinus</i>             | Seabirds            | 1  | GPS                                   |
| <i>Larus thayeri</i>             | Shorebirds          | 1  | Argos Doppler                         |
| <i>Larus vegae</i>               | Shorebirds          | 2  | GPS                                   |
| <i>Lepus arcticus</i>            | Terrestrial mammals | 1  | Argos Doppler                         |
| <i>Limosa haemastica</i>         | Shorebirds          | 1  | Argos Doppler                         |
| <i>Limosa lapponica</i>          | Shorebirds          | 1  | Argos Doppler                         |
| <i>Melanitta fusca</i>           | Seabirds            | 1  | Argos Doppler                         |
| <i>Melanitta nigra</i>           | Seabirds            | 1  | Argos Doppler                         |
| <i>Melanitta perspicillata</i>   | Seabirds            | 3  | Argos Doppler                         |
| <i>Numenius arquata</i>          | Shorebirds          | 1  | GPS                                   |
| <i>Numenius phaeopus</i>         | Shorebirds          | 3  | Argos Doppler                         |
| <i>Oporornis agilis</i>          | Passerines+cuckoo   | 1  | Geolocator                            |
| <i>Ovis dalli</i>                | Terrestrial mammals | 4  | GPS, Radio transmitter                |
| <i>Phalaropus lobatus</i>        | Seabirds            | 3  | Geolocator                            |
| <i>Phoca largha</i>              | Marine mammals      | 1  | Argos Doppler                         |
| <i>Plectrophenax nivalis</i>     | Passerines+cuckoo   | 2  | Geolocator                            |
| <i>Pluvialis dominica</i>        | Shorebirds          | 1  | GPS                                   |
| <i>Pluvialis squatarola</i>      | Shorebirds          | 3  | Argos Doppler                         |
| <i>Pusa hispida</i>              | Marine mammals      | 4  | Argos Doppler                         |
| <i>Rangifer tarandus</i>         | Terrestrial mammals | 17 | GPS, Argos Doppler, Radio transmitter |
| <i>Rissa tridactyla</i>          | Seabirds            | 2  | GPS                                   |
| <i>Somateria fischeri</i>        | Seabirds            | 1  | Argos Doppler                         |
| <i>Somateria mollissima</i>      | Seabirds            | 5  | GPS, Argos Doppler                    |
| <i>Somateria spectabilis</i>     | Seabirds            | 3  | Argos Doppler                         |
| <i>Stercorarius longicaudus</i>  | Seabirds            | 2  | Argos Doppler, Geolocator             |
| <i>Stercorarius parasiticus</i>  | Seabirds            | 4  | GPS, Argos Doppler, Geolocator        |
| <i>Stercorarius pomarinus</i>    | Seabirds            | 1  | Argos Doppler                         |
| <i>Sterna paradisaea</i>         | Seabirds            | 1  | Geolocator                            |
| <i>Tringa flavipes</i>           | Shorebirds          | 1  | GPS, Argos Doppler                    |
| <i>Turdus migratorius</i>        | Passerines+cuckoo   | 1  | GPS, Argos Doppler                    |
| <i>Uria aalge</i>                | Seabirds            | 1  | Geolocator                            |
| <i>Uria lomvia</i>               | Seabirds            | 13 | GPS, Geolocator                       |
| <i>Ursus americanus</i>          | Terrestrial mammals | 1  | GPS                                   |
| <i>Ursus arctos</i>              | Terrestrial mammals | 3  | GPS, Radio transmitter                |
| <i>Vulpes lagopus</i>            | Terrestrial mammals | 1  | Argos Doppler                         |
| <i>Xema sabini</i>               | Seabirds            | 2  | Argos Doppler, Geolocator             |

**Table S.3.**

Permits, licenses and approved protocols for research, animal handling and tagging related to studies participating in the AAMA as of November 2019. ACC = Animal Care Committee, ACUC = Animal Care and Use Committee, AWC = Animal Welfare Committee, IACUC = Institutional Animal Care and Use Committee, WCC = Wildlife Care Committee.

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| <b>Study name</b>   | <b>Authorizing institutions, permits and protocols</b>   |
|---|--|
| ABOVE: ADFG Fortymile River Brown Bears                     | Alaska Department of Fish and Game Protocol 08-08  |
| ABOVE: ADFG Mulchatna Caribou                               | Alaska Department of Fish and Game Division of Wildlife Conservation 2013-10, 2015-33  |
| ABOVE: BC Atlin Caribou                                     | British Columbia Provincial authority under the BC Wildlife Act  |
| ABOVE: Boelman Alberta American Robins                      | Alberta Environment and Parks 16-025, 17-084, 18-305; IACUC protocols AC-AAAR9409, AC-AAAW4470   |
| ABOVE: Boutin Alberta Grey Wolf                             | University of Alberta Animal Use Protocol 00000040   |
| ABOVE: Boutin Alberta Moose                                 | University of Alberta Animal Use Protocol 00000102   |
| ABOVE: Hebblewhite Alberta-BC Wolves                        | University of Alberta Canadian Care and Animal Use Committee Protocol 353112; University of Montana 056-06-MHCES-010207, 059-08MHCES-120908  |
| ABOVE: NPS Dall Sheep Lake Clark                            | National Park Service LACL-2005-SCI-0012   |
| ABOVE: NPS Denali Bears                                     | US National Park Service research permits and IACUC protocols  |
| ABOVE: NPS Denali Wolves                                    | US National Park Service research permits DENA-2005-SCI-0019, DENA-2011-SCI-0002, DENA-2016-SCI-009; Alaska Department of Fish and Game permits Burch_08-008, Burch_09-012, Burch_11-005, Meier_12-006, Arthur_DenaliNP_15-093, Borg_NPS_16-012; US National Park Service IACUC protocols NPS IACUC 2010-1, AKR_YUCH and DENA_Burch_Wolves_2013, AKR_DENA_Borg_Wolves_2016.A3                    |
| ABOVE: NPS Lake Clark Wolves                                | US National Park Service research permits LACL-2009-SCI-0001, LACL-2009-SCI-0018, LACL-2011-SCI-0018; Alaska Department of Fish and Game scientific permits 08-058, 09-003, 10-001, 11-054, 12-004, 13-009, 14-008, and 15-008; US Fish and Wildlife Service IACUC Protocol 2008023; US National Park Service IACUC protocols AKR_LACL_Mangipane_Wolf_2012.A3, AKR_LACL_Mangipane_Wolves_2015.A3 |
| ABOVE: NPS Moose in the Upper Koyukuk Alaska                | State of Alaska IACUC Protocol 07-11   |
| ABOVE: NPS Wolves in Yukon-Charley Rivers National Preserve | National Park Service Research Permit YUCH_DENA_Burch_Wolves_2013.A3   |
| ABOVE: NWT Dehcho Boreal Woodland Caribou                   | Annual Northwest Territories wildlife research permits WCC protocols, including NWTWCC 2018-019  |
| ABOVE: NWT Inuvik Barren Ground Caribou                     | Government of the Northwest Territories wildlife research permits and WCC protocols  |
| ABOVE: NWT Inuvik Boreal Woodland Caribou                   | Government of the Northwest Territories wildlife research permits and WCC protocols  |
| ABOVE: NWT North Slave Barren Ground Caribou: Bathurst      | Government of the Northwest Territories wildlife research permits and WCC protocols  |
| ABOVE: NWT North Slave Boreal Caribou                       | Annual Northwest Territories wildlife research permits WCC protocols, including NWTWCC 2017-010, NWTWCC  |

2018-001

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|---|---|
| ABOVE: NWT Sahtu Barren Ground Caribou: Bluenose-East                 | Government of the Northwest Territories wildlife research permits and WCC protocols   |
| ABOVE: NWT Sahtu Boreal Woodland Caribou                              | Government of the Northwest Territories wildlife research permits and WCC protocols   |
| ABOVE: NWT Sahtu Mountain Woodland Caribou                            | Government of the Northwest Territories wildlife research permits and WCC protocols   |
| ABOVE: NWT South Slave Barren Ground Caribou: Beverly and Ahiak       | Government of the Northwest Territories Wildlife Research Permit WL5000771; Government of the Northwest Territories WCC Protocol NWTWCC 2019-020; reviewed annually   |
| ABOVE: NWT South Slave Barren Ground Caribou: Queen Maud Gulf         | Government of the Northwest Territories Wildlife Research Permit WL5000771; Government of the Northwest Territories WCC Protocol NWTWCC 2019-020; reviewed annually   |
| ABOVE: NWT South Slave Boreal Woodland Caribou                        | Government of the Northwest Territories Wildlife Research Permit WL5000771; Government of the Northwest Territories WCC Protocol NWTWCC 2019-020; reviewed annually   |
| ABOVE: Peters Hebblewhite Alberta-BC Moose                            | University of Montana Protocol 056-06-MHCES-010207Amendment   |
| ABOVE: USFWS R6 Golden Eagles   | US Federal Master Banding Permit 23720; US Fish and Wildlife Service Permit MB204815-0; State of Colorado Scientific Collection License 20TRb4182a; State of Wyoming permits 863, 2066  |
| ABOVE: USGS/WVU Raptors   | Boise State University IACUC Protocol 692-980-020   |
| ABOVE: Yukon Caribou  | Yukon Government Department of Environment  |
| ADACLIM   | Danish Polar Center and the Government of Greenland, Ministry of Environment and Nature and Department of Fisheries, Hunting and Agriculture Permits 512-240, 512-258, 07-501, 66.24/23, 66.01.13, 2011-047447, 2012-065815, 2013- 083634, 2014-098814, 2015-115290 |
| ADF&G Nelchina Caribou  | Alaska Department of Fish and Game Protocol 2012-021  |
| ADF&G Susitna Valley Moose  | Alaska Department of Fish and Game Protocol 2012-022  |
| Adult Golden Eagle Satellite Tracking                                 | US Federal Bird Banding Permit 23353  |
| Alaska Golden Eagles  | Alaska Department of Fish and Game Protocol 2013-036  |
| Aquila chrysaetos interior west N. America, Craigs, Fuller            | US Federal Bird Banding Permit 20537, sub-permit to Permit 06714; US Fish and Wildlife Service Patuxent Wildlife Research Center; Boise State University IACUC  |
| Aquila chrysaetos Mark Fuller North America                           | US Fish and Wildlife Service Patuxent Wildlife Research Center, Boise State University IACUC  |
| Arctic breeding shorebirds; Rausch; various Canadian arctic locations | US Federal Bird Banding Permit  |
| Arctic fox Bylot - Argos tracking                                     | Université du Québec à Rimouski CPA-64-16-169 (R3); Parks Canada Agency SIR-2018-28021  |
| Arctic hare Alert - Argos tracking                                    | Université du Québec à Rimouski CPA-68-17-184 (R2); Government of Nunavut ML-2018-020   |
| Arctic Raptors - www.ArcticRaptors.ca                                 | Environment Canada Banding Permit 10833; University of Alberta Animal Use Protocol AUP00000042  |
| Arctic shorebird migration tracking study - American Golden-Plover    | US Federal Master Banding Permit 23269, ACUC Protocol 2017-007; State of Alaska permits 17-134, 18-161  |

|  |   |
|--|---|
| Arctic shorebird migration tracking study - Dunlin                 | US Federal Master Banding Permit 23269, ACUC Protocol 2017-007; State of Alaska permits 17-134, 18-161  |
| Arctic shorebird migration tracking study - Pectoral Sandpiper     | US Federal Master Banding Permit 23269, ACUC Protocol 2017-007; State of Alaska permits 17-134, 18-161  |
| Arctic shorebird migration tracking study - Semipalmated Sandpiper | US Federal Master Banding Permit 23269, ACUC Permit 2017-007; State of Alaska permits 17-134, 18-161  |
| Arctic Skua, Faroe Islands, GPS                                    | Animal work was approved by the Danish Nature Agency by permission to the Copenhagen Bird Ringing Centre (J.nr. SN 302-009).  |
| Arctic Skua, van Bemmelen, Norway                                  | Norwegian Food Safety Authority (FOTS) IDs 6328, 6329, 5276, 6328, 7421, 8538, 15726  |
| Arctic Skua, van Bemmelen, Tobseda                                 | No permissions were required according to the §44 and §6 of the Federal Law of the Russian Federation No. 52 from 24.04.1995 (last update 18.02.2020) "On Wildlife".  |
| Arctic Tern Alaska   | Federal Permit 09700; Alaska Scientific Permit 17-162; National Zoological Park IACUC 15-20, 18-06  |
| Atlantic puffin in Iceland (Petersen)                              | Ringling Office at the Náttúrufræðistofnun Íslands Permit 199   |
| Atlantic Seabird Study (Red-Throated Loons)                        | US Federal Bird Banding permits 23769, 22636; US Fish and Wildlife Service Permit MB48614B; annual state permits for Delaware, Maryland, North Carolina, Virginia; US Geological Survey Patuxent Wildlife Research Center IACUC Protocol 2010-10  |
| Atlantic Seabird Study (Surf Scoters)                              | US Federal Bird Banding permits 23769, 22636; US Fish and Wildlife Service Permit MB48614B; annual state permits for Delaware, Maryland, North Carolina, Virginia; US Geological Survey Patuxent Wildlife Research Center IACUC Protocol 2010-10  |
| Azores Great Whales Satellite Telemetry Program                    | Direcção Regional do Ambiente (Regional Directorate of the Environment, Regional Government of the Azores) (until 2018), Direcção Regional dos Assuntos do Mar (Regional Directorate for Sea Affairs, Regional Government of the Azores) (after 2018) permits LMAS-DRAM/2018/06, 80/2017/DRA, 37/2016/DRA, 30/2015/DRA, 34/2014/DRA, 20/2013/DRA, 31/2012/DRA, 51/2011/DRA, 16/2010/DRA, 20/2009/DRA, 76/2008/DRA |
| Bald Eagle <i>Haliaeetus leucocephalus</i> Mojica/Watts            | US Federal Bird Banding Permit 21567; William & Mary IACUC Protocol 2018-04-27-12927, IBC Protocol 2017-06-21-12181   |
| Bald Eagles in coastal Alaska; Lewis                               | US Federal Bird Banding Permit 21678; US Fish and Wildlife Service Region 7 IACUC Protocol 2013-002   |
| Barnacle goose (Greenland) Larry Griffin/David Cabot               | British Trust for Ornithology Licence A/5436 and Endorsement 06-01w   |
| Barnacle goose (Svalbard) Larry Griffin                            | British Trust for Ornithology Licence A/5436 and Endorsement 06-01w   |
| Bean Goose <i>Anser fabalis</i> Finnmark.                          | Norwegian Food Safety Authority (FOTS) IDs 6472/2014/82889-1, 15595/18/72904  |
| Beringia Dunlin  | US Federal Master Banding Permit 23269, IACUC Protocol 2016-005; State of Alaska permits 16-111, 17-102, 18-160   |
| Beringia South Migrant Golden Eagle                                | Montana Department of Fish, Wildlife and Parks Scientific Collector's Permit 2012-003, US Federal Bird Banding Permit 22637   |

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| Black-bellied Plover Alaska  | Federal Permit 09700; Alaska Scientific Permit 15-108, 17-162; National Zoological Park ACUC Protocol 14-30, 15-20; USGS Alaska Science Center ACUC 2015-09  |
| Black-legged Kittiwakes; Mallory/Gaston/Akearok, Prince Leopold Island, Nunavut, Canada                  | Canadian scientific and access permits NUN-SCI-08-55, NUN-MBS-12-03, NUN-SCI-12-04, WRP2013040, banding permits 10694, 10322, animal care protocols 0800AG01, WM-01-11   |
| Bowhead whale Admiralty Inlet  | Animal Care Approval FWI-ACC_AUP_2003-2017_016; Licence to Fish for Scientific Purposes S-2003-2017-1006-NU  |
| Bowhead whale Cumberland Sound   | Animal Care Approval FWI-ACC_AUP_2003-2017_016; Licence to Fish for Scientific Purposes S-2003-2017-1006-NU  |
| Bowhead whale Foxe Basin   | Animal Care Approval FWI-ACC_AUP_2003-2017_016; Licence to Fish for Scientific Purposes S-2003-2017-1006-NU  |
| Brant Geese Sean Boyd 2002   | Simon Fraser University permits 781B-06, 999B-06   |
| Brant Geese Sean Boyd 2005   | Simon Fraser University permits 781B-06, 999B-06   |
| Broad-winged Hawk Alberta Boreal   | University of Alberta IACUC Protocol AUP00001523; Federal Banding Permit 10277; National Zoological Park ACUC 15-16; Environment and Climate Change Canada 10277   |
| Brown and Black bear (Ursus spp.), Jerry Belant, Alaska  | National Park Service  |
| Canadian Ringed Plover geolocation tracking, Bylot Island, Canada (data from Léandri-Breton et al. 2019) | Parks Canada Agency research and collection permits SIR-2013-13934, SIR-2015-18822; Université du Québec à Rimouski ACC CPA-56-14-141, CPA-56-14-141-R1, CPA-56-14-141-R2, CPA-56-14-141-R3; Environment and Climate Change Canada permits 10772, 10772N   |
| Common cuckoo, Kamchatka   | Zoological Institute RAS permits 2017-04-17, 2017-04-17; Kaliningrad Regional Agency for Protection, Reproduction and Use of Animal World and Forests permits 12, 17; Kamchatka Krai Government Ministry of Natural Resources and Ecology Permit 38  |
| Common cuckoo, Khakassia   | Zoological Institute RAS permits 2017-04-17, 2018-03-22; Kaliningrad Regional Agency for Protection, Reproduction and Use of Animal World and Forests permits 12, 17; Ministry of Natural Resources and Environment of the Republic of Khakassia permits 9, 18   |
| Common Eiders; Love/Gilchrist; East Bay Island, Canada   | University of Windsor Animal Use Permits 15-05, 19-11  |
| Common Nighthawk   | University of Alberta AUP00001523; National Zoological Park and Conservation Biology 15-16, 18-66; Texas Tech University 15032-04; University of South Dakota 23-05-13-16C, 15-05-16-19C; Environment and Climate Change SFCQ2017-02, US Federal Bird Banding permits 09700, 22199, 22834; Environment and Climate Change Canada Scientific Permit to Capture and Band Migratory Birds 10277, 10365, 10619H, 10534, 10169, 10887, regional permits |
| Common/King Eiders; East Bay Island, Nunavut; Gilchrist 2012 and 2013                                    | University of Windsor Animal Use Permits 15-05, 19-11  |

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| Common/King Eiders; East Bay Island, Nunavut; Gilchrist/Mosbech 2001 and 2003   | University of Windsor Animal Use Permits 15-05, 19-11  |
| Common/King Eiders; Nuuk/Disko Bay/Upernavik, Greenland; Gilchrist/Mosbech; 2002 and 2003                                       | University of Windsor Animal Use Permits 15-05, 19-11  |
| Connecticut Warbler Alberta Boreal  | Smithsonian Institution ACUC NZP-IACUC 17-05, 18-66; Environment and Climate Change Canada 10277   |
| Distribution of spectacled eiders in Russia and Alaska 1993-1996 (data from Petersen et al. 1999)                               | US Federal Bird Banding Permit 20022, US Fish and Wildlife Service Permit MB789758   |
| Disturbance of BG by IFV and IWR  | Lower Saxony State Office for Consumer Protection and Food Safety (LAVES) Permission Akt.Z. 33.19-4202-04-15/1956  |
| Disturbance of GWFG by IFV and IWR  | Lower Saxony State Office for Consumer Protection and Food Safety (LAVES) Permission Akt.Z. 33.19-4202-04-15/1956  |
| Disturbance of GWFG by IFV and IWR 2017-2018  | Lower Saxony State Office for Consumer Protection and Food Safety (LAVES) Permission Akt.Z. 33.19-4202-04-15/1956  |
| Dolphin_Union_Caribou_UAV   | Nunavut Wildlife Research Permit WL2015-037, IACUC exemption 07/10/2015; UAV flights in compliance with Transport Canada regulations   |
| Eagles Wintering in Bitterroot Valley   | US Federal Bird Banding Permit 23353   |
| Earthspan Peregrines  | Boise State University IACUC; Earthspan IACUC; US Federal Master Banding Permit 20127; National Park Service Assateague Island National Seashore and US Fish and Wildlife Service Chincoteague and Laguna Atascosa National Wildlife Refuges permits in Maryland (55662), Virginia (026310) and Texas (SPR-0390-047) |
| Eastern Montana Golden Eagles   | US Federal Bird Banding Permit 22622   |
| Eastern North America Golden Eagles   | Boise State University IACUC Protocol 692-980-020  |
| Eastern Washington Lesser Canada Goose - Delineating the breeding grounds of small Canada geese wintering in the Columbia Basin | US Federal Bird Banding Permit 06508   |
| Fall Migrant Raptors - U.S. Atlantic Flyway - Biodiversity Research Institute   | US Federal Bird Banding Permit 22636   |
| Foraging behaviour and fuel accumulation of pink-footed geese (data from Chudzińska et al. 2016)                                | Danish Ministry of Environment License to Aarhus University Department of Bioscience   |
| FTZ Curlew  | Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung (Kiel, Germany) file numbers V 312-7224.121-37(42-3/13) and V 241-35852/2017(88-7/17)  |
| FTZ Geese Wadden Sea  | Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung (Kiel, Germany) file numbers V 312-7224.121-37(42-3/13) and V 241-35852/2017(88-7/17)  |
| Glaucous Gull Barrow Alaska   | US Federal Bird Banding Permit 09700; Alaska Scientific Permit 15-189; North Slope Borough scientific study permits 16-169, 16-174; National Zoological Park ACUC 15-33  |
| Glaucous Gull BPN KoEco Chaun 2017  | Gimpo City Permit 2017-1   |
| Golden Eagle (Aquila chrysaetos) Eastern N. America Mojica/Watts  | US Federal Bird Banding Permit 21567; William & Mary IACUC Protocol 2018-04-27-12927, IBC Protocol 2017-06-21-12181  |
| Golden Eagle Migration, Denali, Alaska, McIntyre  | Oregon State University ACUC AUF Permit 1962   |
| Golden Eagle Satellite Telemetry Data   | Boise State University IACUC Protocol 692-980-020  |



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| Golden Eagles of Interior Alaska; Lewis                                       | US Federal Bird Banding Permit 21678; US Fish and Wildlife Service Region 7 IACUC Protocol 2012-013  |
| Greenland White-fronted Goose tracking  | British Trust for Ornithology Licence A/5436 and Endorsement 11-57w  |
| Gyr Falcon, High Arctic Institute, central-west Greenland                     | Danish Polar Center permits 512-162, 512-167, 512-179, 512-212, 512-232, 512-254   |
| Gyr Falcon, High Arctic Institute, east Greenland trapping station            | Danish Polar Center permits 512-162, 512-167, 512-179, 512-212, 512-232, 512-254   |
| Gyr Falcon, High Arctic Institute, Maniitsoq trapping station                 | Danish Polar Center permits 512-162, 512-167, 512-179, 512-212, 512-232, 512-254   |
| Gyr Falcon, High Arctic Institute, northwest Greenland                        | Danish Polar Center permits 512-162, 512-167, 512-179, 512-212, 512-232, 512-254   |
| Gyr Falcons Alaska McIntyre   | Oregon State University ACUC AUF Permit 1962   |
| HawkWatch International Golden Eagles   | US Federal Master Bird Banding Permit 21384; state permits administered by Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Wyoming Game and Fish Department, Nevada Department of Wildlife, and New Mexico Department of Game and Fish.  |
| Herring Gull QIA KoEco Korea 2017   | Gimpo City Permit 2017-1   |
| Herring Gulls ( <i>Larus Argentatus</i> ); Gilchrist; East Bay Island, Canada | Government of Canada animal care protocols EC-PN-09-026, EC-PN-13-0; Government of Nunavut animal care protocols NUN-SCI-08-04, NUN-SCI-11-04; WL-2013-044, WL-2009-029; Banding Permit 10650.   |
| Hudsonian Godwit ( <i>Limosa haemastica</i> ) Canada Smith/Watts              | Government of the Northwest Territories Wildlife Research Permit WL500153 and WCC Approval NWTWCC 2013-009; Environment Canada Western and Northern ACC Approval EC-PN-13-006; Environment Canada Scientific permits 10565J, 10565N, 10565M; Environment Canada Wildlife and Landscape Science Directorate and Canadian Wildlife Service ACC Approval EC-PN-14-006 |
| iceSeals_NSB_Alaska_vonDuyke  | National Marine Fisheries Service Research Permits 358-1787, 15324; Alaska Department of Fish and Game ACUC protocols 2010-13R, 2016-23  |
| Kidd et al. Rough-legged Hawk Movements in North America                      | US Federal Master Bird Banding permits 22636, 24140  |
| Kittiwake, Brides & Petersen, Iceland   | Ringling Office at the Náttúrufræðistofnun Íslands Permit 199  |
| Latham Alberta Wolves   | University of Alberta ACUC Protocol 471503   |
| Lesser White-fronted Goose <i>Anser erythropus</i> Finnmark                   | Norwegian Food Safety Authority (FOTS) IDs 6472/2014/82889-1, 15595/18/72904   |
| Lesser Yellowlegs ( <i>Tringa flavipes</i> ) Migratory Connectivity           | Alaska Department of Fish and Game IACUC Protocol 0058-2019-39   |
| LifeTrack Peregrine falcon  | No permissions were required according to the §44 and §6 of the Federal Law of the Russian Federation No. 52 from 24.04.1995 (last update 18.02.2020) "On Wildlife".   |
| LifeTrack Rough-legged buzzards   | No permissions were required according to the §44 and §6 of the Federal Law of the Russian Federation No. 52 from 24.04.1995 (last update 18.02.2020) "On Wildlife".   |
| LifeTrack Whooper Swan Latvia   | No permissions were required according to the §44 and §6 of the Federal Law of the Russian Federation No. 52 from 24.04.1995 (last update 18.02.2020) "On Wildlife".   |

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| Light-bellied brent goose (Canadian High Arctic)<br>Kendrew Colhoun  | British Trust for Ornithology Licence A/5436   |
| Long-tailed ducks ARGOS 2019   | No permissions were required according to the §44 and §6 of the Federal Law of the Russian Federation No. 52 from 24.04.1995 (last update 18.02.2020) "On Wildlife". St Petersburg State University Ethic Committee Permission 131-03-4.   |
| Long-tailed ducks GLS 2018   | No permissions were required according to the §44 and §6 of the Federal Law of the Russian Federation No. 52 from 24.04.1995 (last update 18.02.2020) "On Wildlife".   |
| Long-tailed Jaeger Alaska  | US Federal Bird Banding Permit 09700; Alaska scientific permits 15-33, 17-162, 18-156, 19-157; National Zoological Park ACUC 15-33, 18-06; National Park Service AKR_DENA_Harrison_Jaegers_2018; Environment and Climate Change Canada Scientific Permit 10565N; Government of Nunavut wildlife research permits WL2018-052, WL2019-041; Environment Canada Western and Northern ACC approvals EC-PN-13-006, 18JR01, 19JR01; Environment Canada scientific permits 10565J, 10565M, 10565N; Environment Canada Wildlife and Landscape Science Directorate and Canadian Wildlife Service ACC Approval EC-PN-14-006 |
| Long-tailed Skua, van Bemmelen, Sweden   | Jordbruksverket permits M160-11, M470-12, M472-12  |
| Lower 48 GOEA Migration<br>LTDU  | US Federal Bird Banding permits 23353, 24140<br>US Federal Bird Banding permits 23769, 22636; US Fish and Wildlife Service Permit MB48614B; annual state permits for Delaware, Maryland, North Carolina, Virginia; US Geological Survey Patuxent Wildlife Research Center IACUC Protocol 2010-10   |
| Migration of Sabine's gulls from the Canadian High Arctic  | CWS Animal Care EC-PN-11-020; CWS Scientific Permit NUN-SCI-09-01; Government of Nunavut Wildlife Research Licence WL 2010-042; Nunavut Water Board Licence 3BC-TER0811; Indian and Northern Affairs Land Use Reserve 068H16001; CWS Banding Permit 10694  |
| Migration Patterns of Pacific Sea Ducks  | Simon Fraser University permits 781B-06, 999B-06   |
| Migration timing in barnacle geese (Barents Sea) (data from Kölzsch et al. and Shariatinajafabadi et al. 2014) | Lower Saxony State Office for Consumer Protection and Food Safety (LAVES) Permission 33-42502-04-10/0307; Institute of Avian Research, Wilhelmshaven, Germany; National Park Administration of Lower Saxony, Wilhelmshaven, Germany  |
| Migration timing in barnacle geese (Greenland) (data from Kölzsch et al. and Shariatinajafabadi et al. 2014)   | British Trust for Ornithology Licence A/5436 and Endorsement 06-01w  |
| Migration timing in barnacle geese (Svalbard) (data from Kölzsch et al. and Shariatinajafabadi et al. 2014)    | British Trust for Ornithology Licence A/5436 and Endorsement 06-01w  |
| Migration timing in white-fronted geese (data from Kölzsch et al. 2016)  | Russian Academy of Sciences Institute of Geography (no approval needed); Wageningen Environmental Research (no approval needed)  |
| Mountain caribou in British Columbia   | British Columbia Wildlife Act Permits FJ08-59586, FJ07-40107 and FJ17-282173   |

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| Movement of long-tailed ducks marked on the Yukon-Kuskokwim Delta, Alaska 1998-2000 (data from Petersen et al. 2003) | US Federal Bird Banding Permit 20022, US Fish and Wildlife Service Permit MB789758  |
| North Sea population tracks of greater white-fronted geese 2014-2017 (data from Kölzsch et al. 2019)                 | Lower Saxony State Office for Consumer Protection and Food Safety (LAVES) Permission Akt.Z. 33.19-4202-04-15/1956, AZ 33.19-42502-04-15; Royal Netherlands Academy of Arts and Sciences AWC DEC NIOO13.14;  |
| North Slope Cackling Geese   | US Fish and Wildlife Service IACUC 2018-010 and appropriate state and federal permits   |
| NPS Dall Sheep Gates of the Arctic   | No permits were required (research conducted prior to the establishment of the National Park Service IACUC).  |
| NPS Dall Sheep in Yukon-Charley Rivers National Preserve   | No permits were required (research conducted prior to the establishment of the National Park Service IACUC).  |
| NPS Denali Dall Sheep  | US National Park Service permits DENA-2005-SCI-0019, DENA-2011-SCI-0002, DENA-2016-SCI-009; Alaska Department of Fish and Game permits Burch_08-008, Burch_09-012, Burch_11-005, Meier_12-006, Arthur_DenaliNP_15-093, Borg_NPS_16-012; US National Park Service IACUC protocols NPS IACUC 2010-1, AKR_YUCH and DENA_Burch_Wolves_2013, AKR_DENA_Borg_Wolves_2016.A3        |
| NWT South Slave Boreal Wolves  | Government of the Northwest Territories Wildlife Research Permit WL5000771; Government of the Northwest Territories WCC Protocol NWTWCC 2019-020; reviewed annually   |
| NYSDEC Raptor Tracking   | US Federal Bird Banding permits 10072, 20723, 20734, 21963  |
| Oystercatcher 2016 Alvs Iceland  | Icelandic Institute of Natural History  |
| Oystercatcher 2017 Alvs Iceland  | Icelandic Institute of Natural History  |
| Pacific Loons Alaska Colville River Delta  | Federal Permit MB789758-0; Alaska Scientific Permit 15-108; National Zoological Park ACUC 15-20; US Geological Society Alaska Science Center ACUC 2015-09, 2016-04; US Geological Society IACUC Protocols 2008-23, 2010-4, 2014-12, 2016-04, 2017-05  |
| Pannonic population tracks of greater white-fronted geese 2013-2017 (data from Kölzsch et al. 2019)                  | Lower Saxony State Office for Consumer Protection and Food Safety (LAVES) AZ 33.19-42502-04-15/1956; Royal Netherlands Academy of Arts and Sciences AWC DEC NIOO13.14; Hunting and Fishing Department of Zala County Government Office (Hungary) XX-H-004/1386-2/2012; Hunting and Fishing Department of Bács-Kiskun County Government Office (Hungary) BKH/001/1135-2/2016 |

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| Parasitic Jaeger/Arctic Skua North America  | US Federal Bird Banding Permit 09700; Alaska scientific permits 17-162, 18-156, 19-157; National Zoological Park ACUC 15-33, 18-06; Environment and Climate Change Canada scientific permits 10565J, 10565M, 10565N; Government of Nunavut wildlife research permits WL2018-052, WL2019-041; Environment Canada Western and Northern ACC protocols EC-PN-13-006, 18JR01, 19JR01; Environment Canada Wildlife and Landscape Science Directorate and Canadian Wildlife Service ACC Protocol EC-PN-14-006 |
| Peregrine Falcon, High Arctic Institute, northwest Greenland                      | Danish Polar Center permits 512-162, 512-167, 512-179, 512-212, 512-232, 512-254   |
| Pomarine Jaeger North America   | US Federal Bird Banding Permit 09700; Alaska Scientific permits 17-162, 18-156, 19-157; National Zoological Park ACUC 15-33, 18-06; Environment and Climate Change Canada scientific permits 10565J, 10565M, 10565N; Government of Nunavut wildlife research permits WL2018-052, WL2019-041; Environment Canada Western and Northern ACC protocols EC-PN-13-006, 18JR01, 19JR01; Environment Canada Wildlife and Landscape Science Directorate and Canadian Wildlife Service ACC Protocol EC-PN-14-006 |
| Pre-breeding prospecting behaviour of snowy owls (data from Therrien et al. 2015) | Université Laval Animal Care permits   |
| Red-necked Phalarope southern Chukotka (data from Mu et al. 2018)                 | Princeton University IACUC protocols 2073F-16 and 2073F-19   |
| Red-necked Phalarope, van Bemmelen, Norway  | Norwegian Food Safety Authority (FOTS) IDs 6328, 6329, 5276, 6328, 7421, 8538, 15726   |
| Red-necked Phalarope, van Bemmelen, Sweden  | Permits by Jordbruks verket to Lund University, Sweden. Permit numbers: M160-11, M470-12, M472-12  |
| redThroatedLoon_USGS_ASC_argos  | US Geological Survey IACUC protocols 2008-23, 2010-4, 2014-12, 2016-4, 2017-05   |
| Ringed seals Igloolik   | Animal Care Approval FWI-ACC_AUP_2006-2014_009; Licence to Fish for Scientific Purposes S-2006-2014-1014-NU  |
| Ringed seals Resolute   | Animal Care Approval FWI-ACC_AUP_2006-2014_009; Licence to Fish for Scientific Purposes S-2006-2014-1014-NU  |
| Ringed seals Sanikiluaq   | Animal Care Approval FWI-ACC_AUP_2006-2014_009; Licence to Fish for Scientific Purposes S-2006-2014-1014-NU  |
| Rough-legged Buzzard in variable environment                                      | Norwegian Food Safety Authority (FOTS) IDs 6472/2014/82889-1, 15595/18/72904   |
| Rusty Blackbird Alberta   | Environment Canada 10277 AJ; National Zoological Park ACUC Protocol 15-16  |
| Sabine's Gulls in the Juan de Fuca Eddy   | Canadian scientific and access permits NUN-SCI-08-55, NUN-MBS-12-03, NUN-SCI-12-04, WRP2013040, banding permits 10694, 10322, animal care protocols 0800AG01, WM-01-11   |
| Seaducks in the Fehmarn Belt (southern Baltic)                                    | Danish Animal Welfare Committee (Dyreforsøgstilsynet) Permit 2009/561-1589   |

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| Short-eared Owl, North America  | US Federal Bird Banding and State Scientific permits, IACUC Protocol 2009007   |
| Skagit County Washington Western High Arctic Brant                          | US Federal Bird Banding Permit 06508   |
| Skagit Valley / Wrangel Island Snow Goose                                   | US Federal Bird Banding Permit 06508   |
| Skagit Valley / Wrangel Island Snow Goose 2016-17 GSM                       | US Federal Bird Banding Permit 06508   |
| Snow Bunting Migration Phenology  | University of Windsor Animal Use permits 13-20, 18-02  |
| Snow bunting, Svalbard  | Norwegian Food Safety Authority (FOTS) ID 4701; Governor of Svalbard Approval 2014/00375-5   |
| Snowy owl - North America   | Université Laval ACC permit no 2006-163,, Environment and Climate Change Canada bird banding permit no 10648, Parks Canada permit no SIR-2007-1091                     |
| Snowy owls from Barrow Alaska 1999-2001 (Fuller)                            | US Fish and Wildlife Service Patuxent Wildlife Research Center, Boise State University IACUC   |
| Solovki Larus Track   | No permissions were required according to the §44 and §6 of the Federal Law of the Russian Federation No. 52 from 24.04.1995 (last update 18.02.2020) “On Wildlife”.   |
| Taiga Bean Geese Larry Griffin  | British Trust for Ornithology License A/5436 and Endorsement 11-02w  |
| TBMUCOMU.GastonMontevecchi.NWAtlantic                                       | Canadian scientific and access permits NUN-SCI-08-55, NUN-MBS-12-03, NUN-SCI-12-04, WRP2013040, banding permits 10694, 10322, animal care protocols 0800AG01, WM-01-11 |
| Thayer's Gulls from the Canadian High Arctic                                | Canadian Wildlife Service NUN-SCI-16-05, NIRB 16YN020/124659, NPC 148548, Acadia 04-17, Canadian Wildlife Service Banding Permit 10694                                 |
| Thick-billed murre Elliott Coats 2010                                       | McGill University Animal Care Protocol 2015-7599   |
| Thick-billed murre Elliott Coats 2011                                       | McGill University Animal Care Protocol 2015-7599   |
| Thick-billed murre Elliott Coats 2013                                       | McGill University Animal Care Protocol 2015-7599   |
| Thick-billed murre Gaston PLI 2014  | Canadian scientific and access permits NUN-SCI-08-55, NUN-MBS-12-03, NUN-SCI-12-04, WRP2013040, banding permits 10694, 10322, animal care protocols 0800AG01, WM-01-11 |
| Thick-billed murre Gilchrist and Elliott Coats 2016                         | McGill University Animal Care Protocol 2015-7599   |
| Thick-billed murre Gilchrist and Elliott Coats 2017                         | McGill University Animal Care Protocol 2015-7599   |
| Thick-billed murre Gilchrist and Elliott Digges 2015                        | McGill University Animal Care Protocol 2015-7599   |
| Thick-billed murre Gilchrist and Elliott Digges 2016                        | McGill University Animal Care Protocol 2015-7599; Government of Nunavut animal care protocols NUN-SCI-16-03, NUN-SCI-16-04; Animal care EC-PN-16-017                   |
| Thick-billed murre Gilchrist Cape Graham Moore 2016                         | McGill University Animal Care Protocol 2015-7599; Government of Nunavut animal care protocols NUN-SCI-16-03, NUN-SCI-16-04; Animal care EC-PN-16-017                   |
| Thick-billed Murres; Gaston/Akearok, Prince Leopold Island, Nunavut, Canada | McGill University Animal Care Protocol 2015-7599   |
| Thick-billed Murres; Gilchrist; Cape Graham Moore, Canada                   | McGill University Animal Care Protocol 2015-7599   |
| Thick-billed Murres; Gilchrist; Digges Island, Canada                       | McGill University Animal Care Protocol 2015-7599   |

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| Tobseda Barnacle Goose  | No permissions were required according to the §44 and §6 of the Federal Law of the Russian Federation No. 52 from 24.04.1995 (last update 18.02.2020) "On Wildlife".  |
| Tracking movements of Peregrine Falcons <i>Falco peregrinus</i> from breeding populations in Arctic Eurasia           | Russian Federation permits  |
| Tracking post-fledging dispersal and migration of juvenile Peregrine Falcons <i>Falco peregrinus</i> in Arctic Russia | Russian Federation permits  |
| Upper Midwest Bald Eagle Project  | Boise State University IACUC Protocol 692-980-020   |
| USGS WERC Dixon Field Station Compiled Avian Telemetry  | US Federal Bird Banding Permit 21142, California Department of Fish and Wildlife Scientific Collection Permit SC-8090   |
| Vega Gull BPN KoEco Russia Chaun 2017   | Gimpo City Permit 2017-1  |
| Wader migration German Wadden Sea: bar-tailed godwits   | Lower Saxony State Office for Consumer Protection and Food Safety (LAVES) 33-42502-04-10/0307; Institute of Avian Research, Wilhelmshaven, Germany; National Park Administration of Lower Saxony, Wilhelmshaven, Germany  |
| Wader migration German Wadden Sea: grey plovers   | Lower Saxony State Office for Consumer Protection and Food Safety (LAVES) 33-42502-04-10/0307; Institute of Avian Research, Wilhelmshaven, Germany; National Park Administration of Lower Saxony, Wilhelmshaven, Germany  |
| Washington State Surf Scoter  | US Federal Bird Banding Permit 06508  |
| Washington State White-winged Scoter  | US Federal Bird Banding Permit 06508  |
| Western GOEA Conservation   | US Federal Bird Banding Permit  |
| Whimbrel <i>Numenius phaeopus</i> Acadian Peninsula   | US Federal Bird Banding Permit 21567; William & Mary IACUC Protocol 2018-04-27-12927, IBC Protocol 2017-06-21-12181   |
| Whimbrel <i>Numenius phaeopus</i> North America Smith/Watts/Winn  | Government of the Northwest Territories Wildlife Research permits WL500153, WL500252; Government of the Northwest Territories Wildlife Care Committee protocols NWTWCC 2013-009, NWTWCC 2014-007; Environment Canada Wildlife and Landscape Science Directorate and Canadian Wildlife Service ACC Approval EC-PN-14-006; Environment Canada scientific permits 10565J, 10565N, and 10565M |
| White fronted Goose QIA KoEco Korea 2017  | Gimpo City Permit 2017-1  |
| White-fronted goose (Greenland) Larry Griffin   | British Trust for Ornithology Licence A/5436 and Endorsement 11-57w   |
| White-fronted goose full year tracks 2006-2010 Alterra IWWR   | Russian Academy of Sciences Institute of Geography (no approval needed); Wageningen Environmental Research (no approval needed)   |
| Whooper swan (Icelandic) Larry Griffin II   | British Trust for Ornithology Licence A/5436  |
| Whooper swan (Icelandic) Larry Griffin/Colin Pennycuik  | British Trust for Ornithology Licence A/5436  |
| Whooper swan (Icelandic) Larry Griffin/Kendrew Colhoun  | British Trust for Ornithology Licence A/5436  |
| Whooper swans in Latvia 2016  | Latvian Ringing Centre Permit 171   |
| yellowBilledLoon_USGS_ASC_argos   | US Geological Survey IACUC protocols 2008-23, 2010-4, 2014-12, 2016-4, 2017-05  |

**Table S.4.**

Acknowledgements and funding for studies participating in the AAMA. Organization funding might extend beyond the subdivisions, grants, and programs listed.

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| Aarhus University  |
| Acadia University<br>Biology Department  |
| Alaska Department of Fish & Game<br>Federal Aid in Wildlife Restoration (Project 4.39, Grants W-33-7—W-33-12)<br>State Wildlife Grant Program<br>Statewide Waterfowl Program |
| Alberta Caribou Committee  |
| Alberta Conservation Association   |
| Alberta Cooperative Conservation Research Unit   |
| Alberta Sport, Recreation, Parks & Wildlife Foundation   |
| Alexander Wetmore Research Award   |
| American Cyanamid  |
| American Eagle Foundation  |
| American Honda Motor Company   |
| American Ornithological Society  |
| American Wind Wildlife Institute   |
| Animal & Plant Quarantine Agency   |
| Aquila Environmental   |
| Archbold Biological Station  |
| Arctic Raptor Project  |
| Arctic Raptors   |
| ArcticNet - Network of Centers of Excellence of Canada   |
| Arizona Department of Game and Fish  |
| Audubon Society<br>Golden Eagle Chapter  |
| Belmont Forum (TAMANI Project)   |
| Bijl2, Maatschappelijke Adviesraad Faunaschade (previously Faunafonds), the Netherlands  |
| BioConsult SH  |
| Biodiversity Research Institute<br>Raptor Research Program   |
| Bird Studies Canada<br>James L. Baillie Memorial Fund  |
| BirdLife Norway  |
| Black Rock Forest  |
| Blake-Nuttall Fund Grant   |
| Boise State University<br>Raptor Research Center   |
| British Antarctic Survey   |
| British Broadcasting Corporation (BBC)   |
| British Columbia Ministry of Environment   |

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| Bundesamt für Naturschutz  |
| Bureau of Ocean Energy Management  |
| Bureau Waardenburg   |
| California Department of Fish & Wildlife   |
| California Department of Water Resources   |
| California Waterfowl Association   |
| Canada Foundation for Innovation   |
| Canada Research Chairs Program<br>Aboriginal Affairs   |
| Canadian Circumpolar Institute C/Bar   |
| Canadian Foundation for Innovation   |
| Canadian Wildlife Service  |
| Cinnabar Foundation  |
| Coastal Bend Bays & Estuaries Program  |
| Collaborative Offshore Wind Research Into The Environment (COWRIE)   |
| College of William & Mary<br>Center for Conservation Biology   |
| Columbia University<br>Lamont-Doherty Earth Observatory  |
| ConocoPhillips Charitable Investments Global Signature Program   |
| Conservation Science Global, Inc.  |
| County Governor of Finnmark, Norway  |
| Craighead Beringia South   |
| Danish National Research Foundation<br>DNRF96  |
| DHI A/S  |
| Dr. Ezekiel R. and Edna Wattis Dumke Foundation  |
| Ducks Unlimited  |
| Ducks Unlimited Canada   |
| Durham University  |
| Earth Rangers  |
| Earthspan Foundation   |
| Environment & Climate Change Canada<br>National Wildlife Research Centre, Carleton University<br>Pacific Wildlife Research Centre<br>Science & Technology Branch             |
| Environment Agency Abu Dhabi   |
| Environment Canada   |
| Environment Yukon  |
| Esmee Fairbairn  |
| European Commission<br>Career Integration Grant, 7th Framework Programme (Project 631203)<br>Marie Curie Intra-European Fellowship, 7th Framework Programme (Project 273061) |
| Faroe Islands National Museum  |



Federal Ministry for the Environment, Federal Agency for Nature Conservation, Germany (BfN)

Project 'Birdmove'

Project FKZ 3510 860 1000

Federal Ministry of Education and Research, Germany (BMBF)

Project 'StopP—From Sediment to Top Predator'

Femern A/S

Fisheries and Oceans Canada

Fledgling Fund Foundation

Fonds de recherche du Québec—Nature et technologies (FQRNT)

French National Agency for Research

Project MAMBA ANR-16-TERC-0004

French National Center for Scientific Research (CNRS)

French Polar Institute IPEV

ADACLIM Project 388

Fundação para a Ciência e Tecnologia

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UID/AMB/50017/2019

Georgetown University

German Aerospace Centre (DLR)

Government of Canada

Department of National Defence

[International Polar Year Program](#)

Northern Development Canada

Northern Scientific Training Program (NSTP)

Polar Knowledge Canada

Government of Nunavut

Nunavut Wildlife Management Board

Government of the Northwest Territories,

Cumulative Impact Monitoring Program.

Department of Renewable Resources, Western Biophysical Program.

Greenfalk Consultants

Gurinas Family

Gwich'in Renewable Resources Board

Wildlife Studies Fund

Hawk Mountain Sanctuary Association

HawkWatch International

Heritage Lottery Fund

Awards for All

High Arctic Gull Research Group

High Arctic Institute

High Meadows Foundation

Highland County eagle watchers

Icelandic Research Fund (RANNIS)

Grant 152470-052

Idaho Department of Fish & Game

Idaho Wildlife Society

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| Institute for Avian Research ‘Vogelwarte Helgoland’   |
| James Bay Shorebird Project   |
| James S. McDonnell Foundation<br>Studying Complex Systems Scholar Award   |
| <b>JEPS Foundation</b>  |
| Justus Liebig University, Giessen, Germany  |
| Kanuti Kanuti National Wildlife Refuge  |
| Katherine W. Dumke and Ezekiel R. Dumke Jr. Foundation  |
| Kenneth M. Molson Foundation  |
| Kidd Biological, Inc.   |
| Kiel University, Research and Technology Centre (FTZ)   |
| Kinross Gold  |
| Klamath Bird Observatory  |
| Korea Institute of Environmental Ecology  |
| Latvian Swan Research Society   |
| Liz Claiborne & Art Ortenberg Foundation  |
| Louise L. Borick Foundation   |
| M.J. Murdock Charitable Trust   |
| Manaaki Whenua—Landcare Research  |
| Manomet, Inc.   |
| Max Planck Institute of Animal Behavior<br>Department of Migration  |
| McGill University<br>Department of Natural Resource Sciences  |
| Ministry of Food, Agriculture and Consumer Protection, Lower Saxony, Germany  |
| Minnesota Department of Natural Resources   |
| Moscow State University, Solovetskiy Branch of White Sea Biological Station   |
| Mountaineers Foundation   |
| National Aeronautics and Space Administration (NASA)<br>ABoVE Project NNX15AV92A  |
| National Fish & Wildlife Foundation   |
| National Geographic Society<br>Global Exploration Fund Northern Europe GEFNE 41-12  |
| National Trust for Scotland   |
| Natural Environment Research Council<br>Grant NE/M012549/1  |
| Natural History Museum of Latvia  |
| Natural Resources Canada Polar Continental Shelf Program  |
| Natural Sciences & Engineering Research Council of Canada (NSERC)<br>Discovery Grants<br>Discovery, Fisheries, & Oceans Canada<br>Integrated Landscape Management Chair<br>Northern Internship Program & Discovery Grant<br>Ocean Tracking Network<br>Research Tools & Instruments Grants |
| Nature Conservation & Nuclear Safety  |

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Netherlands Institute of Ecology, Department of Animal Ecology (NIOO-KNAW)  
Netherlands Organisation for Scientific Research (NWO) Polar Programme  
New Brunswick Wildlife Trust Fund  
New Mexico Department of Game & Fish  
New York State Department of Environmental Conservation  
Niedersächsische Wattenmeerstiftung  
Project 18/19  
Norcross Wildlife Foundation  
North Carolina Museum of Natural Sciences  
North Carolina State University, College of Natural Resources  
North Slope Borough  
Department of Wildlife Management  
Shell Baseline Studies Program  
North Star Science and Technology  
Northern Arizona University  
Norwegian Birds Protection Fund  
Norwegian Research Council (MIGRAPOP)  
Novartis Pesticide Division  
Nuttall Ornithological Society  
Offield Family Foundation  
Oregon Department of Fish & Wildlife  
Ornitela UAB  
Outer Continental Shelf Program  
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Owl Research Institute, Charlo, Montana  
Parks Canada, Government of Canada  
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Russian Academy of Sciences  
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Institute of Biological Problems of the North FEB  
Institute of Geography  
Laboratory of Ornithology, Institute of Biological Problems of the North  
Plant and Animal Ecology UD RAS

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| Ruth O. Mutch   |
| Scottish Natural Heritage   |
| Sea Duck Joint Venture  |
| Signals of Spring   |
| Smithsonian Conservation Biology Institute, Migratory Bird Center   |
| Solway Coast Area of Outstanding Natural Beauty Sustainable Development Fund  |
| SOVON   |
| State of Alaska Wildlife Grant  |
| State University of New York, College of Environmental Science and Forestry, Camp Fire Program in Wildlife Conservation                 |
| Teton Raptor Center   |
| Texas Tech University   |
| The American Bird Conservancy   |
| The Bailey Wildlife Foundation  |
| The Bluestone Foundation  |
| The County Governor of Oslo and Viken, Norway   |
| The County Governor of Trøndelag, Norway  |
| The Danish Council for Independent Research<br>MATCH Project 1323-00048B  |
| The Environmental Resources Network (TERN)  |
| The Grasslans Foundation  |
| The Haldan Family Foundation  |
| The Nature Conservancy  |
| The Norwegian Environmental Agency  |
| The Ocean View Foundation   |
| The Ohio State University<br>Department of Civil, Environmental and Geodetic Engineering<br>School of Environment and Natural Resources |
| The Paul A. Stewart Grant   |
| The Peregrine Fund  |
| The Rockwell Foundation   |
| The Svalbard Environmental Protection Fund<br>Grant 14/63   |
| Trent University  |
| Trust for Mutual Understanding  |
| UK Department of Energy and Climate Change (DECC)   |
| UK Ministry of Defence  |
| Université du Québec à Chicoutimi   |
| Université du Québec à Rimouski<br>Département de Biologie and Centre d'études nordiques  |
| Université Laval<br>Département de Biologie & Centre d'Études Nordiques   |
| Université Montpellier, Centre d'Ecologie Fonctionnelle et Evolutive, CEFE-CNRS   |
| University College Cork<br>School of Biological, Earth and Environmental Sciences   |

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| University of Alaska Anchorage  |
| University of Alberta<br>Department of Biological Sciences<br>Faculty of Science  |
| University of Aveiro<br>Department of Biology<br>Centre for Environmental and Marine Studies (CESAM)  |
| University of California—Davis  |
| University of Cape Town<br>Percy Fitzpatrick Institute of African Ornithology, NRF-DST Centre of Excellence   |
| University of Colorado<br>Department of Integrative Biology   |
| University of Copenhagen<br>Center for Macroecology, Evolution and Climate<br>GLOBE Institute   |
| University of Glasgow   |
| University of Iceland<br>South Iceland Research Centre  |
| University of Idaho<br>Department of Natural Resources and Society  |
| University of Konstanz<br>Centre for the Advanced Study of Collective Behaviour<br>Department of Biology  |
| University of Latvia<br>Institute of Biology  |
| University of Maine<br>School of Biology and Ecology  |
| University of Manitoba  |
| University of Massachusetts Amherst<br>Northeast Climate Adaptation Science Center  |
| University of Montana<br>W.A. Franke College of Forestry and Conservation, Department of Ecosystem and Conservation Sciences,<br>Wildlife Biology Program |
| University of Regina  |
| University of South Dakota  |
| University of the Azores<br>Institute of Marine Research (IMAR)<br>Marine and Environmental Sciences Centre (MARE)<br>Okeanos R&D Centre                  |
| University of Washington<br>College of the Environment<br>School of Aquatic & Fishery Sciences  |
| University of Windsor<br>Department of Biological Sciences<br>Great Lakes Institute for Environmental Research, School of the Environment                 |
| US Bureau of Ocean Energy Management (formerly, Minerals Management Service)  |
| US Bureau of Reclamation<br>Upper Colorado Regional Office  |
| US Department of Agriculture<br>US Forest Service   |
| US Department of the Army   |
| US Department of Defense  |

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US Department of Energy  
Award DE-EE0005362

US Department of the Interior  
Bureau of Land Management  
US Fish & Wildlife Service  
Arctic National Wildlife Refuge  
Candidate Conservation Species Grant  
Migratory Bird Management, Alaska Region  
Migratory Bird Management, Mountain-Prairie Region  
Migratory Bird Management, Southwest Region  
Yukon Delta National Wildlife Refuge

US Geological Survey  
National Biological Service  
Alaska Science Center  
Ecosystems Mission Area  
Forest and Rangeland Ecosystem Science Center  
Park Oriented Biological Research Program  
Patuxent Wildlife Research Center  
Science Support Partnership Program  
Western Ecological Research Center

US National Park Service  
Alaska Inventory and Monitoring Program  
Beringia Program  
Denali National Park and Preserve  
Gates of the Arctic National Park & Preserve  
Lake Clark National Park and Preserve  
Yukon-Charley Rivers National Preserve, Central Alaska Inventory and Monitoring Network

US National Science Foundation (NSF)  
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Virginia Coastal Zone Management Program (VA DEQ)

Virginia Department of Game & Inland Fisheries

Virginia Society of Ornithology

Vogelschutzkommittee e.V., Germany

Vogeltrekstation—Dutch Centre for Avian Migration and Demography

W. Garfield Weston Foundation

Wageningen Environmental Research, Netherlands  
Wageningen University & Research

Wageningen Marine Research

Wageningen University  
Resource Ecology Group

Washington Department of Fish & Wildlife

West Virginia University  
Division of Forestry and Natural Resources

Wildfowl & Wetlands Trust

Wildlife Conservation Society  
Wildlife Conservation Society, Fairbanks, USA

Wilson Ornithological Society

Wolf Creek Charitable Trust

Woods Hole Oceanographic Institution, Biology Department

Yale University  
Department of Ecology and Evolutionary Biology

**Table S.5.**

Studies used in Case Study 1, ‘long-term data reveal importance of decadal climate patterns on summering behavior in a migratory raptor’.

| Study   | Start | End  | Animals | Summering onsets |
|---|-------|------|---------|------------------|
| ABoVE: USFWS R6 Golden Eagles                                     | 2015  | 2017 | 2       | 6                |
| ABoVE: USGS/WVU Raptors   | 2013  | 2013 | 1       | 1                |
| Adult Golden Eagle Satellite Tracking                             | 2012  | 2017 | 10      | 18               |
| Alaska Golden Eagles  | 2014  | 2017 | 33      | 61               |
| <i>Aquila chrysaetos</i> interior west N. America, Craigs, Fuller | 1993  | 1996 | 6       | 6                |
| Beringia South Migrant Golden Eagle                               | 2013  | 2015 | 1       | 3                |
| Eagles Wintering in Bitterroot Valley                             | 2013  | 2017 | 17      | 30               |
| Eastern Montana Golden Eagles                                     | 2013  | 2017 | 11      | 20               |
| Golden Eagle Migration, Denali, Alaska, McIntyre                  | 1998  | 2000 | 6       | 6                |
| Golden Eagles of Interior Alaska; Lewis                           | 2015  | 2017 | 10      | 15               |
| HawkWatch International Golden Eagles                             | 2003  | 2008 | 4       | 9                |
| Western GOEA Conservation   | 2015  | 2017 | 2       | 4                |

**Table S.6.**

Studies used in Case Study 2, ‘large-scale geographic differences in parturition timing of caribou’.

| <b>Study</b>   | <b>Start</b> | <b>End</b> | <b>Animals</b> | <b>Parturitions</b> |
|--|--------------|------------|----------------|---------------------|
| ABoVE: BC Atlin Caribou  | 2000         | 2001       | 7              | 7                   |
| ABoVE: NWT Dehcho Boreal Woodland Caribou                          | 2007         | 2017       | 80             | 164                 |
| ABoVE: NWT Inuvik Barren Ground Caribou                            | 2006         | 2017       | 193            | 387                 |
| ABoVE: NWT Inuvik Boreal Woodland Caribou                          | 2002         | 2012       | 23             | 56                  |
| ABoVE: NWT North Slave Barren Ground Caribou:<br>Bathurst          | 2006         | 2017       | 90             | 142                 |
| ABoVE: NWT North Slave Boreal Caribou                              | 2017         | 2017       | 15             | 15                  |
| ABoVE: NWT Sahtu Barren Ground Caribou: Bluenose-<br>East          | 2006         | 2017       | 103            | 165                 |
| ABoVE: NWT Sahtu Boreal Woodland Caribou                           | 2007         | 2011       | 11             | 22                  |
| ABoVE: NWT Sahtu Mountain Woodland Caribou                         | 2008         | 2010       | 3              | 4                   |
| ABoVE: NWT South Slave Barren Ground Caribou:<br>Beverly and Ahiak | 2006         | 2017       | 109            | 224                 |
| ABoVE: NWT South Slave Boreal Woodland Caribou                     | 2006         | 2017       | 122            | 219                 |
| ABoVE: Yukon Caribou   | 2000         | 2017       | 71             | 98                  |
| Mountain caribou in British Columbia                               | 2001         | 2015       | 90             | 127                 |



**Table S.7.**

Studies used in Case Study 3, ‘temperature and precipitation response in movement rates of terrestrial mammals’.

| Study   | Start | End  | Animals | Species                          |
|---|-------|------|---------|----------------------------------|
| ABoVE: BC Atlin Caribou   | 2000  | 2002 | 10      | <i>Rangifer tarandus caribou</i> |
| ABoVE: Boutin Alberta Grey Wolf                                 | 2013  | 2014 | 20      | <i>Canis lupus</i>               |
| ABoVE: Boutin Alberta Moose                                     | 2010  | 2012 | 24      | <i>Alces alces</i>               |
| ABoVE: Hebblewhite Alberta-BC Wolves                            | 2000  | 2011 | 53      | <i>Canis lupus</i>               |
| ABoVE: NPS Denali Wolves  | 2004  | 2016 | 68      | <i>Canis lupus</i>               |
| ABoVE: NPS Wolves in Yukon-Charley Rivers National Preserve     | 2003  | 2015 | 47      | <i>Canis lupus</i>               |
| ABoVE: NWT Dehcho Boreal Woodland Caribou                       | 2007  | 2018 | 85      | <i>R. tarandus caribou</i>       |
| ABoVE: NWT Inuvik Barren Ground Caribou                         | 2006  | 2018 | 264     | <i>R. tarandus groenlandicus</i> |
| ABoVE: NWT Inuvik Boreal Woodland Caribou                       | 2002  | 2012 | 26      | <i>R. tarandus caribou</i>       |
| ABoVE: NWT North Slave Barren Ground Caribou: Bathurst          | 2009  | 2019 | 172     | <i>R. tarandus groenlandicus</i> |
| ABoVE: NWT North Slave Boreal Caribou                           | 2017  | 2018 | 20      | <i>R. tarandus caribou</i>       |
| ABoVE: NWT Sahtu Barren Ground Caribou: Bluenose-East           | 2006  | 2019 | 120     | <i>R. tarandus groenlandicus</i> |
| ABoVE: NWT Sahtu Boreal Woodland Caribou                        | 2004  | 2011 | 15      | <i>R. tarandus caribou</i>       |
| ABoVE: NWT Sahtu Mountain Woodland Caribou                      | 2008  | 2010 | 3       | <i>R. tarandus caribou</i>       |
| ABoVE: NWT South Slave Barren Ground Caribou: Beverly and Ahiak | 2006  | 2019 | 156     | <i>R. tarandus groenlandicus</i> |
| ABoVE: NWT South Slave Boreal Woodland Caribou                  | 2006  | 2018 | 174     | <i>R. tarandus caribou</i>       |
| ABoVE: Peters Hebblewhite Alberta-BC Moose                      | 2008  | 2010 | 18      | <i>Alces alces</i>               |
| ABoVE: Yukon Caribou  | 2000  | 2019 | 219     | <i>R. tarandus caribou</i>       |
| Brown and Black bear ( <i>Ursus</i> spp.), Jerry Belant, Alaska | 1998  | 2000 | 40      | <i>Ursus</i> spp.                |
| Latham Alberta Wolves   | 2006  | 2007 | 7       | <i>Canis lupus</i>               |
| Mountain caribou in British Columbia                            | 2001  | 2016 | 172     | <i>R. tarandus caribou</i>       |
| NWT South Slave Boreal Wolves                                   | 2016  | 2018 | 7       | <i>Canis lupus</i>               |

**Table S.8.**

Mixed-model results from Case Study 1, ‘long-term data reveal importance of decadal climate patterns on summering behavior in a migratory raptor’. Conditional average linear mixed-model results for golden eagle summering onset dates from 1993 to 2017. Only models in which the parameter of interest is retained within the model are used in the averaging. We scaled year by centering on the mean and dividing by the standard deviation. Here we list the covariates, coefficient estimates from model averaging (‘estimate’), standard errors (‘se’), Satterthwaite degrees of freedom (‘df’), z-values, and p-values (‘Pr(>|z|)’). The full model did not have the highest weight for juveniles or sub-adults > 2011, but we report it here for consistency with other age class models.

| covariate   | estimate | se     | df  | z-value | Pr(> z ) |
|---|----------|--------|-----|---------|----------|
| <b>All golden eagle age classes (N = 179):</b>  |          |        |     |         |          |
| Full model: df = 11, BIC = 1420, AICc = 1386.5, R <sup>2</sup> = 0.68, weight = 0.712 |          |        |     |         |          |
| year  | -2.6429  | 2.0015 | 140 | 1.313   | 0.189    |
| latitude  | 1.0774   | 0.3595 | 139 | 2.976   | 0.003    |
| wPDO  | -2.2927  | 1.0208 | 131 | 2.230   | 0.026    |
| age:sub-adult   | -19.4730 | 3.3982 | 124 | 5.690   | < 0.001  |
| age:adult   | -33.1718 | 3.7255 | 165 | 8.842   | < 0.001  |
| sex:male  | 1.6117   | 2.7835 | 81  | 0.575   | 0.565    |
| year:wPDO   | -2.3417  | 1.4212 | 155 | 1.636   | 0.102    |
| <b>Adult golden eagles (n = 89):</b>  |          |        |     |         |          |
| Full model: df = 9, BIC = 590.8, AICc = 570.7, R <sup>2</sup> = 0.37, weight = 0.451  |          |        |     |         |          |
| year  | -1.2118  | 1.9583 | 78  | 0.610   | 0.542    |
| latitude  | 0.7673   | 0.3429 | 53  | 2.204   | 0.028    |
| wPDO  | -2.2371  | 0.8535 | 53  | 2.584   | 0.010    |
| sex:male  | -0.1475  | 1.9167 | 47  | 0.076   | 0.939    |
| year:wPDO   | -1.2476  | 2.8593 | 79  | 0.430   | 0.667    |
| <b>Adult golden eagles &gt; 2011 (n = 83):</b>  |          |        |     |         |          |
| Full model: df = 8, BIC = 548.3, AICc = 530.9, R <sup>2</sup> = 0.39, weight = 0.257  |          |        |     |         |          |
| year  | 0.1717   | 1.1802 | 57  | 0.144   | 0.886    |
| latitude  | 0.9727   | 0.3582 | 56  | 2.673   | 0.008    |
| wPDO  | -3.0814  | 1.5912 | 49  | 1.915   | 0.055    |
| sex:male  | 0.4051   | 1.7995 | 45  | 0.222   | 0.825    |
| year:wPDO   | -1.8036  | 1.3218 | 53  | 1.343   | 0.179    |
| <b>Sub-adult golden eagles (n = 72):</b>  |          |        |     |         |          |
| Full model: df = 8, BIC = 600.9, AICc = 585.0, R <sup>2</sup> = 0.49, weight = 0.755  |          |        |     |         |          |
| year  | -4.7449  | 3.4452 | 65  | 1.353   | 0.176    |
| latitude  | 1.5994   | 0.5505 | 66  | 2.851   | 0.004    |
| wPDO  | -2.6644  | 2.0656 | 46  | 1.266   | 0.206    |
| sex:male  | 2.6074   | 5.4413 | 44  | 0.470   | 0.638    |
| year:wPDO   | -9.6732  | 3.6669 | 48  | 2.588   | 0.010    |
| <b>Sub-adult golden eagles &gt; 2011 (n = 67):</b>                                    |          |        |     |         |          |
| Full model: df = 8, BIC = 552.8, AICc = 537.6, R <sup>2</sup> = 0.41, weight = 0.337  |          |        |     |         |          |
| year  | 2.4633   | 2.4982 | 49  | 0.967   | 0.333    |

|           |         |        |    |       |        |
|-----------|---------|--------|----|-------|--------|
| latitude  | 0.6672  | 0.6334 | 46 | 1.032 | 0.302  |
| wPDO      | -8.5069 | 2.6366 | 33 | 3.162 | 0.002  |
| sex:male  | -0.1708 | 5.0829 | 43 | 0.033 | 0.974  |
| year:wPDO | -9.4866 | 2.4671 | 51 | 3.768 | <0.001 |

Juvenile golden eagles (n = 18):

Full model: df =6, BIC = 142.8, AICc = 145.0, R<sup>2</sup> = 0.50, weight = 0.057

|           |         |        |    |       |       |
|-----------|---------|--------|----|-------|-------|
| year      | 1.0892  | 4.4923 | NA | 0.230 | 0.818 |
| latitude  | 0.9474  | 0.7820 | NA | 1.121 | 0.262 |
| wPDO      | 1.4309  | 2.2793 | NA | 0.579 | 0.563 |
| year:wPDO | -6.4330 | 2.3073 | NA | 2.546 | 0.011 |

**Table S.9.**

Model selection results (weight > 0.01) from Case Study 1, ‘long-term data reveal importance of decadal climate patterns on summering behavior in a migratory raptor’, evaluating the influence of year (fixed, continuous, centered and scaled), latitude of summering behavior start (fixed, continuous), eagle sex (fixed, categorical; excluded in ‘Juvenile’ model), eagle age (fixed, categorical; only included in ‘All’ model), mean monthly PDO index for the proceeding winter (PDO; fixed, continuous), and the interaction of year and PDO. We included individual identifier as a random term and fit our linear mixed-effect model by restricted maximum likelihood. Here we present a subset of the models, ranked by model weight, including their degrees of freedom (df), log-likelihood (LL), pseudo-R<sup>2</sup> (Nagelkerke’s modified statistic; R<sup>2</sup>), Bayesian Information Criterion (BIC), Akaike Information Criterion corrected for small sample sizes (AICc), and delta AICc (delta).

| Model covariates                             | df | LL     | R <sup>2</sup> | BIC   | AICc  | delta | weight |
|--|----|--------|----------------|-------|-------|-------|--------|
| <b>All golden eagle age classes:</b>         |    |        |                |       |       |       |        |
| year + latitude + PDO + age + sex + year:PDO | 11 | -681.5 | 0.68           | 1420  | 1387  | 0.00  | 0.712  |
| year + latitude + PDO + age + sex            | 10 | -684.1 | 0.68           | 1420  | 1389  | 2.87  | 0.170  |
| year + latitude + PDO + age + year:PDO       | 9  | -686.6 | 0.68           | 1420  | 1392  | 5.76  | 0.040  |
| year + PDO + age + sex + year:PDO            | 10 | -685.6 | 0.67           | 1423  | 1393  | 6.01  | 0.035  |
| year + latitude + age + sex                  | 9  | -686.9 | 0.67           | 1421  | 1393  | 6.40  | 0.029  |
| <b>Adult golden eagles:</b>                  |    |        |                |       |       |       |        |
| year + latitude + PDO + sex + year:PDO       | 9  | -275.2 | 0.37           | 590.8 | 570.7 | 0.00  | 0.451  |
| year + latitude + PDO + sex                  | 8  | -277.3 | 0.37           | 590.4 | 572.3 | 1.62  | 0.201  |
| year + PDO + sex + year:PDO                  | 8  | -277.5 | 0.33           | 590.8 | 572.7 | 2.00  | 0.166  |
| year + PDO + sex                             | 7  | -279.5 | 0.33           | 590.5 | 574.4 | 3.72  | 0.070  |
| year + latitude + PDO + year:PDO             | 7  | -280.3 | 0.36           | 591.9 | 575.9 | 5.20  | 0.034  |
| latitude + PDO + sex                         | 7  | -280.7 | 0.33           | 592.8 | 576.8 | 6.06  | 0.022  |
| PDO + sex                                    | 6  | -282.3 | 0.30           | 591.5 | 577.5 | 6.85  | 0.015  |
| year + latitude + sex                        | 7  | -281.1 | 0.32           | 593.7 | 577.6 | 6.92  | 0.014  |
| year + latitude + PDO                        | 6  | -282.5 | 0.36           | 591.9 | 577.9 | 7.24  | 0.012  |
| <b>Adult golden eagles &gt; 2011:</b>        |    |        |                |       |       |       |        |
| year + latitude + PDO + sex + year:PDO       | 8  | -256.5 | 0.39           | 548.3 | 530.9 | 0.00  | 0.257  |
| year + latitude + PDO + year:PDO             | 7  | -258.0 | 0.39           | 546.9 | 531.5 | 0.58  | 0.192  |
| latitude + PDO + sex                         | 6  | -259.5 | 0.38           | 545.5 | 532.1 | 1.22  | 0.140  |
| year + latitude + PDO + sex                  | 7  | -258.6 | 0.38           | 548.1 | 532.7 | 1.80  | 0.104  |
| latitude + PDO                               | 5  | -261.0 | 0.38           | 544.1 | 532.8 | 1.93  | 0.098  |
| year + latitude + PDO                        | 6  | -260.1 | 0.38           | 546.8 | 533.4 | 2.48  | 0.074  |
| year + PDO + sex + year:PDO                  | 7  | -259.7 | 0.34           | 550.3 | 534.9 | 3.96  | 0.036  |
| year + PDO + year:PDO                        | 6  | -261.3 | 0.34           | 549.0 | 535.6 | 4.72  | 0.024  |
| year + PDO + sex                             | 6  | -261.7 | 0.33           | 549.9 | 536.4 | 5.54  | 0.016  |
| year + latitude + sex                        | 6  | -262.0 | 0.34           | 550.5 | 537.1 | 6.22  | 0.011  |
| year + PDO                                   | 5  | -263.3 | 0.33           | 548.6 | 537.3 | 6.38  | 0.011  |
| PDO + sex                                    | 5  | -263.3 | 0.31           | 548.7 | 537.3 | 6.44  | 0.010  |

| Sub-adult golden eagles:               |   |        |      |       |       |      |       |
|--|---|--------|------|-------|-------|------|-------|
| year + latitude + PDO + sex + year:PDO | 8 | -283.4 | 0.49 | 600.9 | 585.0 | 0.00 | 0.755 |
| year + latitude + PDO + year:PDO       | 7 | -286.1 | 0.49 | 602.1 | 587.9 | 2.93 | 0.174 |
| year + PDO + sex + year:PDO            | 7 | -287.6 | 0.43 | 605.1 | 590.9 | 5.91 | 0.039 |
| year + latitude + PDO + sex            | 7 | -288.9 | 0.44 | 607.8 | 593.6 | 8.65 | 0.010 |
| year + PDO + year:PDO                  | 6 | -290.2 | 0.43 | 606.0 | 593.7 | 8.68 | 0.010 |
| Sub-adult golden eagles > 2011:        |   |        |      |       |       |      |       |
| year + PDO + sex + year:PDO            | 7 | -260.6 | 0.39 | 550.6 | 537.1 | 0.00 | 0.443 |
| year + latitude + PDO + sex + year:PDO | 8 | -259.6 | 0.40 | 552.8 | 537.6 | 0.55 | 0.337 |
| year + PDO + year:PDO                  | 6 | -263.1 | 0.39 | 551.5 | 539.6 | 2.57 | 0.122 |
| year + latitude + PDO + year:PDO       | 7 | -262.1 | 0.40 | 553.7 | 540.1 | 3.05 | 0.096 |
| Juvenile golden eagles:                |   |        |      |       |       |      |       |
| year + PDO + year:PDO                  | 5 | -63.2  | 0.48 | 140.8 | 141.3 | 0.00 | 0.372 |
| Null                                   | 2 | -69.0  | 0.00 | 143.8 | 142.8 | 1.49 | 0.177 |
| latitude                               | 3 | -67.9  | 0.12 | 144.4 | 143.4 | 2.15 | 0.127 |
| Year                                   | 3 | -68.3  | 0.07 | 145.3 | 144.3 | 3.04 | 0.081 |
| PDO                                    | 3 | -68.6  | 0.04 | 145.9 | 145.0 | 3.67 | 0.059 |
| year + latitude + PDO + year:PDO       | 6 | -62.7  | 0.50 | 142.8 | 145.0 | 3.75 | 0.057 |
| year + PDO                             | 4 | -67.2  | 0.18 | 145.9 | 145.4 | 4.14 | 0.047 |
| year + latitude                        | 4 | -67.5  | 0.15 | 146.5 | 146.1 | 4.76 | 0.034 |
| latitude + PDO                         | 4 | -67.5  | 0.15 | 146.6 | 146.1 | 4.82 | 0.033 |
| year + latitude + PDO                  | 5 | -66.6  | 0.24 | 147.6 | 148.1 | 6.85 | 0.012 |

**Table S.10**

Population-level summary statistics for caribou parturition analysis (case study 2). The trend for mountain caribou was modeled by generalized additive models (GAMs) that include linear latitude and longitude effects and a spline on elevation. The woodland caribou trend models only include latitude and longitude effects. The barren-ground trend model is a linear mixed effects models with random intercepts and slopes (year effect) on herd (sub-population) as a random effect. The  $r^2$  values are the *conditional* as opposed to *marginal*  $r^2$  following (63). The  $p$ -value and trend are on the collective main effect and do not account for variation among herds.

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| Population           | N   | Obs. period | Parturition date, mean | Parturition date, sd | Parturition minimum date | Parturition maximum date | Trend | Trend se | $p$ -value | $r^2$ |
|----------------------|-----|-------------|------------------------|----------------------|--------------------------|--------------------------|-------|----------|------------|-------|
| <b>N. mountain</b>   | 109 | 2000-2017   | 22-May                 | 8.351275             | 5-May                    | 25-Jun                   | -0.68 | 0.220    | 0.002      | 0.26  |
| <b>S. mountain</b>   | 127 | 2006-2015   | 29-May                 | 9.590992             | 30-Apr                   | 21-Jun                   | 0.23  | 0.347    | 0.513      | 0.13  |
| <b>N. boreal</b>     | 78  | 2002-2011   | 18-May                 | 8.320673             | 3-May                    | 11-Jun                   | -1.04 | 0.459    | 0.027      | 0.07  |
| <b>S. boreal</b>     | 398 | 2006-2017   | 13-May                 | 9.183419             | 29-Apr                   | 25-Jun                   | -0.03 | 0.156    | 0.832      | 0.002 |
| <b>Barren-ground</b> | 918 | 2006-2017   | 4-Jun                  | 6.390228             | 22-May                   | 29-Jun                   | -0.43 | 0.061    | <0.001     | 0.44  |

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