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Birds of a Feather Lockdown Together: Mutual bird-human benefits during a global pandemic

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Birds of a Feather Lockdown Together: Mutual bird-human benefits during a global pandemic

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Abstract

Feeding backyard wildlife has impure public good characteristics – it can satisfy specific human motivations whilst 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 that begin very soon after lockdown. Responses are stronger for areas with more important bird habitat. Investments appear sustained, at the first beginning with bird feeders, then seed and baths. We estimate that lockdown feeding may increase spring populations of birds that visit feeders by 1-5% and avoided the death of 30,000-161,000 fledgling birds, potentially more than offsetting declines in bird populations from habitat loss and pesticide use for 2020. Bird engagement in response to lockdown likely enhanced resilience for both humans and birds alike.

JEL: Q26, Q57, H41

Keywords: Covid-19, birds, bird feeding, connectivity, impure public goods

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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] Though policy is evolving to reflect the importance of biodiversity to human wellbeing (Díaz et al., 2018), people privately reconnecting with nature may also help. 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, yet feeding constitutes an "impure public good", a term first coined by Samuelson in 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 may help wild birds in the face of habitat degradation and pesticide use, key factors in their decline (Stanton et al., 2018).

In the US, about half of all households feed wild birds on their property (Lepczyk et al., 2012). During Covid-19 lockdown, time spent at home rose by approximately 15% (See Figure A1).[3] However, the way in which Covid-19 lockdowns have affected people's engagement with backyard birds is unclear. On the one hand, a rapid increase in the unemployment rate and reduced household income due to the pandemic lockdown may negatively affect households' spending (Baker et al., 2020), including bird feeding investment. On the other hand, Covid-19 lockdowns may pique people's interest in birds through several channels.

First, and most obviously, forced time at home reduces the opportunity costs associated with viewing wildlife in one's backyard. Second, bird engagement during the lockdown may be 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 interactions, particularly with birds, are known to be soothing and relieve stress (Ratcliffe et al., 2013) whilst also

[1] We see a similar pattern in the UK, where farmland and woodland bird numbers have fallen by 45% and 25% respectively since 1970 (DEFRA, 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.'

creating urban resilience (Colding and Barthel, 2013).[4] However, given the isolation from other humans that lockdowns create (Brodeur et al., 2020), people may seek out a greater connection to birds and birdsong. Birdsong may be particularly valuable given genetic relationships between human and bird vocalisations (Vargha-Khadem et al., 2005; Haesler et al., 2007; Lange-Küttner, 2010) and enhanced by quieter streets.[5]

We use an event study design to measure changes in bird engagement in the US during lockdown, and estimate the implications of such changes for bird populations. If people allocate 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 may serve as pivotal opportunities for people to re-engage with their local natural world. By doing so, they may better recognise why their local environment holds both intrinsic and anthropocentric value and mutual advantages from continued engagement with it.

2 Data

We measure bird engagement using data from three sources: bird feeder enrolment from Project Feeder Watch, search interest from Google Trends, and app downloads from a bird identification app company. We link these to lockdown timing and important bird habitat by state.

Project FeederWatch (PFW): PFW 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).[6] Participants commit to recording bird feeder visitors from November to the first week of April for each season. 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 A1, we see that the vast majority of users spend at least an hour formally identifying birds. About one-fifth of users spend more

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

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

[6] PFW includes feeders from the US and Canada. Participation is fairly broadly dispersed across the US, though more concentrated on the east coast. See Figure A4.

than four hours and about 5% spend more than eight hours.

Google Trends: Google as the most used search engine in the US[7] provides an unbiased sample of search query volumes data via Google Trends. 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 (6/28/2015 to 6/21/2020) 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 (2015-2020) for PFW and Google Trends to ensure our findings are comparable.[8]

App Data: We present descriptive graphs of user downloads of bird identification apps produced by Spiny Software using the change in 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.[9,10]

Lockdown Timing: The Covid-19 pandemic emerged on a global scale in February and

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

[8]In addition, as PFW is a winter time project and data are available from November to April each year, we drop non-PFW months in Google Trends data as a robustness check. Results (Table A4) are consistent with findings using the full-length Google Trends data.

[9]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.

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

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. In our preferred specification, we use the timing of the first lockdown in the United States, which was March 19, 2020 in California, for all states.[11] Americans reduced their mobility in concert, even though the timing of formal state-level lockdowns varied by as much as 19 days. Figure A1 shows the average percentage change in mobility in the United States, which has a steep change in the week of March 15^{th}, 2020.[13]

Important Bird Areas (IBA): BirdLife International has mapped areas critical to bird habitat, creating Important Bird Areas.[14] People who have stronger preference for bird engagement may "vote with their feet" for their preferred location (Tiebout, 1956; Klaiber and Phaneuf, 2010) and sort themselves to locations with more bird habitat. Thus, changes in bird engagement may vary with the quality of bird habitats. We extract the count of IBAs for each state in the US from the Audubon website to measure bird habitat quality in each state and to explore the how changes in bird engagement vary with changes in IBAs.[15]

3 Methods

We use an event study to estimate changes in bird engagement after lockdown. In our main specification we characterise the lockdown as a national event using a simple estimator:[16]

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

where $Post_t$ is a dummy equal to one for the period after March 15th, 2020. For PFW

[11] March 19^{th}, 2020 was in the week of March that began on March 15^{th}, 2020. As a robustness check, 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 states with a lockdown of some kind.[12] Figure A2 shows the change in mobility for each state.

[13] Mobility reports show that most Americans changed their behavior at around the same time, the week of March 15th, 2020. Kapoor et al. (2020) show that lockdown timing is correlated with state characteristics, including median income, education level, race, and age. Modeling changes in behavior 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 uniform timing as our main specification and state-level timing reported in the Appendix.

[14] IBAs can be of local, national, or global conservation importance. We include all types of IBAs in our analysis. See BirdLife's website: http://datazone.birdlife.org/site/ibacritglob for details on criteria.

[15] We used each state's page on Audubon's website, https://www.audubon.org/important-bird-areas, accessed 5/20/2020, and counted all types of IBAs.

[16] We use a staggered event design as a robustness check.

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

Next, we estimate how responses vary across areas with more and less important bird habitat. We interact the post-event dummy with binary variables for the tercile of important bird area, IBA_s:

$$Y_{ist} = \alpha + \beta Post_t + \phi_1(Post_t * IBA1_s) + \phi_2(Post_t * IBA2_s) + \Gamma_{ist} + \epsilon_{ist} \tag{2}$$

where the omitted category is the lowest tercile of the count of important bird areas.[18] 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 habitat.

Our specification to estimate the dynamic treatment effect for the Google Trends data 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 March 15^{th}, the first lockdown in the United States ($k = 0$ 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 independent tests for pre-trends by extending our baseline specification with leads of treatment associated with weeks before the first lockdown:

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

If the coefficients associated with periods preceding treatment are not jointly statistically

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

[18] Results are qualitatively the same when using quantiles.

different from zero, we fail to reject the parallel trends assumption.

4 Results

Beginning with the PFW data, in Table 1 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 3.1 percentage points or 3.7%. For more than four hours, the change is greater: an increase of 4.3 percentage points or 19.5%. For eight hours or more, the change in percentage points is smaller, at 1.6, but this corresponds to a 33% increase because the initial share of people who spend more than eight hours watching their feeder is very low. Based on Figure A3, changes in each threshold are not driven by pre-trends. 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 Google Trend index, which measures search popularity, for the search term 'bird feeder" is estimated as a jump of 20.9 points after lockdown. The other search terms also increase, albeit by a smaller magnitude: "bird seed" increases by 7.7 points and "bird bath" by 9.7 points.[19] Figure 1 suggests that the parallel trends assumption is satisfied for all three search terms.To address the concern that search intensity for other 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 Figure 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 2 that although "bird feeder" increases immediately, increases in relative search frequency for "bird seed" and "bird bath" occur about two weeks after the lockdown. The response doubles in week two, increases further in week three, and then appears to stabilise despite relaxations of lockdown status.[20]

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

[20] Results hold with a staggered event study design, where lockdown timing varies across states (see Table A3). Comparing results across tables A2 and A3 show that results are consistent across a single event or staggered event design. Coefficient estimates are smaller for the single event design, consistent with measurement error.

This behaviour could be consistent with people increasingly adopting a "guardian" or "warden" perspective on their backyard, adding specialty seed and baths to their initial investments in feeders to make habitat enjoyable for birds.

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

For both populations, we see greater increases in areas with more important bird habitat (shown in Table 1). The coefficient on the interaction term for the middle tercile is positive and statistically significant at the 10% level for all effort thresholds in Panel A of Table 1. The coefficient on the interaction term for the top tercile is also positive, however we only reject the null for the lowest effort threshold, one hour, and the search term "bird feeder." This suggests the effect 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 Figure 2. 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 be the primary driver for bird feeding (Brock et al., 2017), but as an impure public good the potential enhancement to bird populations during Covid-19 lockdowns can be large. The investments in bird engagement during pandemic lockdowns not only satisfy people's own recreational desire but also add quality to the surrounding ecological infrastructure, and do so during a critical time for birds, as they migrate and raise families. Previous ornithological research on supplementary feeding impacts show that bird-feeding activities appear to help a wild bird's health (Wilcoxen et al., 2015). Based on our estimates of changes in bird engagement during lockdown in Table 1, we predict in Table 3 that increases in bird feeding investment in 2020 can be as large as $324-1,710 million. Such large increase in expenditure on bird engagement may help bird populations through avoiding the death of 30,000-161,000 fledgling birds in spring 2020, or 1-5% of the feeder bird population. Given the annualized decline of sparrows of about 0.8%, the largest decline reported in Rosenberg et al. (2019), this could more than offset declines in bird populations from habitat loss and pesticide use for 2020.

Beyond habitat and food provision, 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. Thus, people who interacted with birds in their backyards and gained interests in birds during the lockdown period may 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 giving only increased by 1% (Blackbaud Institute, 2021). Future research can explore the impact of bird engagement on willingness to pay for general wildlife conservation and donations.

Feeding and watching backyard birds improve human well-being beyond bird survival, and, for humans, the psychological well-being from engaging with the natural world in this way are well-documented (Keyes 2002; Dutcher et al. 2007; Yang and Na 2017). Given the anticipated nature of Covid-19, 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 wellbeing (Diener and Biswas-Diener, 2011). Moreover, a potential increase in the likelihood of birds visiting feeders (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 lockdowns, and that these continue after a lockdown status is relaxed, the extent to which these habits persist in the long run is 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 United States as a consequence of "lockdown" periods created from the coronavirus pandemic. 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 immediately following lockdowns. Interestingly, responses in the United States are stronger for areas with more 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, 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). Together, this body of work suggests that bird population resilience should receive more attention as a policy goal.

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, if greater awareness of and a connection to wildlife ignite further support for habitat conservation. Here, we refer back to the literature on impure public goods and recognise the dual effects of adaptation our purchasing patterns have through periods of lockdown. These signal not only a heightened private motivation to engage with backyard wildlife but also, whether consciously or subconsciously, an intensification of contributions to a public good.

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 understanding how and when such local engagement occurs is already recognised as important within the literature (Goddard et al., 2013). Moreover, these interactions may provide an essential boost to human wellbeing 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 persistence of these engagements and their dynamic implications for both humans and birds.

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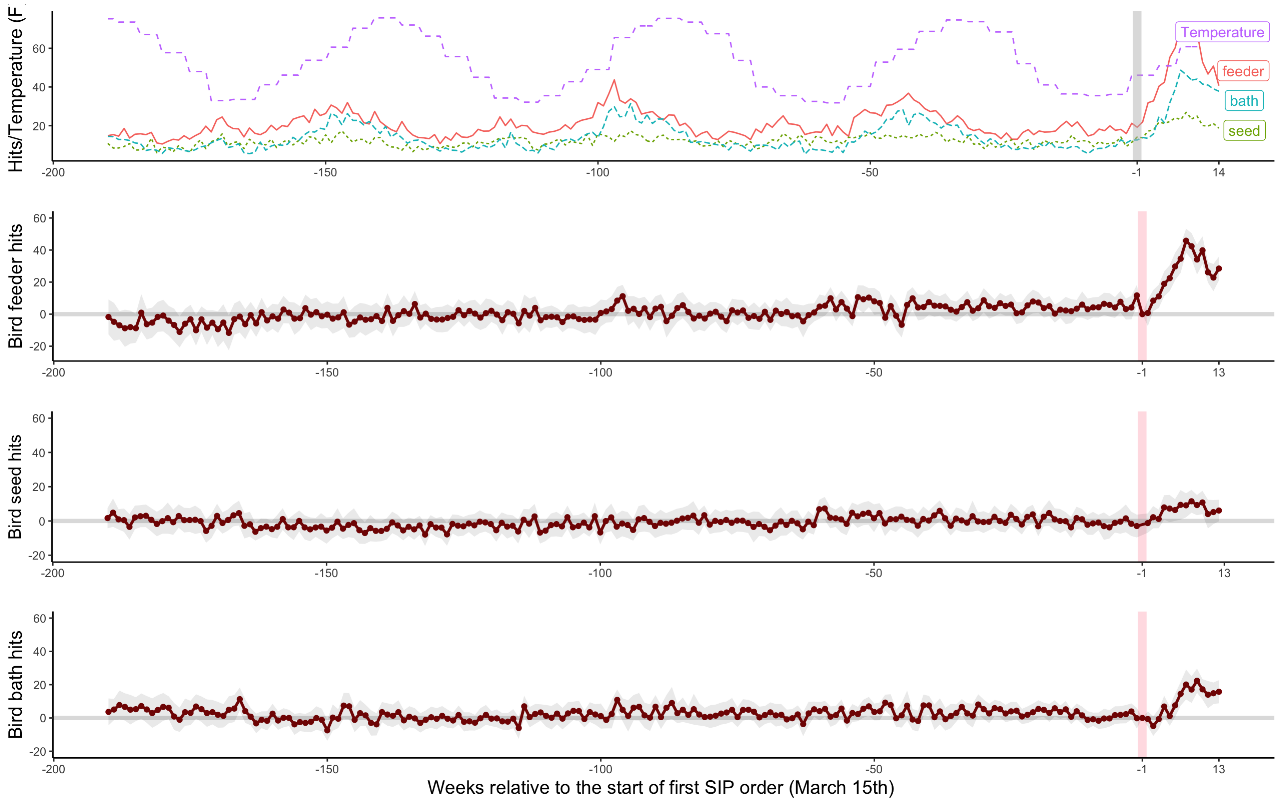
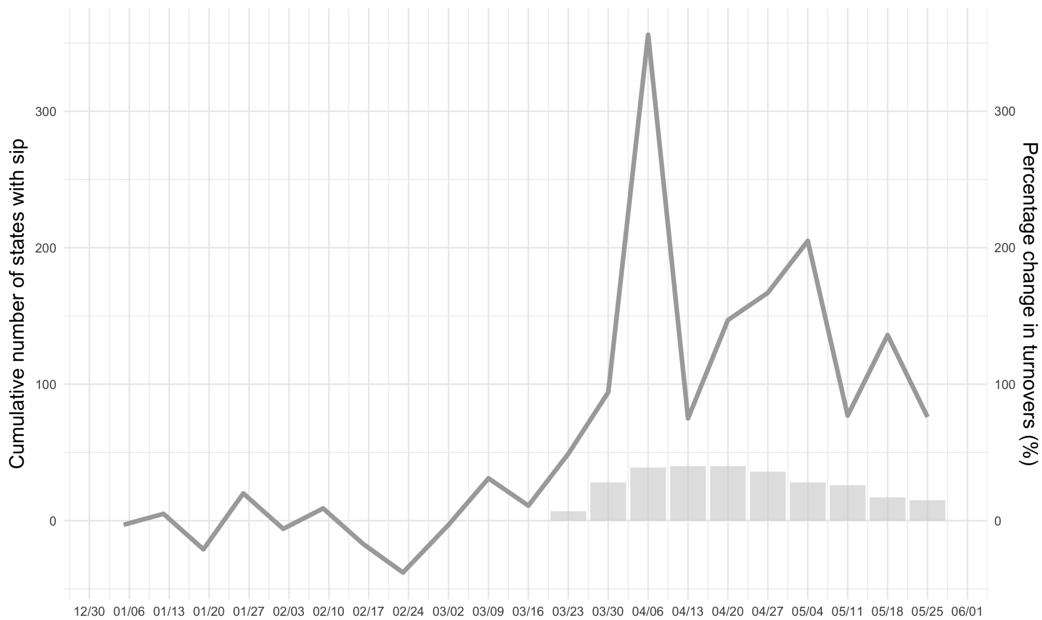


Figure 1: Raw and Estimated Google Trends Search Indices

Notes: 2015-2020 Google Trends search term data by state-week for the US. Search terms include “bird feeder,” “bird seed,” and “bird bath.” The y-axis shows the average search index for that week, across states. The maximum value is 100. The top panel includes the average temperature in the US for that week and raw search data. The bottom three panels are first-differenced to remove seasonality.

Figure 2: 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 shelter-in-place (SIP) policy.

Table 1: Variation in US Response by Important Bird Area

	post		postxIBA1		postxIBA2		FE	R2	Mean	SD
Panel A: Project Feeder Watch: N=712,027										
1 hour	0.031***	(0.003)					M+S+Y	0.005	0.85	0.36
1 hour	0.020***	(0.005)	0.015*	(0.008)	0.018***	(0.007)	M+S+Y	0.005	0.85	0.36
4 hours	0.043***	(0.004)					M+S+Y	0.007	0.22	0.41
4 hours	0.034***	(0.006)	0.014*	(0.008)	0.012	(0.008)	M+S+Y	0.007	0.22	0.41
8 hours	0.016***	(0.002)					M+S+Y	0.005	0.05	0.22
8 hours	0.012***	(0.004)	0.008*	(0.004)	0.002	(0.006)	M+S+Y	0.005	0.05	0.22
Panel B: Google Trends (first differenced): N=10,400										
Feeder	20.947***	(1.740)					S+Y	0.067	1.66	21.06
Feeder	17.053***	(2.335)	3.872	(3.394)	8.037**	(3.705)	S+Y	0.069	1.66	21.06
Seed	7.739***	(0.819)					S+Y	0.012	0.70	16.47
Seed	7.774***	(1.470)	-0.585	(1.805)	0.413	(1.579)	S+Y	0.012	0.70	16.47
Bath	9.715***	(1.211)					S+Y	0.029	1.15	17.46
Bath	8.779***	(1.700)	-0.416	(2.210)	3.119	(2.336)	S+Y	0.03	1.15	17.46

Notes: Data from 2015-2020. Each row is a separate regression and includes a constant term (not reported). IBA1 and IBA2 are binary variables for the second and third tercile of the count of BirdLife International's important bird areas, 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. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Table 2: Dynamic Response to Lockdowns

	(1) Feeder		(2) Seed		(3) Bath	
t=0	-4.420	(3.443)	0.130	(2.296)	-1.292	(2.181)
t=1	3.280	(3.126)	3.570	(2.368)	-5.512**	(2.677)
t=2	5.920*	(3.161)	2.550*	(1.530)	-1.352	(2.303)
t=3	13.760***	(3.145)	9.290***	(2.779)	6.208**	(2.467)
t=4	17.280***	(3.395)	8.630***	(2.556)	0.488	(2.338)
t=5	24.600***	(3.693)	7.770***	(2.114)	6.908**	(3.108)
t=6	29.420***	(3.316)	10.770***	(2.853)	13.848***	(3.038)
t=7	40.660***	(3.493)	10.510***	(2.075)	19.428***	(4.026)
t=8	37.220***	(3.027)	12.870***	(2.370)	16.428***	(3.432)
t=9	28.940***	(4.246)	10.650***	(2.553)	21.708***	(3.080)
t=10	34.680***	(3.837)	12.170***	(2.394)	16.548***	(2.964)
t=11	20.960***	(3.268)	5.390*	(2.993)	13.328***	(3.710)
t=12	17.660***	(3.527)	6.570***	(2.118)	14.188***	(2.892)
t=13	23.300***	(3.811)	7.470***	(2.227)	15.088***	(2.865)
R2	0.092		0.016		0.045	

Notes: First-differenced data from Google Trends for 2015-2020, N=10,400. Fixed effects at the state and year level. Standard errors clustered by state reported in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Table 3: Spending and Fledgling Success from Increased Feeding during Covid-19 Lockdowns

	Units	Extensive	Scenario A		Scenario B		Scenario C	
			Intensive	Total	Intensive	Total	Intensive	Total
Increase in Feeding Effort[1]	%	4%[2]	3%[3]		18%[4]		33%[5]	
Increase in Annual Spending[6]	$, millions	$ 185[7]	$ 139	$ 324	$834	$1,158	1,528	$ 1,714
Avoided Death[8]	Birds	17,360	13,020	30,380	78,120	108,500	143,220	160,580

[1] To estimate how changes in birdwatching affect birdfeeding, we assume a linear relationship between supplying bird seed and birdwatching. 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 21, the same as the average for the panel. If Google Trends reflects new bird feeders, this is a 100% increase in the growth of bird feeders, which is 4% (**(alias?)**).

[3] Lower estimate of change by existing feeders based on results in Table1 Panel A (PFW)

[4] The average amount of birdwatching across the panel is 0.845*0.5h + 0.218*3h + 0.049*8 = 88 min/birdwatcher using summary statistics for share of feeders in each bin and the midpoint for the 1 and 4 hour bins from Table A1. In Table 1 we see an increase of 3 pp for 1 h bin, 4 pp for 4 h bin and 1.6pp for 8 h bin. This corresponds to an average increase in birdwatching of 30 min*.03 + 180 min*.04 + 480 min*.016 = 15.8 min. Given the average amount is 88 min/birdwatcher, the percentage increase is 15.8 min/88 min = 18%.

[5] Higher estimate of change by existing feeders based on results in Table1 Panel A (PFW)

[6] In 2015, 52 million households fed birds and average annual spending was $37.88 for bird feeders and $59.73 for seed (**(alias?)**). We assumed persistence of post-lockdown change in feeding from April to December (3 quarters), making the prorated annual total spending per household 75%*$(37.88+59.73)=$73.20.

[7] 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 4% increase during lockdown, the estimated change in spending by new bird feeders would be 63M*$73.30*4%=$185 million.

[8] The total population of feeder birds was estimated as 3.1M using Rosenberg et al. (2019) and restricting to finches and sparrows, as birds from these families were the most commonly encountered at feeders by Horn et al. (2014). The change in fledgling mortality is 14% from Robb et al. (2008). Thus, for example, at the extensive margin, as the feeding effort increases by 4%, the estimated avoided death would be 3.1M*14*%4%=17,360

Online Appendix

Tables

Figures

Table A1: Summary Statistics

	N	Mean	St. Dev.	Min	Max
Panel A: Subnational, Project Feeder Watch					
1 hour	712,027	0.845	0.362	0	1
4 hours	712,027	0.218	0.413	0	1
8 hours	712,027	0.049	0.216	0	1
Panel B: Subnational, Google Trends					
Feeder	13,050	22.061	18.102	0	100
Feeder (detrended)	10,400	1.66	21.057	-100	100
Seed	13,050	12.148	12.651	0	100
Seed (detrended)	10,400	0.704	16.468	-100	100
Bath	13,050	14.234	15.103	0	100
Bath (detrended)	10,400	1.149	17.46	-100	100

Notes: Data from 2015-2020. PFW data begin in November and end in April each season. Subnational Google Trends data first differenced due to seasonality in search.

Table A2: Dynamic Treatment Effect, Single Event, PFW

	(1) 1 hour	(2) 4 hours	(3) 8 hours
t=0	0.012***	0.022***	0.010***
	(0.004)	(0.003)	(0.002)
t=1	0.035***	0.043***	0.017***
	(0.003)	(0.004)	(0.002)
t=2	0.043***	0.051***	0.019***
	(0.003)	(0.005)	(0.003)
t=3	0.028***	0.046***	0.019***
	(0.005)	(0.006)	(0.003)
t=4	0.021*	0.048***	0.022***
	(0.012)	(0.015)	(0.008)
R2	0.005	0.007	0.005

Notes: 2015-2020, N=712,027. Data at the user-state-week level for the US. Estimates include a constant term and fixed effects at the month, state, and year level. Standard errors clustered by state are in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Table A3: Dynamic Treatment Effect, Staggered Events, PFW and GT

	1	2	3	4	5	6
	1 hour	4 hours	8 hours	Feeder	Seed	Bath
t=0	0.030***	0.037***	0.015***	2.258	4.512**	0.209
	(0.004)	(0.004)	(0.002)	(2.770)	(1.899)	(2.929)
t=1	0.038***	0.045***	0.015***	18.258***	5.838***	1.186
	(0.004)	(0.006)	(0.004)	(3.927)	(2.178)	(2.101)
t=2	0.032***	0.048***	0.019***	20.026***	7.675***	3.418
	(0.008)	(0.011)	(0.004)	(3.487)	(2.805)	(2.943)
t=3	0.041***	0.020	0.023**	20.375***	10.466***	9.511***
	(0.014)	(0.017)	(0.011)	(3.821)	(2.277)	(3.307)
t=4				34.933***	8.722***	16.767***
				(3.508)	(2.523)	(3.755)
t=5				38.770***	12.419***	14.674***
				(3.364)	(2.536)	(3.936)
t=6				35.816***	11.861***	19.232***
				(3.331)	(2.265)	(3.514)
t=7				35.398***	9.442***	21.372***
				(4.245)	(2.316)	(2.805)
t=8				27.793***	13.535***	19.511***
				(3.614)	(1.865)	(3.667)
t=9				25.979***	6.512**	21.162***
				(3.640)	(2.904)	(3.435)
t=10				21.199***	7.343**	15.554***
				(3.301)	(3.499)	(3.027)
t=11				18.814***	7.045**	14.367***
				(4.909)	(2.836)	(3.264)
t>11				22.510**	2.152	21.579***
				(9.541)	(3.503)	(6.747)
FE	M+S+Y	M+S+Y	M+S+Y	S+Y	S+Y	S+Y
Observations	679,829	679,829	679,829	8,944	8,944	8,944
R2	0.005	0.007	0.005	0.103	0.019	0.052

Notes: 2015-2020. Estimates include a constant term (not reported). Google Trends data first-differenced. In the staggered event study, only states with lockdown policies are included in the analysis (43 states). Standard errors clustered by state are in parentheses. $*p < 0.1; **p < 0.05; ***p < 0.01$.

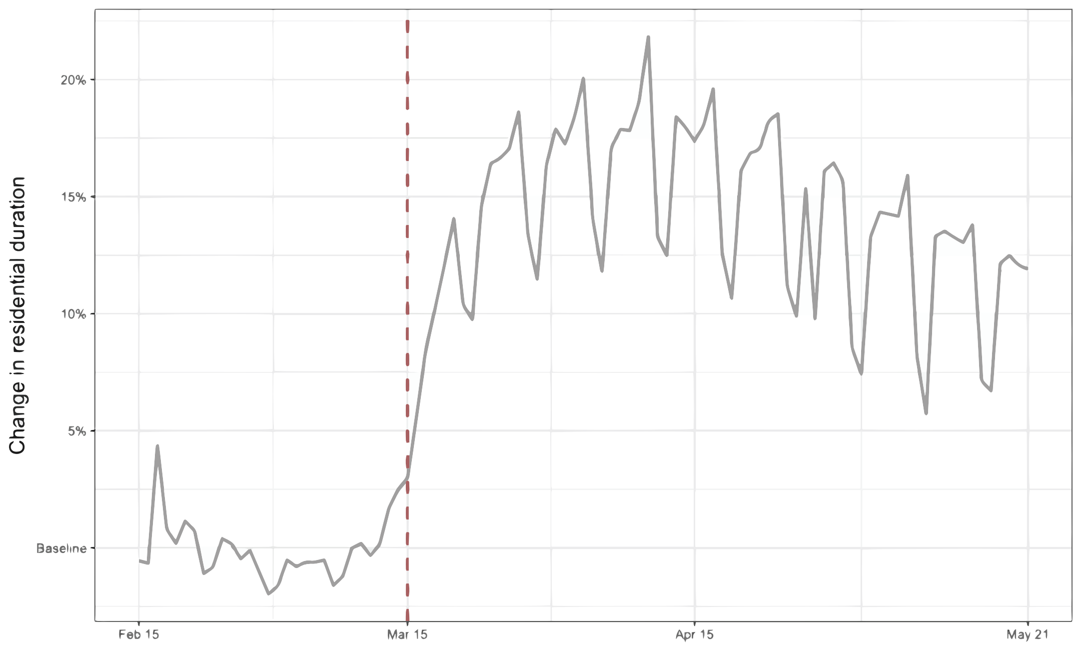
Table A4: Variation in US Response by Important Bird Area - Robustness check for Google Trends

	post		postxIBA1		postxIBA2		FE	R2
Google Trends (first differenced): N=6,050								
Feeder	21.025***	(1.720)					S+Y	0.091
Feeder	17.550***	(2.135)	3.260	(3.203)	7.344*	(3.754)	S+Y	0.093
Seed	7.858***	(0.807)					S+Y	0.018
Seed	7.184***	(1.393)	0.372	(1.725)	1.656	(1.539)	S+Y	0.018
Bath	8.895***	(1.227)					S+Y	0.037
Bath	7.578***	(1.889)	0.774	(2.317)	3.190	(2.551)	S+Y	0.038

Notes:Since Project FeederWatch is a winter time citizen science program and only provides data from Nov to the next April annually, we also get matching time frames from Google Trends by dropping non-PFW months as a robustness check. Results are consistent with findings in Table 1 Panel B.

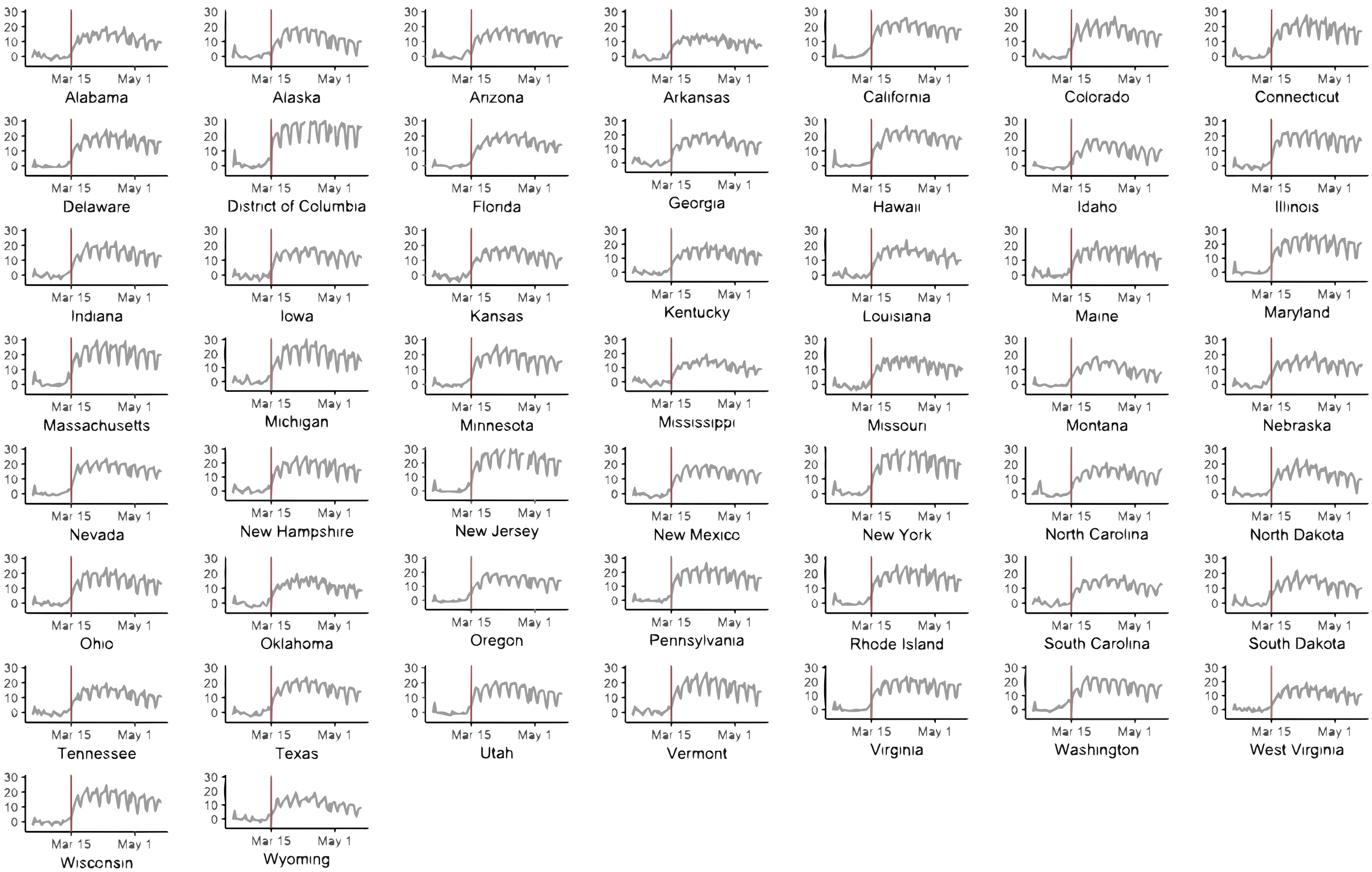
$*p < 0.1; **p < 0.05; ***p < 0.01$.

Figure A1: Community Mobility in the US, National



Notes: Data from Google Community Mobility Reports, created using data from users who turn on Location History: https://www.google.com/covid19/mobility/.

Figure A2: Community Mobility in the US, by State



Notes: Data from Google Community Mobility Reports, created using data from users who turn on Location History: https://www.google.com/covid19/mobility/.

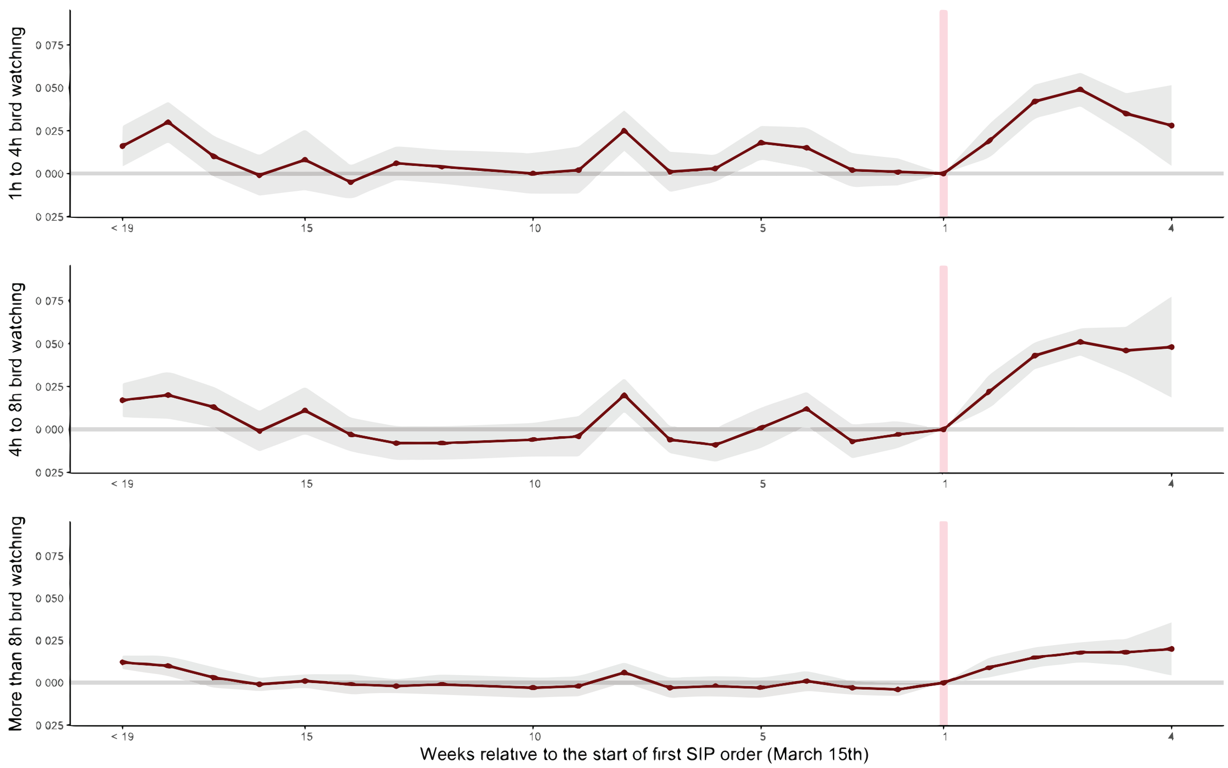


Figure A3: Change in Bird Identification Effort by Existing PFW Feeders

Notes: 2015-2020 data from Project Feeder Watch at the user-week level. Coefficients for Equation 3 plotted, showing the number of weeks relative to the start of the first shelter-in-place order. Respondents classify effort bird watching, resulting in three binary outcome variables associated with the three panels.

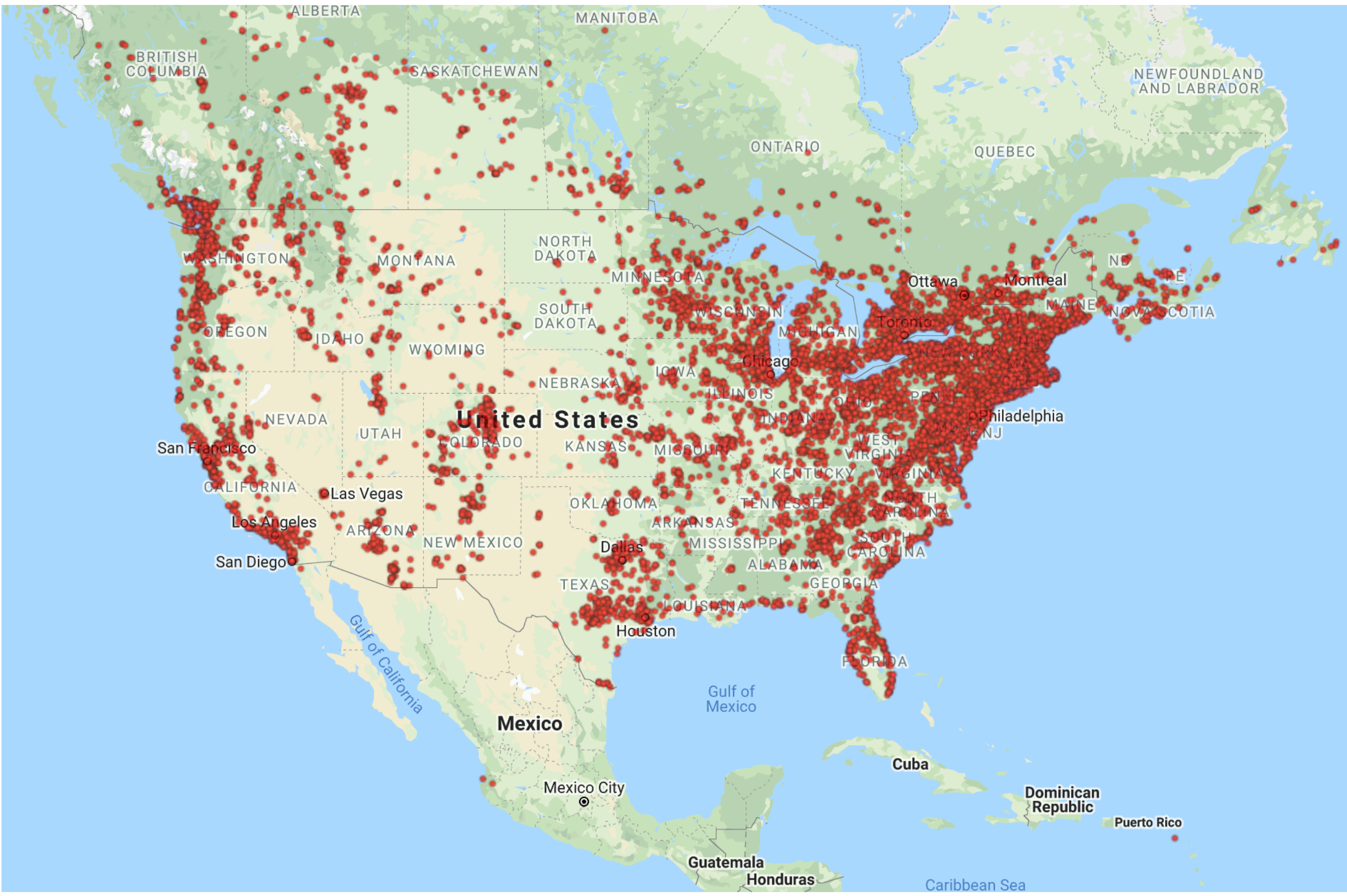


Figure A4: 2019-2020 Feeders from Project Feeder Watch

Notes: Map generated on Project Feeder Watch website, https://feederwatch.org/PFWMaps/participants.

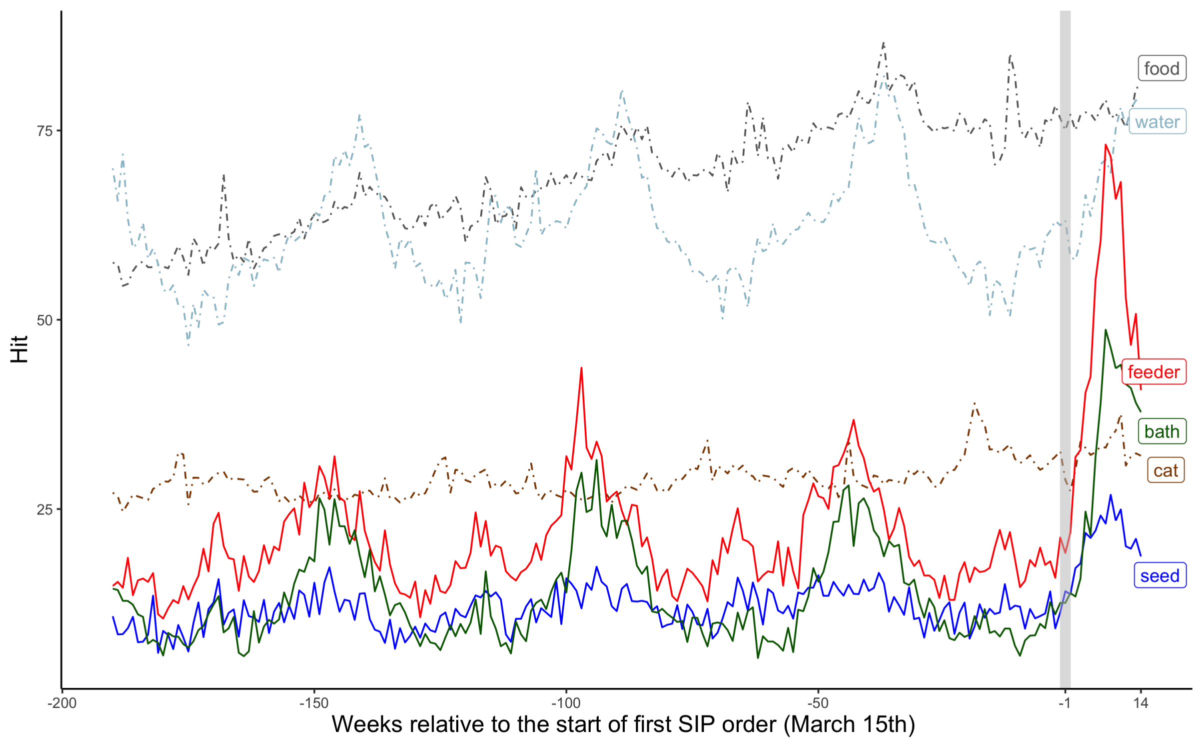


Figure A5: Google Trends search intensity for other words

Notes: Compare Google Trends search intensity for "Bird feeder", "Bird bath", and "Bird seed" with other words (food, cat, dog, water).