Ecological Economics 189 (2021) 107174

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Birds of a feather lockdown together: Mutual bird-human benefits during a global pandemic

Michael Brock [a], Jacqueline Doremus [b], Liqing Li [c,*]

[a] University of East Anglia, Norwich, UK
[b] Department of Economics, California Polytechnic State University, San Luis Obispo, USA
[c] Department of Economics, California State University Fullerton, Fullerton, 800 N. State College Blvd., CA 92831, USA

ARTICLE INFO

Keywords:
Covid-19
Birds
Bird feeding
Connectivity
Impure public goods

ABSTRACT

Feeding backyard wildlife has impure public good characteristics - it provides satisfaction to humans, both private and public, while also improving bird populations. We document a surge in human interest in connecting with wild birds during lockdowns in response to the Covid-19 pandemic. Using an event-study design, we find large increases in bird engagement began soon after the start of the COVID-19 lockdowns in Spring 2020. Responses were stronger for areas with more bird species. Investments appear sustained, beginning first with bird feeders, then seed and finally baths. Beyond bird survival, bird feeding can potentially enhance humans' connection to nature and improving human well-being. Increases in bird engagement in response to lockdowns may have been good for humans and good for birds.

1. Introduction

The rate and frequency of species decline is now a global challenge, with some of the largest concerns relating to the most economically developed nations on the planet (Strong et al., 2011). Over the last forty years, bird populations have plummeted by 30% across the North American continent, with losses concentrated among migratory birds such as finches, sparrows, warblers, and blackbirds (Rosenberg et al., 2019).[1] For some species, backyard feeding has been shown to help wild birds survive during critical periods when foraging is difficult (Robb et al., 2008).[2] Brock et al. (2017) find the most common motivations for bird feeding are personal enjoyment and helping birds, making bird feeding an "impure public good", a term first coined by Samuelson in Samuelson, 1954. These goods deliver both a private stream of utility to the individual (Clucas et al., 2015) and produce a non-rival advantage to others. In this case, increases in bird feeding could enhance human welfare by connecting humans to nature. They may also aid certain species of wild birds in an era where many face threats to include habitat degradation and loss, climate change, and the use of pesticides (Stanton et al., 2018), which bring benefits to both ecological and social resilience (Dutcher et al., 2007).

In the US, about half of all households feed wild birds on their property (Lepczyk et al., 2012; U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Depart- ment of Commerce, U.S. Census Bureau, 2016; Martinson and Flaspohler, 2003). During Covid-19 lockdowns, time spent at home rose by approximately 15% (See Fig. A1).[3] However, the way in which lockdowns affected people's engagement with backyard birds is unclear. For example, a rapid increase in the unemployment rate and reduced household income may have negatively affected households' spending (Baker et al., 2020).

Despite this, Covid-19 lockdowns may have piqued people's interest in birds through several channels. First, and most obviously, forced time at home reduced the opportunity costs associated with viewing wildlife in one's backyard. Second, bird engagement during the lock- down may

* Corresponding author.
E-mail address: liqing@fullerton.edu (L. Li).

[1] We see a similar pattern in the UK, where farmland and woodland bird numbers have fallen by 45% and 25% respectively since 1970 (Department for Environment, Food, and Rural Affairs, 2020).

[2] Note, however, that Wilcoxen et al. (2015) also found negative effects, including greater infectious disease prevalence, though they conclude that "in general, birds that had access to supplemental food were in better physiological condition."

[3] We call the suite of policies that restricted public access to public and private areas 'lockdowns.'

https://doi.org/10.1016/j.ecolecon.2021.107174
Received 29 January 2021; Received in revised form 19 July 2021; Accepted 26 July 2021
Available online 5 August 2021
0921-8009/

have been especially helpful for human well-being. Recent work finds bird diversity strongly linked to human well-being in Europe (Methorst et al., 2021). Human-wildlife inter- actions, particularly with birds, are known to be soothing and relieve stress (Ratcliffe et al., 2013) whilst also creating urban resilience (Colding and Barthel, 2013).[4] Given the isolation from other humans that lockdowns created (Brodeur et al., 2020), people may have sought out a greater connection to birds and birdsong.[5] Appreciation of birdsong may have been enhanced during lockdown periods due to quieter urban areas.[6]

We use an event study design to measure changes in bird engagement in the US during the first Covid-19 lockdowns in 2020 and estimate how changes in bird engagement may have affected bird populations. If people allocated more time to bird engagement during Covid-19 lockdowns, we might expect an increase in total provision of avian public goods (Andreoni, 1990). Crucially, we believe that lockdown periods served as pivotal opportunities for people to re-engage with their local natural world. By doing so, people may have better recognized why their local environment holds both intrinsic and anthropocentric value, and hence the mutual advantages from a continued engagement with it.

We contribute to a rich literature documenting the benefits from human connectivity to nature and ecosystem services from birds. Birds provide a variety of important ecosystem services (Gaston et al., 2018), including pest control (Crawford and Jennings, 1989), nutrient cycling (Kitchell et al., 1999), and seed dispersal (Garćıa and Martı́nez, 2012). Our results point to a different channel by which birds contribute to ecosystem services, by increasing people's connection to their local environment and likely improving their well-being. We join other work that recognises the benefits such 'connectivity' can yield for human well-being, in general (Dutcher et al., 2007; Cox et al., 2017; Whitburn et al., 2020), and from birds in particular (Cox and Gaston, 2016).[7] Our work suggests policies should reflect the importance of biodiversity to human well-being (Ďıaz et al., 2018), and for local wildlife to act as an ecosystem service that people can utilise for reconnection (Andersson et al., 2014; Ives et al., 2017). Furthermore, people's connection to nature is positively correlated with their pro-environmental behaviour (Whitburn et al., 2020) and preference for environmental protection (Czajkowski et al., 2015). For example, bird watching experience is associated with greater willingness to pay for grassland restoration (Li and Ando, 2020). This evidence suggests that human-bird interaction can promote people's interests in environmental protection over the long-term.

2. Data

We measure bird engagement by using data from three sources: bird feeder enrolment from Project FeederWatch, search interest from Google Trends, and app downloads from "Spiny Software," a bird identification app company. We link these to lockdown timing and bird watching quality by state.

Project FeederWatch: Project FeederWatch is a citizen science program run by Cornell University. We use a five-year panel of weekly bird feeding effort (1/1/2015 to 4/10/2020).[8] Participants commit to recording bird feeder visitors from November to the first week of the next April annually. Users record effort spent on bird identification, classifying the effort into one of four categories: less than an hour, between one and four hours, between four and eight hours, and more than eight hours. We create binary outcome variables for if the user watched birds for more than one, four, or eight hours that week. From Table 1, we see that the vast majority of users spend at least an hour formally identifying birds. About one-fifth of users spend more than four hours and about 5% spend more than eight hours.

Table 1
Summary statistics.

	N	Mean	St. Dev.	Min	Max
Panel A: Project FeederWatch					
1 h	711,916	0.845	0.362	0	1
4 h	711,916	0.218	0.413	0	1
8 h	711,916	0.049	0.216	0	1
Panel B: Google Trends					
Feeder	13,050	16.134	18.649	0	100
Feeder (detrended)	10,400	3.620	21.662	−100	100
Seed	13,050	7.348	11.041	0	100
Seed (detrended)	10,400	1.573	14.334	−100	100
Bath	13,050	9.371	14.242	0	100
Bath (detrended)	10,400	2.330	16.564	−100	100
Panel C: State-level Number of Bird Species					
Species (Project Feeder Watch)	711,916	313.306	49.727	212	483
Species (Google Trends)	13,050	302.24	42.74	212	483

Notes: Project FeederWatch Data from 2015 to 2020 and Google Trends data from 2016 to 2021. Project Feeder- Watch data begin in November and end in the next April annually. Google Trends data first differenced due to seasonality in search.

Google Trends: Google is the most used search engine in the US and thus provides a representative sample of internet search queries via Google Trends.[9] Google Trends supplies an index to show relative numbers of search queries and the popularity of a search term within a given region r and chosen period T. The relative search intensity (RSI) of a search term is defined as the number of daily search for the search term at day t and in region r relative to all other search queries at day t and region r. The Google Trends index for a search term is calculated as the RSI at day t and in region r divided by the maximum RSI for the chosen time period T in that region r then times 100 (Siliverstovs and Wochner, 2018). Thus, this index is scaled from 0 to 100, where 100 indicates the highest search volume for that search term and 0 shows the lowest search volume.

Google Trends data has been widely used in research to assess online search behaviour (Siliverstovs and Wochner, 2018; Rousseau and Deschacht, 2020; Walker et al., 2020). We use a five-year panel (4/10/2016 to 04/04/2021) at state-week level for our search terms "bird feeder," "bird seed" and "bird bath" to study bird engagement via online search. We use data from similar time periods (2016–2020) for Project FeederWatch and Google Trends to ensure our findings are comparable.[10]

App Data: We present descriptive graphs of user downloads of bird identification apps produced by Spiny Software using the change in

[4] Of course, not all bird encounters are positive, particularly in agricultural contexts (Williams et al., 2012; Bennett et al., 2018).

[5] Birdsong may have been particularly valuable, given the genetic relationships between human and bird vocalisations (Vargha-Khadem et al., 2005; Haesler et al., 2007; Lange-Küttner, 2010).

[6] In Guildford, UK, ambient noise reportedly fell by eight decibels during the Covid-19 lockdown (Randall, 2020).

[7] This relationship between well-being and connection to one's local environment holds in the opposite direction as well. Riechers et al. (2020) find that habitat loss leads to a loss of human connection to nature.

[8] Project FeederWatch includes feeders from the US and Canada. Participation is fairly broadly dispersed across the US, though more concentrated on the east coast. See Fig. A4.

[9] It takes more than 95% search engine market share in the US as of 2020.

[10] In addition, as Project FeederWatch is a winter time project and data are available from November to April each year, we drop non-Project FeederWatch months in Google Trends data as a robustness check. Results (Table A1) are consistent with findings using the full-length Google Trends data.

year-over-year downloads for the period January 2020 to May 2020. This data shows the user app purchase in 2020 as the change in purchase compared to the same period in 2019.[11,12]

Lockdown Timing: The Covid-19 pandemic emerged on a global scale in February and March 2020. In response, policymakers issued "shelter in place" and "safer at home" policies, which we call lockdowns, that restricted public access to public and private areas. We use data from Raifman et al. (2020) on the initiation of lockdown timing by state. We supplemented Raifman et al. (2020) with news searches for the timing of lockdowns with weaker restrictions, ending up with 43 of our fifty states with a lockdown of some kind.[13,14]

Measure of Local Bird Diversity: People who have stronger preferences for bird engagement may "vote with their feet" by moving to locations with more bird species (Tiebout, 1956; Klaiber and Phaneuf, 2010). If so, changes in bird engagement may vary with bird diversity. We obtain state-level bird species data from BirdLife International and Handbook of the Birds of the World (2020) to measure local bird diversity. The data provides information regarding the number of bird species in each state. The summary statistics for local bird diversity are available in Table 1. We also show the distribution of bird diversity at the state-level in Fig. 4.[15]

3. Methods

We use an event study to estimate changes in bird engagement after lockdown. In our main specification we characterise lockdown as an event that began at various times across states using a simple estimator:

$$Y_{ist} = \alpha + \beta Post_t + \Gamma_{ist} + \epsilon_{ist} \tag{1}$$

where $Post_t$ is a dummy equal to one for the period after the start of the state's first lockdown. For Project FeederWatch data, the outcome Y_{ist} measures a user i's bird watching effort in year - week t of state s. It is a binary variable equal to one if the user exceeded the effort threshold and zero otherwise. Γ_{ist} includes month, state, and year fixed effects. For Google Trends data, the outcome measures the search intensity of a search term in year - week t of state s and include state and year fixed effects. The data are first-differenced at a lag equal to the period to address seasonal effects in the search intensity in Google Trends data.[16]

Standard errors are clustered at the state level for both analyses.

Next, we estimate how responses vary across areas with more and less bird diversity. We interact the post-event dummy with binary variables for the tercile of the number of bird species, $Species_s$:

$$\begin{aligned} Y_{ist} = {} & \alpha + \beta Post_t + \varphi_1 (Post_t{*}Species_s) \\ & + \varphi_2 (Post_t{*}Species_s) + \Gamma_{ist} + \epsilon_{ist} \end{aligned} \tag{2}$$

where the omitted category is the lowest tercile of the count of bird species in a state.[17] The coefficients φ_1 and φ_2 indicate if, compared to states in the bottom tercile, bird engagement is higher in states with more bird species.

Our specification to estimate the dynamic treatment effect for each dataset is:

$$Y_{st} = \alpha + \sum_{k=0}^{K} \tau_k Z_{st}^k + \Gamma_{st} + \epsilon_{st} \tag{3}$$

Where the variable Z_{st}^{k} is an indicator for the number of k weeks relative to the week of a state's first lockdown ($k = 0$ is the week of initial treatment). Y_{st} measures the outcome variable in state s in year-week t. Γ_{st} includes state, month, and year fixed effects. The coefficients of interest, the τ_k terms, measure changes in search interests in each of the weeks following the beginning of the lockdown. Standard errors are clustered at the state level.

We conduct several tests to probe whether pre-trends could be driving our results. First, we test for pre-trends by extending our baseline specification with leads of treatment associated with weeks before the first lockdown:

$$Y_{st} = \alpha_0 + \sum_{k=-2}^{-K} \sigma_k Z_{st}^k + \sum_{k=0}^{K} \tau_k Z_{st}^k + \delta_y + \gamma_s + \epsilon_{st} \tag{4}$$

We use an F-test suggested by Borusyak and Jaravel (2017) to test the no-pretrend assumption. The model in Eq. 3 considers a restricted model, while Eq. 4 considers a full model. In addition, we do a placebo test, shifting treatment to one year prior to lockdown. These results, shown in Fig. A3, suggest pre-trends are not driving our results. Finally, we plot trends in Fig. 1 to visually inspect for trends.

4. Results

Beginning with the Project FeederWatch data, in Table 2 we see increases in the likelihood users spend more time identifying birds for each of the thresholds. The coefficients report the percentage point change in the likelihood a bird feeder spends more time than the listed threshold. Bird watching of at least one hour increases by 3.2 percentage points or 3.8%. For more than four hours, the change is greater: an increase of 4.0 percentage points or 19%. For eight hours or more, the change in percentage points is smaller, at 1.5, but this corresponds to a 31% increase because the initial share of people who spend more than eight hours watching their feeder is very low. These results suggest that people who already fed birds increased their engagement once their mobility was restricted.

Next, we consider the Google Trends data to assess changes in bird engagement among a broader group of people: internet users. We find the relative search intensity for the search term "bird feeder" is estimated to jump 10.2 points after lockdown. The other search terms also

[11] Spiny Software specialises in mobile apps that encourage human-wildlife interaction through identification of birds and other organisms and birdsong recognition. Note that Spiny Software launched a new version of some of their apps in early March. This may have affected app downloads; for example, users seem to prefer to download recently updated apps (Nayebi et al., 2016). For this reason, we interpret changes in app downloads cautiously.

[12] We also approached Cornell Lab and Audubon seeking access to data on downloads of their popular bird apps but were unable to get access.

[13] As a robustness check, we use the timing of the first lockdown in the United States, which was March 19, 2020 in California, for all states. March 19*th*, 2020 was in the week of March that began on March 15*th*, 2020. Americans reduced their mobility in concert, even though the timing of formal state-level lockdowns varied by as much as 19 days, as seen in Fig. A2. Kapoor et al. (2020) show that lockdown timing is correlated with state characteristics, including median income, education level, race, and age. Modeling changes in behaviour as responding to state-level lockdown timing may introduce selection bias. Modeling lockdown timing as uniform across states introduces measurement error, which should bias our estimate downward. We estimate both models, with the state-level lockdown timing as our main specification. Results are qualitatively the same and available upon request.

[14] Note that some localities instituted lockdowns before states, which we expect to cause measurement error that will bias our estimate toward zero.

[15] As a reviewer pointed out, local bird diversity may change over the year. Future research may explore more on whether bird diversity of different seasons may affect changes in human-bird engagement. We thank the reviewer for this comment.

[16] We set the lag equal to 52 because the data is by week.

[17] Results are qualitatively the same when using quantiles or terciles of important bird habitat.

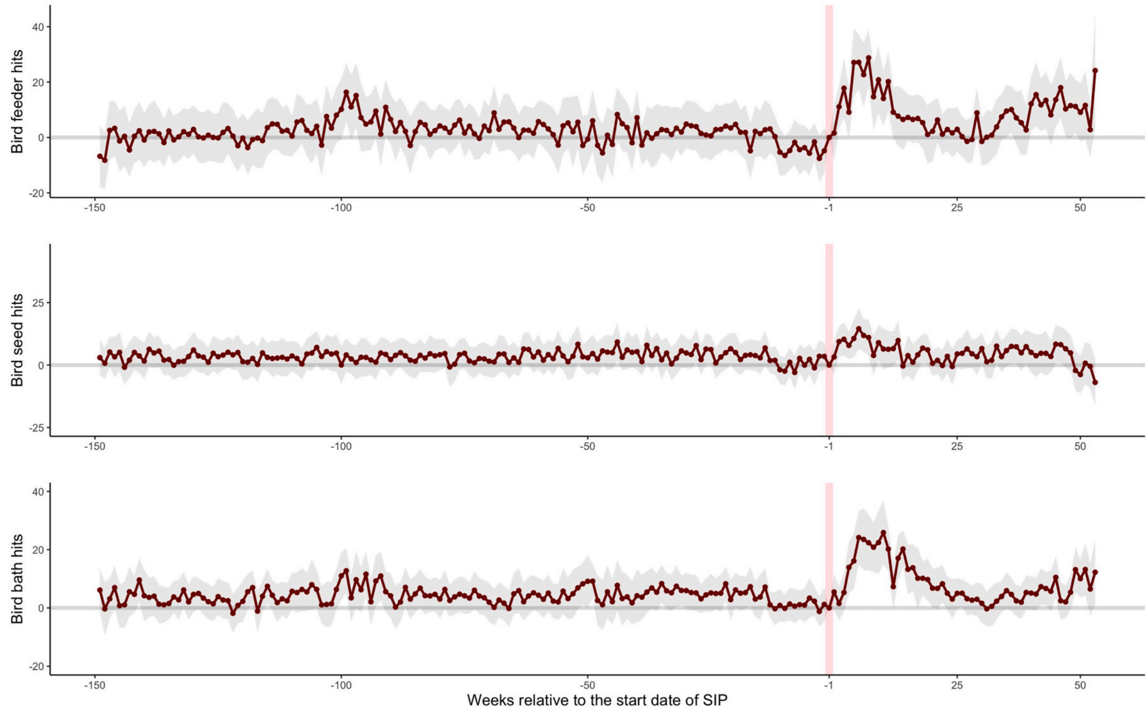

Fig. 1. Graphical assessment of pre-trends: google trends data.
Notes: 2016–2021 Google Trends search term data by state-week for the US. Data is first-differenced to remove seasonality. Search terms include "bird feeder," "bird seed," and "bird bath." The figure shows the estimated coefficients before and after the treatment with 95% confidence intervals. The coefficients are estimated using a staggered event study design.

Table 2
Average response and variation by local bird diversity.

	Post		PostxSpecies1		PostxSpecies2		FE	R^2	Mean	SD
Panel A: Project FeederWatch: $N = 711,916$										
1 h	0.032***	(0.004)					M + S + Y	0.005	0.85	0.36
1 h	0.028***	(0.008)	0.004	(0.009)	0.009	(0.012)	M + S + Y	0.005	0.85	0.36
4 h	0.040***	(0.004)					M + S + Y	0.007	0.22	0.41
4 h	0.040***	(0.008)	0.000	(0.009)	−0.003	(0.013)	M + S + Y	0.007	0.22	0.41
8 h	0.015***	(0.002)					M + S + Y	0.005	0.05	0.22
8 h	0.018***	(0.004)	−0.006	(0.006)	0.000	(0.006)	M + S + Y	0.005	0.05	0.22
Panel B: Google Trends (first differenced): $N = 10,400$										
Feeder	10.171***	(0.879)					S + Y	0.05	3.62	21.66
Feeder	9.184***	(1.148)	−0.552	(1.325)	2.883**	(1.215)	S + Y	0.051	3.62	21.66
Seed	3.684***	(0.591)					S + Y	0.02	1.57	14.33
Seed	3.018***	(0.772)	0.799	(0.891)	1.123	(0.817)	S + Y	0.020	1.57	14.33
Bath	7.073***	(0.677)					S + Y	0.037	2.33	16.56
Bath	6.143***	(0.884)	0.449	(1.021)	2.034**	(0.936)	S + Y	0.037	2.33	16.56

Notes: Project FeederWatch data from 2015 to 2020 and Google Trends data from 2016 to 2021. Each row is a separate regression and includes a constant term (not reported). Species1 and Species2 are binary variables for the second and third tercile of the count of bird species, by state. The omitted category is the lowest tercile. Google Trends data first differenced. The last two columns report the mean and standard deviation of the dependent variable. Standard errors clustered by state reported in parentheses next to coefficient. Fixed effects (FE) at month (M), state (S), or year (Y) level. $*p < 0.1$; $**p < 0.05$; $***p < 0.01$.

increase, albeit by a smaller magnitude: "bird seed" increases by 3.7 points and "bird bath" by 7.1 points.[18,19] To address the concern that the relative search intensity for other household terms may also increase due to reduced mobility and extended hours spending online, we compare the search intensity for bird engagement with other terms (food, cat, water) in Fig. A5 as a placebo test. We do not observe a significant jump in search intensity for these placebo search terms.

For the dynamic treatment effect for internet users, we see in Table 3 that although "bird feeder" and"bird seed" increase almost immediately, increases in relative search frequency for "bird bath" occur about three weeks after the lockdown. This behaviour could be consistent with people increasingly adopting a "guardian" or "warden" perspective on their backyard, adding baths to their initial investments in feeders to make their backyards more attractive to birds. The search interests in bird feeding persist in the first three months of the lockdown despite relaxations of lockdown status. In addition, Fig. 2 shows the effects for "bird feeder" and"bird seed" come back in spring when the feeding season occurs, which suggests that people are still engaging in bird

[18] We follow the convention on how to interpret the estimates based on the Google Trends data Rousseau and Deschacht, 2020.

[19] An F-test comparing a model with and without pre-period indicators fails to reject the null hypothesisthat the pre-period coefficients do not improve model fit. This implies that there are no non-linear pre-trends Borusyak and Jaravel, 2017. Figure 1 also suggests that the parallel trends assumption is satisfied for all three search terms.

Table 3
Dynamic treatment effect, project feederwatch and google trends.

	1	2	3	4	5	6
	1 h	4 h	8 h	Feeder	Seed	Bath
$t = 0$	0.020***	0.025***	0.012***	3.575	1.545	3.372
	(0.005)	(0.004)	(0.002)	(3.71)	(2.58)	(2.31)
$t = 1$	0.031***	0.038***	0.016***	13.064***	7.707***	(0.558)
	(0.004)	(0.004)	(0.002)	(2.999)	(2.201)	(2.446)
$t = 2$	0.038***	0.046***	0.016***	19.761***	8.638***	3.209
	(0.004)	(0.006)	(0.004)	(4.180)	(2.388)	(2.880)
$t = 3$	0.031***	0.048***	0.018***	11.087***	6.173***	11.814***
	(0.008)	(0.011)	(0.004)	(3.988)	(2.155)	(3.523)
$t = 4$				29.064***	8.940***	14.000***
				(4.998)	(2.828)	(4.357)
$t = 5$				29.134***	12.870***	22.093***
				(4.263)	(3.342)	(4.271)
$t = 6$				24.645***	10.149***	21.442***
				(4.791)	(3.110)	(4.561)
$t = 7$				30.738***	9.335***	20.302***
				(3.934)	(2.735)	(3.914)
$t = 8$				16.668***	2.149	18.744***
				(5.541)	(3.572)	(3.908)
$t = 9$				22.785***	7.289***	20.349***
				(5.309)	(2.521)	(4.324)
$t = 10$				16.041***	4.731	23.790***
				(4.204)	(3.258)	(4.664)
$t = 11$				22.157***	4.638*	18.139***
				(4.653)	(2.613)	(3.323)
$t = 12$				11.087***	4.870**	5.186
				(3.501)	(2.314)	(3.577)
$t > 13$				6.428***	2.375***	4.210***
				(1.250)	(0.766)	(0.845)
FE	M + S + Y	M + S + Y	M + S + Y	S + Y	S + Y	S + Y
Observations	711,916	711,916	711,916	10,400	10,400	10,400
R2	0.005	0.007	0.005	0.07	0.026	0.063

Notes: Project FeederWatch data 2015–2020. Google trends data 2016–2021. Estimates include a constant term (not reported). Google Trends data first-differenced. Standard errors clustered by state are in parentheses. Fixed effects (FE) at month (M), state (S), or year (Y) level. $*p < 0.1$; $**p < 0.05$; $***p < 0.01$.

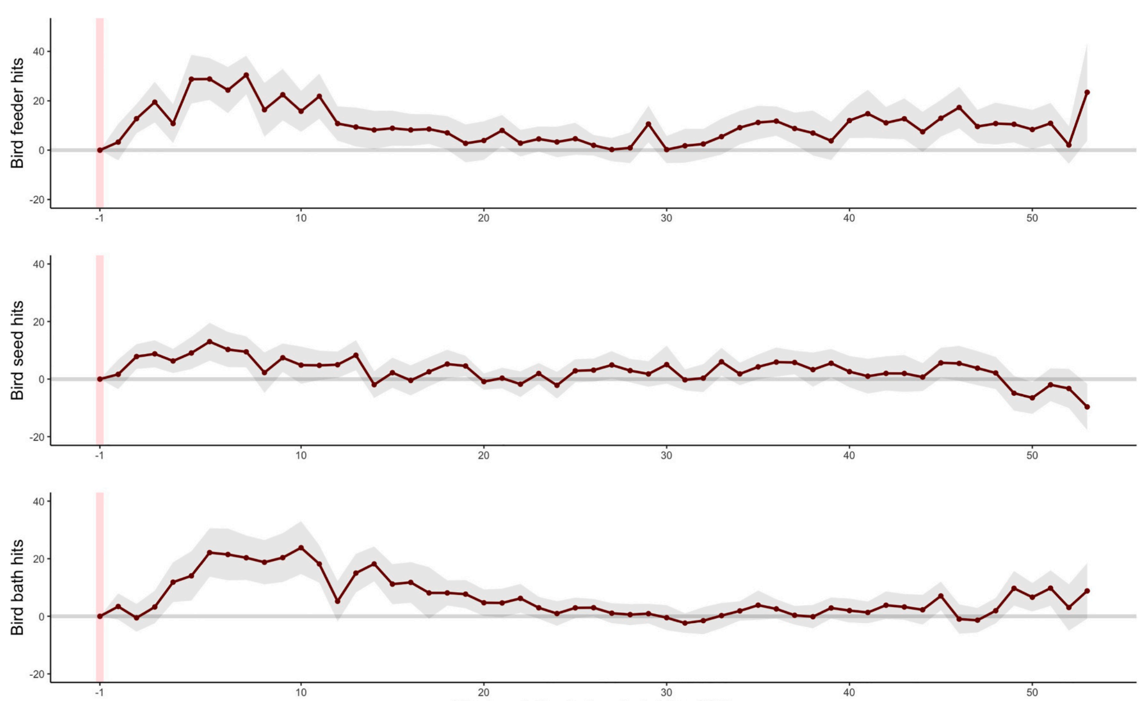

Fig. 2. Estimated dynamic effects - google trends relative search intensity.
Notes: 2016–2021 Google Trends search term data by state-week for the US. Search terms include "bird feeder," "bird seed," and "bird bath." The figure shows the estimated dynamic effects of lockdown on relative search intensity for terms related to bird engagement. Lockdowns vary by state. The x-axis presents the number of weeks relative to the start date of lockdown.

feeding activities almost one year after the initial lockdown. However, we do not observe a similar effect in searching for "bird bath", which makes intuitive sense. As durable goods, people may not need to keep searching for birdbaths after their initial purchase.

Because Google Trends includes all Google users, the data includes people who did not previously feed birds, something we could not capture using Project FeederWatch data. Thus, we interpret our two sets of results as suggesting increases in bird feeding effort along both intensive (Project FeederWatch) and extensive (Google Trends) margins, although we acknowledge an inability to test the latter claim directly.

For both populations, we see some evidence of greater increases in bird engagement in areas with more bird species. In Table 2, the coefficients for terciles of bird species are near zero for the Project FeederWatch data in Panel A. However, in Panel B, we find the highest tercile of bird species is statistically significant for searches for "bird feeder" and "bird bath." This suggests that any effect from bird diversity may be stronger for people on the margin, in terms of bird engagement.

To further assess increases in engagement, we plot data on year-over-year changes in bird app purchases from January to May 2020 against the cumulative number of states with a shelter-in-place policy in Fig. 3. Prior to lockdowns the app had modest growth compared to 2019. Yet as lockdowns became more common, app purchases spiked, and then stabilised. These further suggests that lockdown pushes people with a marginal interest in birds to increase their birding effort after spending time at home. Unlike with Google Trends, for app purchases we can be reasonably sure that each purchase roughly corresponds to one person.

5. Implications

Enhanced environmental quality may not always be the primary driver for bird feeding (Brock et al., 2017), but the 'impure public good' qualities of bird feeding may enhance both human welfare and avian populations during Covid-19 lockdowns. Investments in bird engagement during the pandemic not only satisfy people's own recreational desire and aid their well-being, but also add quality to the surrounding ecological infrastructure, and do so during a critical time for birds (i.e. as they migrate and raise families). Previous ornithological research on supplementary feeding impacts show that bird feeding appears to help a wild bird's health (Wilcoxen et al., 2015), implying that bird feeding during lockdown may change future bird populations.

We used our results on changes in bird engagement during the Covid-19 lockdowns (Table 2), to estimate how bird feeding expenditures might respond in the spring of 2020. From our Google Trends coefficient on "bird feeders," we estimate an increase in the growth of new bird feeders to be 63%. Given annual growth in bird feeding of 4% (Ask Your Target Market, 2015), this implies excess annual growth in bird feeding in 2020 due to Covid-19 lockdowns of 63%*4% = 2.5%. Using this and estimates of changes in bird feeding intensity from the Project FeederWatch coefficients, we predict that increases in bird feeding investment in 2020 can be as large as $292–1533 million (Table 4). Such large increases in expenditure on bird engagement may improve bird survival (Castro et al., 2003; Gonzalez et al., 2006).

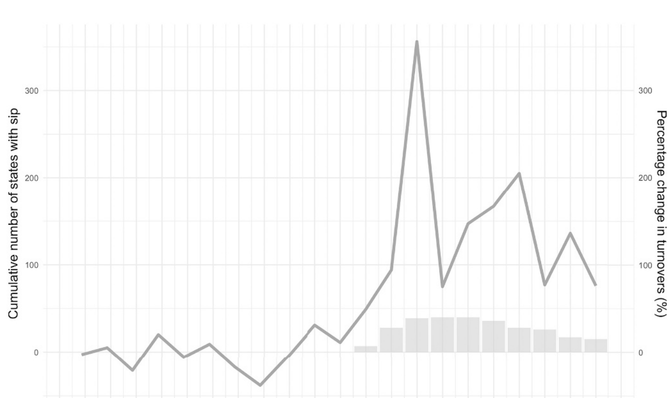

Fig. 3. Change in year-over-year bird app purchases.
Notes: The line is the change in user app purchases as compared to the same period in 2019 for Spiny Software's bird and nature mobile apps. The grey bars represent the cumulative number of states that had initiated a Covid-19 lockdown.

Benefits in psychological well-being from engaging with the natural world are well-documented (Keyes, 2002; Dutcher et al., 2007; Pritchard et al., 2020; Wyles et al., 2019; Yang and Na, 2017).

For Covid-19 and future pandemics, it is possible that regions may find themselves in a fluid state of lesser and greater social restrictions as cases of the virus rise and fall over time. Engagement with backyard birds may play a vital role in offering a safe way to release stress and feel interconnected, proven qualities to enhance subjective well-being (Diener and Biswas-Diener, 2011). Moreover, a potential increase in bird feeder visitors due to increased feeding and lower pollution (Liang et al., 2020) creates a higher payoff for bird feeding, thus reinforcing a positive feedback loop between bird feeding and bird conservation.

Although we find significant elevations in bird engagement immediately following lock- downs, and that these continue after a lockdown status is relaxed, the extent to which these habits persist in the long run remains an open question and should be addressed in future research.

6. Conclusion

In this paper we use an event study design to estimate changes in bird engagement within the US as a consequence of "lockdown" periods created from the coronavirus pandemic in 2020. We use data on bird feeding from a bird identification program, Google users search frequency, and mobile app users of a bird identification app to estimate these changes.

Across each population and scale, we find a significant increase in bird engagement im- mediately following lockdowns. Interestingly, responses in the US are stronger for areas with more bird species and important bird habitat, echoing work to suggest there is a human sensitivity to wildlife diversity and the opportunity to experience variety embedded within bird feeding (Kolstoe and Cameron, 2017). Consistent with a "warden" mentality (Brock et al., 2017), people seek out additional features for their backyards about two weeks after lockdowns. These include information-seeking on seed, bird baths, and the identification of species. Our work joins emerging evidence that supports the sensitivity of humans to birds and the importance of birds to human well-being (Methorst et al., 2021).

These trends have implications for the resilience of declining bird populations, especially given that the investments occurred during a critical time of year. In our regions of study, lockdown periods began when birds migrate and nest, corresponding also to times when extra food provision has been shown to have an important impact on bird mortality and morbidity (Robb et al., 2008). There may be indirect benefits, too. Here, we refer back to the literature on impure public goods and recognise the dual effects that adapting our bird engagement behaviour have had through periods of lockdown. Increases in human-bird interaction in response to lockdowns may have been good for human and good for birds. Since bird engagement can potentially benefit ecological and social resilience, policymakers should consider programs and policies that promote and support bird-feeding and other nature-related activities.

Furthermore, increased interest and investment in local wildlife during lockdown may enhance people's awareness of and willingness to pay for wildlife conservation. Experience with environmental goods affects willingness to pay for ecosystem services (Ready et al., 1995; Czajkowski et al., 2015). Fraser et al. (2020) found that bird watching for rare, migrant birds heavily overlaps with membership to domestic avian conservation charities. Likewise, Li and Ando (2020) find that people who had experience with bird watching are willing to pay more

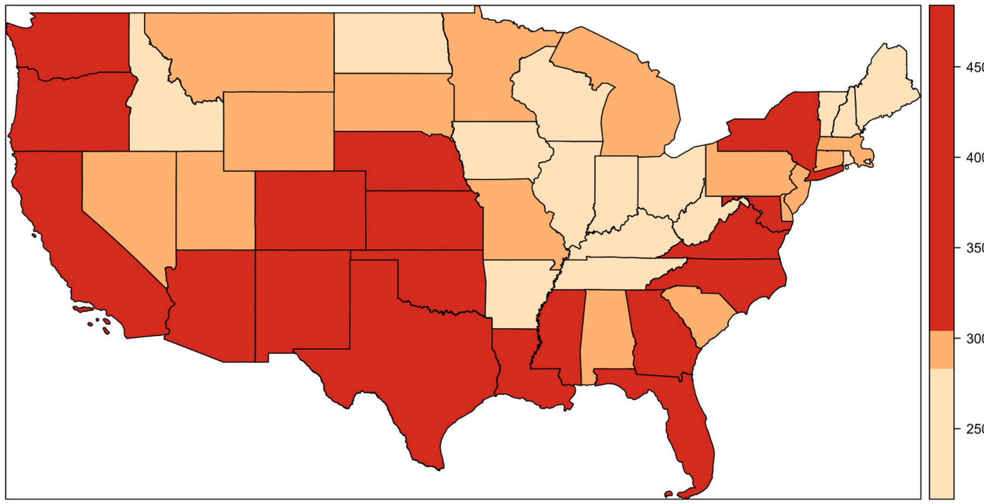

Fig. 4. Distribution of bird diversity in the U.S.
Notes: The figure shows the number of bird species in each state from BirdLife International, https://www. birdlife.org/.

Table 4
Changes in spending from increased feeding during covid-19 lockdowns.

		Scenario A			Scenario B		Scenario C	
	Units	Extensive	Intensive	Total	Intensive	Total	Intensive	Total
Increase in Feeding Effort[1]	%	2.5%[2]	3.8%[3]		17%[4]		31%[5]	
Increase in Annual Spending[6]	$, millions	$ 116[7]	$ 176	$ 292	$806	$1098	1417	$ 1533

Note: we interpret our two sets of results as suggesting increases in bird feeding effort along both intensive (Project FeederWatch) and extensive (Google Trends) margins. Scenario A, B, and C present the change in feeding/spending/avoided death based on intensive margins results for three bird watching effort groups (1 h, 4 h, 8 h) respectively. The total number under each scenario shows the summation of changes in extensive and intensive margins.

[1] To estimate how changes in birdwatching affect birdfeeding, we assume a linear relationship between supplying bird seed and bird- watching. In reality, the relationship is likely much more complex and the effects on mortality more nuanced. For example, increases in birdwatching may lead to more timely refilling bird feeders, the addition of new feeder stations and types, investment in higher quality or different varieties of bird seed, installation of bird baths and drinking stations, and planting bird-friendly trees and shrubs. If, however, there is excess supply of bird food and bird amenities, increased birdwatching may not be accompanied by increases in access to bird seed. Given declining bird populations and habitat loss, excess demand by birds for bird seed and amenities seems more likely.

[2] The Google Trends coefficient for feeders was 10.2 and the average for the panel was 16.2. If Google Trends reflects new bird feeders, this is a 63% increase in the growth of bird feeders, which leads to a 2.5% increase in feeding effort(63%*4% = 2.5%).The annual growth rate in the number of bird feeders is 4% (Ask Your Target Market, 2015).

[3] Lower estimate of change by existing feeders based on results in Table?? Panel A (PFW).

[4] The average amount of birdwatching across the panel is 0.845*0.5 h + 0.218*3 h + 0.049*8 = 88 min/birdwatcher using summary statistics for share of feeders in each bin and the midpoint for the 1 and 4 h bins from Table A1. In Table 1 we see an increase of 3pp for 1 h bin, 4 pp. for 4 h bin and 1.5 pp. for 8 h bin. This corresponds to an average increase in birdwatching of 30 min*0.03 + 180 min*0.04 + 480 min*0.015 = 15.3 min. Given the average amount is 88 min/birdwatcher, the percentage increase is 15.8 min/88 min = 17%.

[5] Higher estimate of change by existing feeders based on results in Table?? Panel A (PFW).

[6] In 2015, the average annual spending was $37.88 for bird feeders and $59.73 for seed (Ask Your Target Market, 2015). We assumed persistence of post-lockdown change in feeding from April to December (3 quarters), making the prorated annual total spending per household 75%*$(37.88 + 59.73) = $73.20.

[7] In 2015, 52 million households fed birds. Given 4% annual growth since 2015, the number of feeders in March 2020, before lockdowns, was 63 million households. Given the prorated spending and a 2.5% increase during lockdown, the estimated change in feeders from Covid- 19 lockdowns would be 63 M*2.5% = 1.575 M and the estimated change in spending by new bird feeders would be 1.575 M*$73.30 = $116 million.

for grassland restoration. Thus, people who interacted with their backyard birds, and thus gained an interest in birds during the lockdown period, may now be more inclined to support conservation efforts or donate to wildlife charities. Indeed, annual charitable giving to animal welfare charities increased by 2.5% in 2020, while total charitable giving only increased by 1% (Blackbaud Institute, 2021). Such evidence implies that human-bird interaction may promote people's interests in environmental protection in the long-term. Future research should therefore explore the impact of bird engagement on willingness to pay for general wildlife conservation and donations.

However, there are even broader implications from our work. Relatively speaking, the extent of bird feeding is still poorly understood by ornithologists, despite its importance for bird populations. Humans feed birds not just during the winter, and therefore trying to understanding how and when such local engagement occurs is already recognized as important within the literature (Goddard et al., 2013). Moreover, these interactions may provide an essential boost to human well-being that forms a substitute mechanism for delivering consistency, purpose, and routine to our lives. This may be particularly pivotal during a pandemic, which requires people to endure periods with restricted (human) interaction. Thus, amidst the enormous mental health and economic costs from lockdowns, an increase in human-wildlife connectivity like those we document here may support both human and bird resilience. Future research should assess the long-term persistence of these engagements and their dynamic implications for both humans and birds.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors offer sincere thanks and gratitude to David Bonter and Wesley Hochachka at Project FeederWatch at Cornell University and Hilary Lind at Spiny Software for sharing data to support this work, to Bree and Matt Lang for early feedback and support, and to Grace Westle for excellent research assistance.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2021.107174.

References

Andersson, Erik, Barthel, Stephan, Borgström, Sara, Colding, Johan, Elmqvist, Thomas, Folke, Carl, Gren, Asa, 2014. Reconnecting cities to the biosphere: steward- ship of green infrastructure and urban ecosystem services. Ambio 43 (4), 445–453.
Andreoni, James, 1990. Impure altruism and donations to public goods: a theory of warm-glow giving. Econ. J. 100 (401), 464–477.
Ask Your Target Market, 2015. USA Wild Bird Feeding Industry Yearly Research 2015. Technical Report, Wild Bird Feeding Industry. Accessed: 2020-04-20.
Baker, Scott R., Farrokhnia, Robert A., Meyer, Steffen, Pagel, Michaela, Yannelis, Constantine, 2020. How Does Household Spending Respond to an Epidemic? Consumption During the 2020 Covid-19 Pandemic. Technical Report, National Bureau of Economic Re- search.
Bennett, Michael T., Gong, Yazhen, Scarpa, Riccardo, 2018. Hungry birds and an- gry farmers: using choice experiments to assess "eco-compensation" for coastal wetlands protection in China. Ecol. Econ. 154, 71–87.
BirdLife International and Handbook of the Birds of the World, 2020. Bird Species Distribution Maps of the World. Version 2020.1. Available at. http://datazone.birdlife.org/species/requestdis.
Blackbaud Institute, January 2021. The Blackbaud Institute Index - Your Source for Charitable Giving Trends.
Borusyak, Kirill, Jaravel, Xavier, 2017. Revisiting event study designs, 2826228. Available at SSRN.
Brock, Michael, Perino, Grischa, Sugden, Robert, 2017. The warden attitude: an investigation of the value of interaction with everyday wildlife. Environ. Resour. Econ. 67 (1), 127–155.
Brodeur, Abel, Clark, Andrew E., Flèche, Sarah, Powdthavee, Nattavudh, 2020. COVID-19, Lockdowns and Well-Being: Evidence from Google Trends, CEP Discussion Paper No 1693.
Castro, Isabel, Brunton, Dianne H., Mason, Karen M., Ebert, Brice, Griffiths, Richard, 2003. Life history traits and food supplementation affect productivity in a translocated population of the endangered Hihi (Stitchbird, *Notiomystis cincta*). Biol. Conserv. 114 (2), 271–280.
Clucas, Barbara, Rabotyagov, Sergey, Marzluff, John M., 2015. How much is that birdie in my backyard? A cross-continental economic valuation of native urban songbirds. Urban Ecosyst. 18 (1), 251–266.
Colding, Johan, Barthel, Stephan, 2013. The potential of 'urban green commons' in the resilience building of cities. Ecol. Econ. 86, 156–166.
Cox, Daniel T.C., Gaston, Kevin J., 2016. Urban bird feeding: connecting people with nature. PLoS One 11 (7).
Cox, Danielle T.C., Shanahan, Danielle F., Hudson, Hannah L., Plummer, Kate E., Siriwardena, Gavin M., Fuller, Richard A., Anderson, Karen, Hancock, Steven, Gaston, Kevin J., 2017. Doses of neighborhood nature: the benefits for mental health of living with nature. Bioscience. 67 (2), 147–155.
Crawford, Hewlette S., Jennings, Daniel T., 1989. Predation by birds on spruce budworm Choristoneura fumiferana: functional, numerical, and total responses. Ecology 70 (1), 152–163.
Czajkowski, Miko-laj, Hanley, Nick, LaRiviere, Jacob, 2015. The effects of experience on preferences: theory and empirics for environmental public goods. Am. J. Agric. Econ. 97 (1), 333–351.
Department for Environment, Food, and Rural Affairs, 2020. Wild Bird Populations in the UK, 1970–2019.
Díaz, Sandra, Pascual, Unai, Stenseke, Marie, Martín-L'opez, Berta, Wat- son, Robert T., Molnar, Zsolt, Hill, Rosemary, Chan, Kai M.A., Baste, Ivar A., Brau- man, Kate A., et al., 2018. Assessing nature's contributions to people. Science 359 (6373), 270–272.
Diener, Ed, Biswas-Diener, Robert, 2011. Happiness: Unlocking the Mysteries of Psycho-Logical Wealth. John Wiley & Sons.
Dutcher, Daniel D., Finley, James C., Luloff, A.E., Johnson, Janet Buttolph, 2007. Connectivity with nature as a measure of environmental values. Environ. Behav. 39 (4), 474–493.
Fraser, I., Brock, M., Roberts, D., Law, C., 2020. An Economic Analysis of Twitching Behavior and Species Rarity. Working Paper.
García, Daniel, Martínez, Daniel, 2012. Species richness matters for the quality of ecosystem services: a test using seed dispersal by frugivorous birds. Proc. R. Soc. B Biol. Sci. *279* (1740), 3106–3113.
Gaston, Kevin J., Cox, Daniel T.C., Canavelli, Sonia B., García, Daniel, Hughes, Baz, Maas, Bea, Martínez, Daniel, Ogada, Darcy, Inger, Richard, 2018. Population abundance and ecosystem service provision: the case of birds. BioScience 68 (4), 264–272.
Goddard, Mark A., Dougill, Andrew J., Benton, Tim G., 2013. Why garden for wildlife? Social and ecological drivers, motivations and barriers for biodiversity management in resi- dential landscapes. Ecol. Econ. 86, 258–273.
Gonzalez, Luis Mariano, Margalida, Antoni, Sanchez, Roberto, Oria, Javier, 2006. Supplementary feeding as an effective tool for improving breeding success in the Spanish imperial eagle (*Aquila adalberti*). Biol. Conserv. 129 (4), 477–486.
Haesler, Sebastian, Rochefort, Christelle, Georgi, Benjamin, Licznerski, Pawel, Osten, Pavel, Scharff, Constance, 2007. Incomplete and inaccurate vocal imitation after knockdown of FoxP2 in songbird basal ganglia nucleus Area X. PLoS Biol. *5* (12).
Ives, Christopher D., Giusti, Matteo, Fischer, Joern, Abson, David J., Klaniecki, Kathleen, Dorninger, Christian, Laudan, Josefine, Barthel, Stephan, nethy, Paivi Aber-, Martín-L'opez, Berta, et al., 2017. Human–nature connection: a multidisciplinary review. Curr. Opin. Environ. Sustain. 26, 106–113.
Kapoor, Rolly, Rho, Haedong, Sangha, Kinpritma, Sharma, Bhavyaa, Shenoy, Ajay, Xu, Guanghong, 2020. God is in the Rain: The Impact of Rainfall-Induced Early Social Distancing on COVID-19 Outbreaks, 3605549. Available at SSRN.
Keyes, Corey L.M., 2002. The mental health continuum: From languishing to flourishing in life. J. Health Soc. Behav. 207–222.
Kitchell, James F., Schindler, Daniel E., Herwig, Brian R., Post, David M., Olson, Mark H., Oldham, Michael, 1999. Nutrient cycling at the landscape scale: the role of diel foraging migrations by geese at the Bosque del Apache National Wildlife Refuge, New Mexico. Limnol. Oceanogr. 44 (3part2), 828–836.
Klaiber, H. Allen, Phaneuf, Daniel J., 2010. Valuing open space in a residential sorting model of the Twin Cities. J. Environ. Econ. Manag. 60 (2), 57–77.
Kolstoe, Sonja, Cameron, Trudy Ann, 2017. The non-market value of birding sites and the marginal value of additional species: biodiversity in a random utility model of site choice by eBird members. Ecol. Econ. 137, 1–12.
Lange-Küttner, Christiane, 2010. Discrimination of sea-bird sounds vs. garden-bird songs: do Scottish and German-Saxon infants show the same preferential looking behaviour as adults? Eur. J. Dev. Psychol. 7 (5), 578–602.
Lepczyk, Christopher A., Warren, Paige S., Machabée, Louis, Kinzig, Ann P., Mertig, Angela G., 2012. Who feeds the birds. Stud. Avian Biol. 45, 267–284.
Li, Liqing, Ando, Amy W., 2020. Early Exposure to Nature and Willingness-to-Pay for Conservation. Working paper.
Liang, Yuanning, Rudik, Ivan J., Zou, Eric, Johnston, Alison, Rodewald, Amanda D., Kling, Catherine L., 2020. Conservation Co-Benefits from Air Pollution Regulation. Tech- nical Report, National Bureau of Economic Research.
Martinson, Tammie J., Flaspohler, David J., 2003. Winter bird feeding and localized predation on simulated bark-dwelling arthropods. Wildl. Soc. Bull. 510–516.
Methorst, Joel, Rehdanz, Katrin, Mueller, Thomas, Hansjürgens, Bernd, Bonn, Aletta, Böhning-Gaese, Katrin, 2021. The importance of species diversity for human well-being in Europe. Ecol. Econ. *181*, 106917.
Nayebi, M., Adams, B., Ruhe, G., 2016. Release practices for Mobile Apps – What do users and developers think?. In: 2016 IEEE 23rd International Conference on Software Analysis, Evolution, and Reengineering (SANER), Vol. 1, pp. 552–562.
Pritchard, Alison, Richardson, Miles, Sheffield, David, McEwan, Kirsten, 2020. The relationship between nature connectedness and eudaimonic well-being: A meta-analysis. J. Happiness Stud. 21 (3), 1145–1167.
Raifman, J., Nocka, K., Jones, D., Bor, J., Lipson, S., Jay, J., Chan, P., 2020. COVID-19 US State Policy Database. www.tinyurl.com/statepolicies.
Randall, Ian, April 2020. Can you Hear the Birds Singing? Huge Reduction in Ambient Noise from Traffic and Aircraft during the Coronavirus Lockdown Means that Birdsong Is more Audible than Ever, Experts Find. Daily Mail.
Ratcliffe, Eleanor, Gatersleben, Birgitta, Sowden, Paul T., 2013. Bird sounds and their contributions to perceived attention restoration and stress recovery. J. Environ. Psychol. 36, 221–228.
Ready, Richard C., Whitehead, John C., Blomquist, Glenn C., 1995. Contingent valuation when respondents are ambivalent. J. Environ. Econ. Manag. 29 (2), 181–196.
Riechers, Maraja, Balázsi, Ágnes, Abson, David, Fischer, Joern, 2020. The influence of landscape change on multiple dimensions of human–nature connectedness. Ecol. Soc. *25* (3).
Robb, Gillian N., McDonald, Robbie A., Chamberlain, Dan E., Bearhop, Stuart, 2008. Food for thought: supplementary feeding as a driver of ecological change in avian popula- tions. Front. Ecol. Environ. 6 (9), 476–484.
Rosenberg, Kenneth V., Dokter, Adriaan M., Blancher, Peter J., Sauer, John R., Smith, Adam C., Smith, Paul A., Stanton, Jessica C., Panjabi, Arvind, Helft, Laura, Parr, Michael, et al., 2019. Decline of the North American avifauna. Science 366 (6461), 120–124.
Rousseau, Sandra, Deschacht, Nick, 2020. Public awareness of nature and the environment during the COVID-19 crisis. Environ. Resour. Econ. 76 (4), 1149–1159.
Samuelson, Paul A., 1954. The pure theory of public expenditure. Rev. Econ. Stat. 387–389.
Siliverstovs, Boriss, Wochner, Daniel S., 2018. Google Trends and reality: do the proportions match?: appraising the informational value of online search behavior: evidence from Swiss tourism regions. J. Econ. Behav. Organ. 145, 1–23.
Stanton, R.L., Morrissey, C.A., Clark, R.G., 2018. Analysis of trends and agricultural drivers of farmland bird declines in North America: A review. Agric. Ecosyst. Environ. 254, 244–254.
Strong, Aaron, Tschirhart, John, Finnoff, David, 2011. Is economic growth for the birds? Ecol. Econ. 70 (7), 1375–1380.

Tiebout, Charles M., 1956. A pure theory of local expenditures. J. Polit. Econ. 64 (5), 416–424.
U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Depart- ment of Commerce, U.S. Census Bureau, 2016. 2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. Technical Report.
Vargha-Khadem, Faraneh, Gadian, David G., Copp, Andrew, Mishkin, Mortimer, 2005. FOXP2 and the neuroanatomy of speech and language. Nat. Rev. Neurosci. 6 (2), 131–138.
Walker, Abigail, Hopkins, Claire, Surda, Pavol, 2020. The use of google trends to investigate the loss of smell related searches during COVID-19 outbreak. In: International Forum of Allergy & Rhinology. Wiley Online Library.
Whitburn, Julie, Linklater, Wayne, Abrahamse, Wokje, 2020. Meta-analysis of human connection to nature and proenvironmental behavior. Conserv. Biol. 34 (1), 180–193.
Wilcoxen, Travis E., Horn, David J., Hogan, Brianna M., Hubble, Cody N., Huber, Sarah J., Flamm, Joseph, Knott, Madeline, Lundstrom, Lisa, Salik, Faaria, Wassenhove, Saman- tha J., et al., 2015. Effects of bird-feeding activities on the health of wild birds. Conserv. Physiol. 3 (1).
Williams, Kristen J., Reeson, Andrew F., Drielsma, Michael J., Love, Jamie, 2012. Optimised whole-landscape ecological metrics for effective delivery of connectivity-focused conservation incentive payments. Ecol. Econ. 81, 48–59.
Wyles, Kayleigh J., White, Mathew P., Hattam, Caroline, Pahl, Sabine, King, Haney, Austen, Melanie, 2019. Are some natural environments more psychologically beneficial than others? The importance of type and quality on connectedness to nature and psycho- logical restoration. Environ. Behav. 51 (2), 111–143.
Yang, Ji-Hye, Na, Min-Hwan, 2017. The Effects of Urban Farming on well-being of the elderly: a focus on social, psychological, and environmental well-being. Int. J. Soc. Sci. Humanit. *7* (2).