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Short communication

Additional data confirms the impact of the COVID19 lockdown on the behavior and fattening of migratory snow geese

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ABSTRACT

The COVID19 lockdown provided a unique opportunity to study the impact of human activities and conservation measures on wildlife. However, most lockdown studies were opportunistic and based on limited data, because this 'natural experiment' was unexpected and short-lasting. Replication of scientific results is the cornerstone of the scientific method and ensures that conclusions from such short-term studies are robust. Here, we test predictions arising from a previous study where we showed the impact of the lockdown-induced reduction in hunting disturbance on the body condition and behavior of greater snow geese (*Anser caerulescens a.*), a species whose management is crucial for the conservation of northern ecosystems. The analysis of two additional years of data confirmed our predictions. The return to a high hunting pressure in springs 2021–2022 (post-lockdown) reduced overall goose body condition compared to the lockdown year. Goose fattening in post-lockdown springs was very similar to pre-lockdown years, differing from 2020 when a high body condition was reached earlier in spring than in any other year. Radio-tracked birds spent more time in profitable but risky agricultural lands in 2021 compared to 2020, as was the case in the pre-lockdown year. Our study provides robust evidence confirming the impacts of spring hunting on greater snow goose physiology. It demonstrates the long-lasting efficiency of the spring conservation hunt established two decades ago to limit the size of the population with the aim of preserving Arctic ecosystems from overgrazing and associated negative impacts on other arctic-nesting birds.

1. Introduction

The global lockdown induced by the COVID-19 pandemic in spring 2020 was an unprecedented opportunity to measure human impacts on wildlife. Indeed, this quasi-experimental, worldwide reduction of human activity has been extensively studied and reviewed (e.g. Bates et al., 2021; Derryberry et al., 2020) and revealed both positive and negative impacts on wildlife. Unsurprisingly, species suffering from the overbearing presence of humans were temporarily relieved from anthropogenic pressures while those benefitting from human presence have suffered from this hiatus in human activity (Manenti et al., 2020).

Researchers invested considerable efforts to evaluate the impacts of this unique 'Anthropause', but this has been a challenging task. First, the lockdown was unexpected and happened rapidly, leaving little time for designing proper protocols. Studies on the effects of the lockdown on wildlife are thus entirely opportunistic and their results are based on a few pre-lockdown years and one "experimental" (i.e. covid lockdown) period (e.g., Seress et al., 2021, among others). Consequently, revisiting the results from these studies with post-lockdown data is essential to confirm or refute their findings. The unexpected nature of this 'manipulation' has restricted the breadth of the data scientists were able to collect, potentially weakening the robustness of their conclusions. For instance, most data on wildlife responses to the lockdown focus on changes in the presence or abundance of species (e.g., Gilby et al., 2021; Vardi et al., 2021). Still, some research teams had the opportunity to measure lockdown effects on life-history traits of wild species (Manenti et al., 2020; Hentati-Sundberg et al., 2021; Corsini et al., 2022) including our work that investigated the impact of the lockdown on physiological changes in an overabundant migratory species, the greater snow goose (*Anser caerulescens atlantica*) (LeTourneux et al., 2021).

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The control of overabundant goose populations is a major conservation challenge that has large implications for the preservation of Arctic ecosystems worldwide (Samelius and Alisauskas, 2009; Flemming et al., 2016, 2019; Hessen et al., 2017). Indeed, overgrazing, grubbing and fecal deposition of expanding goose populations have led to severe degradation of Arctic habitats and plant communities (Srivastava and Jefferies, 1996; Handa et al., 2002; Abraham et al., 2005), disruption of nutrient cycles and plant-soil interactions (Bazely and Jefferies, 1986; Deschamps et al., 2023), and irreversible shifts of ecological communities (Jefferies and Rockwell, 2002). Eutrophication of freshwater wetlands and ponds by goose feces was shown to alter the productivity and community composition of Arctic freshwater ecosystems (Hessen et al., 2017; Jensen et al., 2019). Adverse effects on Arctic species are also commonly reported for a wide range of taxa that share the same habitat and predators (invertebrates: Sherfy and Kirkpatrick, 2003, shorebirds: Duchesne et al., 2021; Flemming et al., 2016, 2019; Lamarre et al., 2017; Beardsell et al., 2023, passerines: Peterson et al., 2014, small mammals: Samelius and Alisauskas, 2009). These strong negative effects could locally exclude vulnerable species, and are often cited as a potential cause for the circumpolar decline of shorebird populations (Flemming et al., 2016, 2019; Beardsell et al., 2023).

Successful conservation of Arctic ecosystems and the species they harbor depends on adequate management of overabundant goose populations in many areas, which is a challenge for conservation agencies (Fox and Madsen, 2017). The special spring conservation harvest of greater snow geese established in 1999 in Canada was an attempt to control this rapidly-growing population and limit its impacts on Arctic habitats (Lefebvre et al., 2017). This conservation measure largely contributed to maintain the population below one million individuals, partly through an indirect effect on reproductive investment (Lefebvre et al., 2017) that was mediated by a reduction of spring body condition (LeTourneux et al., 2021). Spring staging is a critical period in the annual cycle of snow geese because they need to accumulate enough resources for the 3000-km migration to their Arctic breeding grounds and for the subsequent reproduction (Gauthier et al., 2003). In LeTourneux et al. (2021), we took advantage of the COVID lockdown to confirm that the impact of spring hunting on pre-breeding body condition was still effective after 20 years. Our results suggested that this conservation measure could be switched on or off with immediate consequences on goose physiology. However, the evidence was limited by the absence of post-lockdown data, calling for follow-up studies to strengthen these conclusions.

In the current study, we revisit the results of LeTourneux et al. (2021), with additional data on hunting pressure, body condition and use of agricultural lands by staging greater snow geese in two springs following the lockdown (2021 & 2022). Based on our original results, we predicted that an increase in hunting pressure compared to 2020 should decrease goose foraging efficiency and lead to lower body condition during staging compared to the lockdown year. Furthermore, we predicted that geese in lower condition should continue accumulating body reserves later in the season and thus spend more time in agricultural lands despite the high hunting risk associated with this habitat.

2. Methods

2.1. Data acquisition

Geese were captured with baited cannon nets during spring on the staging grounds in 7 years between 2007 and 2022 (2007–2009, 2019–2022) following the procedures described in LeTourneux et al. (2021). Captures took place at Île-aux-Oies (47 N 70 W) in southern Quebec during the last 3 weeks of the snow goose staging period, which occurs from late March to mid-May. All adult females were banded, weighed, and their tarsus and head lengths were measured. Between 29 April and 14 May 2021 and 2022, we captured, weighed, and measured 452 and 249 females, respectively. These data were combined with those presented in LeTourneux et al. (2021) for the period 2007–2020 and were used for the body condition analyses. A subset of 24 females were also marked with GPS collars in 2019 ($n = 10$), 2020 ($n = 7$) and 2021 ($n = 7$) and were used for the habitat use analyses. To compare the physical condition among individuals of different structural size, we obtained an index of body condition independent of size for each bird by correcting body mass with two skeletal measurements (tarsus and head lengths; details in LeTourneux et al. (2021)). Geese gain mass during the migratory stopover (~10 g/day) and they were not always captured on the same dates in different years even though capture periods overlapped between years (Fig. A.1). Consequently, to compare average body condition between years, we corrected the body condition index for the capture date (details in LeTourneux et al., 2021). To determine the proportion of time spent by geese in agricultural land, we used positions of geese marked with GPS radio collars. These positions were obtained at 5-minute intervals. In any given year, we only used birds that spent 3 or more days in the study area (i.e., Île-aux-Oies area and southern shore of St-Lawrence River from Berthier-sur-Mer to Saint-Jean-Port-Joli, see Fig. 2 of LeTourneux et al., 2021) to consider only individuals that used the study area for pre-migratory fattening and exclude those that only passed through the area. We considered that 3 days was a minimum to obtain a reliable sample of the habitat used by geese in the area each year. Annual spring harvest data for 1999–2022 were obtained from Smith and Gendron (2022; see Smith et al., 2022 for estimation method).

2.2. Statistical analyses

With these additional years of data (2021, 2022), we revisited the analyses performed in LeTourneux et al. (2021) for the years 2007 to 2020. First, we contrasted overall spring body condition during the COVID lockdown (2020) with that of pre- (2007–2009, 2019) and post-lockdown years (2021–2022) using a linear mixed model where body mass corrected for size and date was fitted as the response variable, year as a fixed categorical variable and capture IDs as random intercepts. Next, we compared the rate of condition gain of 2020 (lockdown year) with pre- and post-lockdown years using a linear mixed model with body mass corrected for size only as the response variable and year, day of year and their interaction as fixed effects. In this second analysis, the 'year' variable had 5 levels as 2020 (lockdown) was compared to 2021 and 2022 (post-lockdown), 2019 (pre-lockdown) and 2007–2009. We fitted 2019, 2021 and 2022 as separate levels because we were particularly interested in comparing the rate of condition gain during the pandemic to the years just before and after the lockdown. Individual years and captures were fitted as random intercepts in this analysis to account for repeated mass measurements within years and capture groups. Including individual years as random intercepts was necessary in this analysis because of repeated measurements within years in the 2007–2009 level. These analyses were conducted using the lmer function from the lme4 package in R (Bates et al., 2015; R Core Team, 2020).

We determined the proportion of time spent in agricultural lands in 2019, 2020 and 2021 between May 6 and May 24, near the end of the staging period. This was based on the number of locations obtained in agricultural lands compared to other habitats (natural marsh and water) in GPS radio-tracked birds. Spatial location data was treated the same way as in LeTourneux et al. (2021). Namely, we restricted locations to our capture area (Île-aux-Oies and adjacent shoreline of the St-Lawrence River), we removed locations during flight and during the night, and resampled locations at the frequency of one point every 5 min. The main difference with our original analysis is that we considered habitat use data from all individuals in all years ($n = 24$). We could not restrict the analysis to only individuals present in all 3 years as in LeTourneux et al., 2021 because this would have reduced our sample to a single bird. Still, our previous study showed that analyses based on all individuals or only those seen in both years (2019 and 2020) yielded the same results (see Fig. E.1 in LeTourneux et al., 2021). We analyzed the daily proportion of time spent in agricultural lands with a quasi-binomial generalized linear mixed effects model where year was fitted as a categorical fixed effect and bird IDs as random intercepts to account for differences between individuals. This was done with the `glmmPQL` function from the `MASS` package in `R` (Venables and Ripley, 2002; R Core Team, 2020).

3. Results

As expected, the number of geese harvested during spring, an index of hunting pressure, increased in 2021 and 2022 compared to the very low value of 2020 and was also higher than in 2019 (Fig. 1A). In spring 2021, body mass corrected for structural size and adjusted to 12 May was 75 g [95 % CI = 20 g, 129 g] and 104 g [57, 149 g] lower than in 2020 and 2019, respectively. Body mass in 2022 was comparable to 2021 (non-significant difference of 35 g [−15, 86 g]), and was also 110 g [49, 171 g] and 139 g [86, 193 g] lower than in 2020 and 2019, respectively. Daily mass gain did not differ significantly between 2022 (15.4 g/day [6.1, 24.6 g/day]), 2021 (10.3 g/day [3.5, 17.0 g/day]), 2019 (9.8 g/day [2.7, 16.9 g/day]) and 2007–2009 (11.3 g/day [9.3, 13.8 g/day]). However, we found strong evidence that the seasonal increase in body mass in 2022 and 2021 was higher than in 2020, where no mass gain was observed during our capture period (Fig. 1B). Finally, near the end of spring staging in 2021, geese spent more time in agricultural lands than in 2020 ($\beta_{2021-2020} = 0.70$ [0.17, 1.24]) but not compared to 2019 ($\beta_{2021-2019} = -0.44$ [−0.96, 0.09]). They spent on average 47 % of the daytime in agricultural lands in 2021, 31 % in 2020 and 58 % in 2019 (Fig. 1C).

4. Discussion

Extending our analysis of the impacts of hunting on body condition and behavior of spring-staging snow geese with additional post-covid data allowed us to confirm the conclusions of LeTourneux et al. (2021). More importantly, it enabled us to test the hypotheses that we had put forward to explain those results and to validate the long-lasting efficiency of spring hunting in controlling an overabundant population, a conservation measure essential for the preservation of several Arctic ecosystems.

As we predicted based on the results of LeTourneux et al. (2021), the increase in hunting pressure in spring 2021 and 2022 after the lockdown year led to a lower overall body condition of geese compared to 2020. Geese were also in lower body condition in 2021 than in 2019, probably because the hunting pressure was relatively low in 2019 compared to other recent years (Fig. 1A). Indeed, the overall condition observed in post-lockdown years fits well with our previous evaluation of the impact of hunting pressure on pre-migratory body condition (Fig. A.2). In fact, hunting pressure seems to be the main factor affecting goose body condition in spring at the population level, as almost 70 % of the annual variation in average body condition is explained by our proxy of hunting pressure (Appendix A.2). Also, in accordance with our predictions, we observed a gain in mass late during the staging period in 2021 and 2022 similar to other recent years, including in the year just before the lockdown. This differed from 2020 when geese seemed to have reached a plateau in body condition relatively early with no further increase in body condition during the last two weeks prior to migratory departure. These results thus provide strong evidence that the reduction in hunting-related disturbance during the COVID lockdown allowed staging snow geese to reach a high body condition earlier than in years with high hunting pressure.

According to the hypothesis proposed in LeTourneux et al. (2021), geese in lower pre-migratory body condition should spend more time feeding in profitable agricultural lands compared to those in better condition. This is because agricultural lands pose a high mortality risk as goose hunting only occurs in this habitat in spring. Hence, use of this habitat in spring was hypothesized to occur mostly when the need to accumulate endogenous reserves in preparation for migration and reproduction is high (Gauthier et al., 2003; LeTourneux et al., 2021). Our results support this hypothesis as geese spent more time in agricultural lands near the end of staging in 2021 when they were still accumulating body reserves, unlike in 2020.

Based on the lower population-wide body condition of geese in 2021 compared to 2019, we could have expected geese to spend more time in

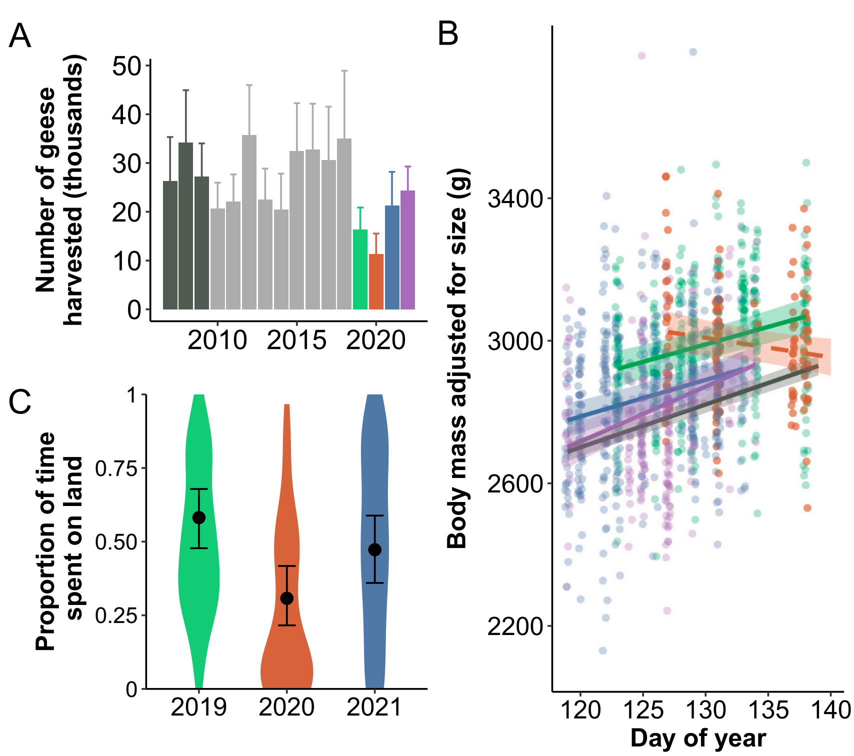

Fig. 1. Impacts of spring hunting on body condition and behavior of spring-staging greater snow geese. In all panels, colors represent years where body condition data is available: 2019 (green); 2020 (orange); 2021 (blue); 2022 (purple); 2007–2009 (dark green). A. Annual spring harvest of greater snow geese. Error bars are the upper 95 % confidence intervals. Data obtained from Smith and Gendron (2022). Gray bars represent springs where no condition data was collected. B. Relationship between body condition index of captured geese and day of the year for 2019 ($n = 378$), 2020 ($n = 195$), 2021 ($n = 452$), 2022 ($n = 249$) and other years (2007–2009, $n = 1974$). Lines are the model prediction for each year along with their 95 % confidence intervals (shading). The dotted line (2020) indicates a non-significant relationship. Individual data points for 2007–2009 were omitted to reduce clutter but are presented in LeTourneux et al. (2021). C. Daily proportion of time spent in agricultural lands near the end of spring staging determined by GPS radio-tracking in 2019 ($n = 10$ birds), 2020 ($n = 7$) and 2021 (n = 7). Black dots are the mean model prediction by year with their 95 % CI. Violins represent the distribution of individual data points. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

agricultural lands in 2021 than in 2019, but it was not the case here. We should remember that our analysis of habitat use relies on a small sample size (24 individuals in total, 7 to 10 per year). Although the use of agricultural lands in our sample should reflect that of the population because snow geese are highly gregarious (Gauthier et al., 1988), individual variation in habitat use or in initial spring body condition may still affect yearly estimates. Despite these limitations, the decrease in body condition in 2021 associated with a return to pre-lockdown level of use of agricultural lands nonetheless suggests that geese faced a trade-off between safety (natural marshes) and food acquisition in a profitable but risky habitat (agricultural lands) and can adjust their behavior to mitigate this risk according to their body condition. The evidence presented here is compelling since the additional data collected in 2021 confirms the interpretations presented in LeTourneux et al. (2021).

We demonstrate that hunting disturbance during spring staging has an immediate but reversible effect on pre-breeding body condition of a migratory waterfowl population. Indeed, the steep reduction of hunting pressure in 2020, and to a lesser extent in 2019, resulted in high goose body condition in those years, while the return to pre-2019 hunting pressure in 2021 and 2022 resulted in a low body condition, comparable to data obtained in the previous decade (2007–2009). Moreover, our results indicate that geese did not habituate to disturbance from spring hunting, despite 20 years of exposure to it. Geese responded instantaneously to changes in the hunting regime, highlighting the high potential of this conservation measure to remain effective in the long run for controlling overabundant populations. In this case, the lack of habituation by geese may stem from the fact that hunting disturbance prevents access to highly profitable food resources (agricultural lands), shortens foraging bouts, and increases flying time, ultimately reducing energy intake and storage (Béchet et al., 2004). Finally, our results show that solely considering harvest mortality when assessing the impact of hunting likely underestimates its overall effect on population dynamics.

5. Conclusion

Studies based on limited or unplanned data sampling should be replicated to reach robust scientific conclusions. This applies to most research on the effects of COVID-related changes in human activities on wildlife because it was an unexpected and short-lasting measure, which increases the risk of obtaining spurious results due to unaccounted confounding factors. While it might not always be possible to replicate a natural experiment, researchers can still make predictions based on their results and test them with additional data. Here, the collection and analysis of additional years of data allowed us to confirm the conclusions of LeTourneux et al. (2021) and provide compelling evidence of the effects of spring hunting activity on the physiology of a wild species. To our knowledge, this is the first study on the impacts of the COVID lockdown on wildlife that has tested the interpretations and hypotheses stemming from their results with additional data.

CRediT authorship contribution statement

Frédéric LeTourneux: Conceptualization, Methodology, Formal Analysis, Investigation, Writing – Original Draft, Writing – Review & Editing, Visualization

Frédéric Dulude-de Broin: Conceptualization, Methodology, Investigation, Writing – Review & Editing, Visualization

Thierry Grandmont: Visualization, Investigation

Marie-Claude Martin: Investigation, Resources

Joël Bêty: Conceptualization, Writing – Review & Editing

Gilles Gauthier: Conceptualization, Writing – Review & Editing, Supervision, Funding acquisition

Pierre Legagneux: Conceptualization, Methodology, Investigation, Writing – Review & Editing, Supervision, Project Administration, Funding acquisition.

Declaration of competing interest

The authors declare they have no known competing interests, financial or otherwise that could have influenced the content of this paper.

Data availability

The data and code for all analyses and figures are available on Mendeley Data: LeTourneux, Frédéric; Legagneux, Pierre; Dulude-de Broin, Frédéric; Grandmont, Thierry; Martin, Marie-Claude; Bêty, Joël; Gauthier, Gilles (2023), "Data for: "Additional data confirms the impact of the COVID19 lockdown on the behavior and fattening of migratory snow geese"", Mendeley Data, V1, doi: 10.17632/ycxxrg8497.1 [http://dx.doi.org/10.17632/ycxxrg8497.1].

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2023.110240.

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