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Prosocial and financial incentives for biodiversity conservation: A field experiment using a smartphone app

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ABSTRACT

Ascertaining the number, type, and location of plant, insect, and animal species is essential for biodiversity conservation. However, it is difficult to comprehensively monitor the situation using only expert-led surveys, and therefore information voluntarily provided by citizens is helpful in determining species distribution. To effectively encourage citizens to share data, this study proposed a prosocial incentive that rewards providing species information with donations for endangered species conservation activities. We conducted a field experiment with users ($N = 830$) of a widely used Japanese smartphone app "biome" where they post species photos and measured the incentive's effect on their posting behavior. In addition, we measured the effect of a financial incentive that provides monetary rewards for posting species photos and compared the two incentives' effects. The analyses revealed that while the prosocial incentive did not increase the number of posts on average, it could influence the content of the posts, increasing the proportion of posts on rare species. In contrast, the financial incentive significantly increased the total number of posts and, in particular, the number of posts on less rare and invasive species. Our results indicate that the prosocial and financial incentives could stimulate different motivations and encourage different posting behaviors.

1. Introduction

Biodiversity loss is proceeding at a pace never seen before in the human history (IPBES, 2024). For effective biodiversity conservation, gathering and maintaining precise scientific data to ascertain locations of biodiversity loss, habitats of rare and invasive species, and changes in land use is essential. Since it is difficult for expert-led surveys to fully carry out the data collection and maintenance, citizen science has recently played a significant role. Citizens worldwide voluntarily provide information to help understand biodiversity loss, distribution of species, and land use changes (Atsumi et al., 2023; Eichenberg et al., 2020; Liu et al., 2022; Negrete et al., 2020).

However, citizen science data faces challenges. Generally, citizens report information based on personal preferences, potentially making the reported data biased. For instance, studies have shown that citizen reports increase on warm days and during weekends and holidays compared to cold days and weekdays (Bas et al., 2008; Brum-Bastos et al., 2018; Courter et al., 2013; Sparks et al., 2008). This makes policymakers cautious about using citizen science data directly.

Research has explored various methods to address the challenges with citizen science data. Some studies have focused on statistically adjusting these biases (Bird et al., 2014; Cameron and Kolstoe, 2022; Van Strien et al., 2013), whereas others have investigated the benefits of merging citizen science and expert-led survey data (Bradter et al., 2018).

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Furthermore, recent works, including Diekert et al. (2023), have started to explore interventions aimed at guiding citizen behavior toward more desirable information reporting of plant, insect, and animal species.

Biodiversity is a type of public good (Perrings and Gadgil, 2003). Thus, contributing species distribution data for biodiversity conservation is also a type of public good provision. Economically, it is well-known that public goods with positive externalities often face under-supply, falling short of socially optimal levels (Cornes and Sandler, 1996). To address this problem, financial incentives have been widely used to increase supply in various fields (Barber and West, 2022).[1] However, the effectiveness of financial incentives in promoting prosocial behavior, which is often driven by intrinsic motives, remains unclear. Traditional economics predict that financial incentives could promote prosocial behavior by decreasing costs, whereas behavioral economics suggests that financial incentives might diminish intrinsic motivation, reducing people's contributions (Bénabou and Tirole, 2003; Gneezy et al., 2011; Handberg and Angelsen, 2019).

Diekert et al. (2023) used non-experimental data and a difference-in-differences (DID) method and then revealed that financial incentives, such as contest prizes, increased species information reporting to an online platform for biodiversity conservation among people in Germany. However, they also found a reduction in diversity of reported species information, which may indicate a tendency to focus on a specific species to obtain monetary rewards.

Our study uses a controlled field experiment and adds new insights to this emerging research stream on intervention strategies. We introduce two interventions to enhance species information reporting, focusing on the conditions where it typically decreases. The first intervention, inspired by Diekert et al. (2023), is providing financial incentives, while the second involves making donations to biodiversity conservation activities in response to experimental participants' posts. We evaluate the effectiveness of these interventions through a randomized controlled trial on a Japan's smartphone app, which is widely-used for posting species information on plants, insects, and animals.

One unique feature of our study is newly added donation-related incentives, which we call "prosocial incentives."[2] These have been studied in laboratories (Imas, 2014; Kroker and Lange, 2024; Schwartz et al., 2021) and applied to charitable giving in the real world as "matching gifts" (Epperson and Reif, 2019; Sasaki et al., 2022). Under the matching gift scheme, people can deliver more than the amount they choose to donate, which is expected to increase their willingness to donate and raise the amount of out-of-pocket donations. Recently, prosocial incentives have been applied to real-world settings other than charitable giving, such as encouraging physical activities (Galárraga et al., 2020; Harkins et al., 2017; Sumida et al., 2014; Yuan et al., 2021). Our prosocial incentive treatment is a new application in the realm of biodiversity conservation. Under this treatment, people can simultaneously gain intrinsic utility from plant, insect, or animal species postings and from matched charitable donations. Both providing data on species information and donating to endangered species conservation efforts can contribute to biodiversity conservation, and these actions are complementary rather than substitutes. As people's utility gains are enhanced by simultaneously engaging in complementary behaviors (Adena and Huck, 2017), this method is predicted to facilitate people's species posting behaviors.

Our findings indicated that the prosocial and financial incentives could stimulate different motivations and promote different posting behaviors. The prosocial incentive did not increase the number of species posts on average. In contrast, the financial incentive had a significant impact on increasing the number of posts. However, we found another tendency when looking at contents of the posted species information. The prosocial incentive could increase the proportion of posts of rare species, while the financial incentive could increase in particular the number of posts of less rare and invasive species.

The structure of this paper is outlined as follows: **Section 2** details the design of the field experiment. **Section 3** presents the basic results of the analysis, followed by **Section 4** which presents the supplementary analysis. The paper discusses and concludes in **Section 5**.

2. Field experiment

2.1. Experimental design

We conducted a field experiment from September to November 2022 in Japan, in partnership with a private company offering a smartphone application (app) called "biome." On this app, Japanese users can post photos of wildlife they encounter, including plants, insects, and animals, and AI identifies the species information (Atsumi et al., 2023). The app records species information, location, and time data for each photo. Thus, it enables the users to create a catalog of the species they encounter. The app gives users non-financial points for posting species photos, and they would enjoy accumulating them to reach a higher level, similar to video games. Launched in April 2019, biome had 630,000 users as of September 2022. The company frequently partners with the Ministry of the Environment, local governments, and other organizations to conduct surveys to ascertain species' distributions. Similarly, we conducted this project in discussion with Japan Conference for 2030 Global Biodiversity Framework, the Ministry of the Environment, Government of Japan.

We recruited Japanese participants from September 15 to 30, 2022, through an in-app advertisement. We obtained their opt-in consent for participation and usage of data recorded in the app and then asked them to answer a questionnaire survey on information such as their socio-economic attributes, app usage insights, etc.[3] We explained to the participants that this project, titled Posting Marathon Campaign,[4] aimed to record people's species posting behaviors and understanding their preferences, contributing to biodiversity conservation. Participants were asked to take and post photos of plant, insect, or animal species in their spare time during this project. Participants who completed the project received a 300 JPY gift certificate for online shopping as a basic reward.[5]

From the initial 887 applications, we excluded those with ID mismatches, duplicate applications, and other issues. This left us with 830 participants for the analysis. We divided the participants into three groups: control group, prosocial incentive treatment group, and

[1] Other interventions are non-financial ones called nudges. Nudges encourage people's desirable behavior by changing the environmental setting in which they make choices and framing of the messages they receive. In the context of biodiversity conservation, nudges have been applied to fundraising activities (Kubo et al., 2018; Kubo et al., 2023). However, in general, the effects of nudges were reported to be small (DellaVigna and Linos, 2022).

[2] Previous studies have referred to interventions tied to monetary donations as "prosocial incentives" and have used this term in their titles (e.g., Imas, 2014; Schwartz et al., 2021). This usage is also found in the field of environmental science (Kroker and Lange, 2024). In line with the terminology of previous studies, we call the interventions tied to monetary donations "prosocial incentive."

[3] Although the external validity of field experiments with informed consent is generally lower than that of natural field experiments without it, the former has the advantages of fewer ethical concerns and possibility of merging naturally occurring data with self-reported survey data for analysis (Harrison and List, 2004). Such field experiments have often been employed in ecological economics (e.g., Kerr et al., 2012)

[4] As the term "experiment" has been reported to be offensive and confusing to the general public (Samek, 2019), we named this project the "Posting Marathon Campaign."

[5] We determined the amount of the reward after a discussion with the app company, considering the non-commercial nature of this app. As of November 2022, one USD equaled 142.62 JPY.

Table 1
Descriptive statistics.

	Control Group		Prosocial Incentive Treatment Group		Financial Incentive Treatment Group	
	n = 275		n = 273		n = 282	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Number of posts of unique, different species photos on weekdays (baseline)	5.602	12.53	4.907	10.259	5.399	11.701
Number of posts of species photos on weekdays (baseline)	6.502	15.804	5.342	11.318	6.282	14.963
Age	45.825	11.685	47.421	12.135	47.004	12.358
Female (1/0)	0.535	0.5	0.498	0.501	0.521	0.5
Having a cohabiting partner (1/0)	0.687	0.464	0.733	0.443	0.759	0.429
Educational years	15.269	2.259	15.234	2.129	15.255	2.265
Economic level (Ability to pay)	7.71	0.56	7.71	0.659	7.653	0.588
Working hours per week	32.978	19.788	33.806	20.016	33.862	20.354
Degree of prosocial motivation for participation to the campaign (from 2 to 10)	6.927	1.407	6.949	1.442	6.901	1.378
Degree of attitude for biodiversity conservation (from 1 to 5)	3.885	0.619	3.910	0.655	3.947	0.608

financial incentive treatment group. We performed stratified randomization for the assignment based on the number of species photo posts during the two-week baseline period before the experiment (the first half of September) and the participants' degree of prosocial motivation ascertained through the survey.

Our two incentive schemes are aimed to increase species posts by users, particularly during periods when posts typically decline, such as during the fall rather than summer and weekdays rather than weekends and holidays. We set a two-week treatment period (October 17–21 and 24–28) and communicated the following information to the participants:

Control group ($n = 275$): Participants assigned to this group were asked to take and post photos of species in their spare time on weekdays.

Prosocial incentive treatment group ($n = 273$): Participants assigned to this group were asked to take and post photos of species in their spare time on weekdays. In addition, based on the number of species photos posted by each participant during the five weekdays, a donation was made to an activity related to biodiversity conservation.

> *"For each different species photo you post during these five weekdays, the campaign office will donate 25 JPY to the endangered species protection activities. If you post photos of 10 different species, the office will donate a maximum of 250 JPY. The donation will be delivered to the Japan Wildlife Conservation Society's Activities to Protect Endangered Species in Japan."*

Financial incentive treatment group ($n = 282$): Participants assigned to this group were asked to take and post photos of species in their spare time on weekdays. In addition, based on the number of species photos posted by each participant during the five weekdays, they received gift certificates that could be used for online shopping.

> *"For each different species photo you post during these five weekdays, you will receive an Amazon gift certificates (e-mail type) of 25 JPY. If you post photos of 10 different species, you will receive a maximum of 250 JPY gift certificates. Amazon gift certificates can be used for online shopping at Amazon."*

A key aspect of the two treatments is that we provided incentives based on the number of posted photos of unique, different species (i.e., posted photos of the same species were not counted) rather than the number of total posted species photos. Participants in the treatment groups received prosocial or financial incentives in each of the first and second treatment weeks, and thus the maximum amount of the incentive they could receive was 500 JPY. We communicated the above message via e-mail on October 11 before the treatment period, and on October 17 and 24 during the treatment period. Appendix A shows the experimental schedule. **Supplementary Materials** contains English translations of the original Japanese messages.

Before starting the experiment, we obtained approval for our research project from the Ethics Committee at The University of Osaka (2022CRER0901). We also pre-registered the experimental design with the AEA RCT Registry (Sasaki and Kubo, 2022).[6]

2.2. Analytical procedure

We received the data on posted species photos and information for each user from the app company. Using the data, we constructed two outcomes:

i. Number of posted photos of unique, different species on weekdays;
ii. Number of posted photos of species on weekdays (including multiple photos of the same species).

The first outcome counts the number of postings of unique, different species photos. Thus, this is different from the second outcome, which counts even if a participant posts multiple photos of the same species.

We examined the treatment effects by applying a Difference-in-Differences (DID) fixed-effects estimation approach to the field experimental panel data. This approach allowed us to eliminate the influence of individual characteristics that remain unchanged over time. Additionally, using standard errors clustered at each participant enabled us to account for within-individual serial correlation.[7]

The baseline period was September 5–9 and 12–16,[8] and the treatment period was October 17–21 and 24–28.[9] We assumed Strongly Ignorable Treatment Assignment and Stable Unit Treatment Values Assumption (SUTVA). We estimated the following equation:

$$\begin{aligned} Posts_{it} = {} & \alpha_0 + \alpha_1 Prosocial_i \times Week1_t + \alpha_2 Prosocial_i \times Week2_t \\ & + \alpha_3 Financial_i \times Week1_t + \alpha_4 Financial_i \times Week2_t \\ & + \alpha_5 Week1_t + \alpha_6 Week2_t + \varepsilon_{it}, \end{aligned} \quad (1)$$

where i and t are participants and week, respectively; $Posts_{it}$ is the participant i's number of photo posts of unique, different species during five weekdays in week t. $Prosocial_i$ takes 1 for the prosocial incentive treatment group, and 0 otherwise. $Financial_i$ takes 1 for the financial incentive treatment group, and 0 otherwise. $Week1_t$ ($Week2_t$) takes 1 in

[6] The URL is https://www.socialscienceregistry.org/trials/10210.

[7] This approach has been employed in field experiments on energy savings, etc. (Ito et al., 2018), because daily behaviors, unlike one-time actions, are often accompanied by time trends.

[8] We pooled the data from September 5–9 and September 12–16 and used the weekly average as the baseline. This aligns with the weekly intervals of the treatments.

[9] We had three time points per participant: baseline, first treatment period, and second treatment period. Thus, the total numbers of participants and observations in our analysis sample were 830 and 2490, respectively.

the first (second) week of the treatment period, October 17–21 (24–28), and 0 otherwise.[10] ε_{it} is an error term.

We used standard errors clustered at each participant. For a robustness check, we also incorporated weather information for prefectures (weekday averages of temperature, rainfall, and sunshine hours, their average deviations from the weekday averages, and number of sunny days during weekdays) and controlled for temporal changes in situations and environments in which participants take and post photos.[11]

The coefficients of interest were α_1, α_2, α_3, and α_4, respectively. α_1 and α_2 captured the difference between the prosocial incentive treatment and control groups in terms of changes in *Posts* from the baseline to the treatment period. α_3 and α_4 captured this difference between the financial incentive treatment and control groups.

2.3. Balance check and participant characteristics

We confirmed the homogeneity between the three groups. First, as shown in **Table 1**, no statistically significant differences were found between the groups for the average numbers of two outcomes at the baseline period. Second, we found no statistically significant differences for age, gender, having a cohabiting partner, educational years, and economic level.[12] We also found no statistically significant differences in working hours,[13] degree of prosocial motivation (reason for participating in this campaign),[14] or degree of attitude for biodiversity conservation.[15]

Since we conducted this field experiment with informed consent, the participants were somewhat selective in their characteristics. The number of posts of species photos at the baseline period ranged from 5.342 to 6.502 among the participants, while non-participant app users posted around one photo, according to the app company. Also, the participants' degree of attitudes toward biodiversity conservation ranged from 3.885 to 3.910, compared to an average of 3.030 in a nationwide online survey of 1555 citizens in Japan.[16] Both averages fall within the "3: neutral" range, while experimental participants leaned more toward "4: somewhat agree." Thus, the participants were relatively more active and showed a slightly higher interest in biodiversity conservation and we needed to consider limitations regarding external validity due to the nature of the consent-based field experiment, whereas the use of a randomized controlled trial (RCT) enabled us to ensure the internal validity of our findings.

We further mapped the posts by the participants from the baseline experimental period (**Fig. 1**). Specifically, we marked circles on each 10 km grid where posts were made during the period. The mapping result revealed that posts were concentrated in major metropolitan areas, such as Tokyo and Osaka, while also being well-distributed across the country.

3. Basic analysis: effects on number of posts

3.1. Descriptive and estimation results

We estimated the treatment effects of prosocial and financial incentives on posts of species photos. Our findings revealed that the prosocial incentive did not enhance either total or unique, different species posting frequency, whereas the financial incentive significantly increased both. The positive effect of the financial incentive was pronounced among participants who had a moderate frequency of unique, different species posts before the experiment. In addition, we confirmed that the increase due to the financial incentive occurred only during weekdays within the treatment period, with no effect during the weekends or after the treatment period ended.

Fig. 2 shows the time trends in the number of posted photos of unique, different species on weekdays (i.e., the primary outcome) for each group. The graphs demonstrate that the number of posts had similar values for each group during the baseline period. The number in the control group dropped during the treatment period.[17] In contrast, the number in the prosocial group increased during the first treatment week but decreased during the second week. In the financial incentive group, the number increased during both of the treatment weeks. Specifically, the number of posted photos of unique, different species in the first treatment week was 4.324 for the control group, 5.755 for the prosocial group, and 6.404 for the financial group. The difference between the control group and the prosocial group was 1.431 ($p = 0.351$), whereas the difference with the financial group was 2.081 ($p = 0.018$). In the second treatment week, the number was 3.822 for the control group, 4.004 for the prosocial group, and 5.436 for the financial group. The difference between the control group and the prosocial group was 0.182 ($p = 0.827$), whereas the difference with the financial group was 1.614 ($p = 0.042$).[18] After the treatment period ended, all groups had similar values.

[10] We estimated the effects of the two weeks separately because our treatment provided incentives for the number of photo posts of unique, different species during five weekdays in each week. Thus, the posts in Week 1 and Week 2 were evaluated independently, with incentives rewarded accordingly.

[11] We also addressed this concern by analyzing weekly rather than daily data. Since the experiment was well-balanced across groups, analyzing weekly data (over five weekdays) reduces the likelihood that weather had different impacts across the groups. For instance, participants could shift their photo-taking to a sunnier day if one was rainy, making weather conditions more comparable on average. Importantly, this approach aligns with the experiment's treatment rule, which provided incentives based on the number of unique, different species photos posted over five weekdays.

[12] After a discussion with the app company, we decided not to ask the participants' income directly. We asked, "What is the maximum amount you would be willing to pay for lunch?" The answers were used as a variable for their economic level.

[13] We asked the participants, "How many days per week do you work?" and "How many hours per day, on average, do you work?" We calculated the length of working hours per week based on their answers.

[14] We used the following two statements to determine the participants' degree of prosocial motivation: "I think that participating in this campaign will contribute to biodiversity conservation and academic research" and "I can receive gift certificates by participating in this campaign." The participants were asked to rate to what extent they agreed with the statements on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). We inverted the latter item and added the scores of the two items to obtain an indicator of the prosocial degree (from 2 to 10).

[15] We used the following six statements to determine the participants' degree of attitude for biodiversity conservation: "My ideal vacation spot is a nature-rich area," "I frequently reflect on how my actions impact the natural environment," "Connecting with nature provides me with emotional support," "I am always conscious of wildlife," "Connecting with nature is essential for me to stay true to myself," and "I feel a deep connection to the earth and all its living creatures." The participants were asked to rate to what extent they agreed with the statements on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). We summed the scores of the six items and calculated the average to obtain an indicator of the biodiversity conservation degree (from 1 to 5).

[16] This online survey was conducted in 2016 with funding from the Ministry of the Environment, Government of Japan (Kyoto University, 2017). For further details on the data, please contact the research team.

[17] The number of posts typically declines from summer to autumn and winter, suggesting that the change in the control group likely reflect this seasonal trend.

[18] We included plots in **Fig. B.1** illustrating the detailed distribution of unique, different species posted during the treatment period. The plots clearly show that the financial incentive generally increased the number of posts. However, the maximum number of posts was higher in the prosocial group. For example, in the first treatment week, one participant in the prosocial group posted 375 species, while the maximum in the financial group was 138 species. This difference is likely driven by a few unusually high values occurring by chance, whereas it remains possible that the prosocial incentive had a stronger influence on a small subset of users.

Fig. 1. Locations of Posts in Japan.
Note: We marked circles on each 10 km grid where posts were made during the baseline period.

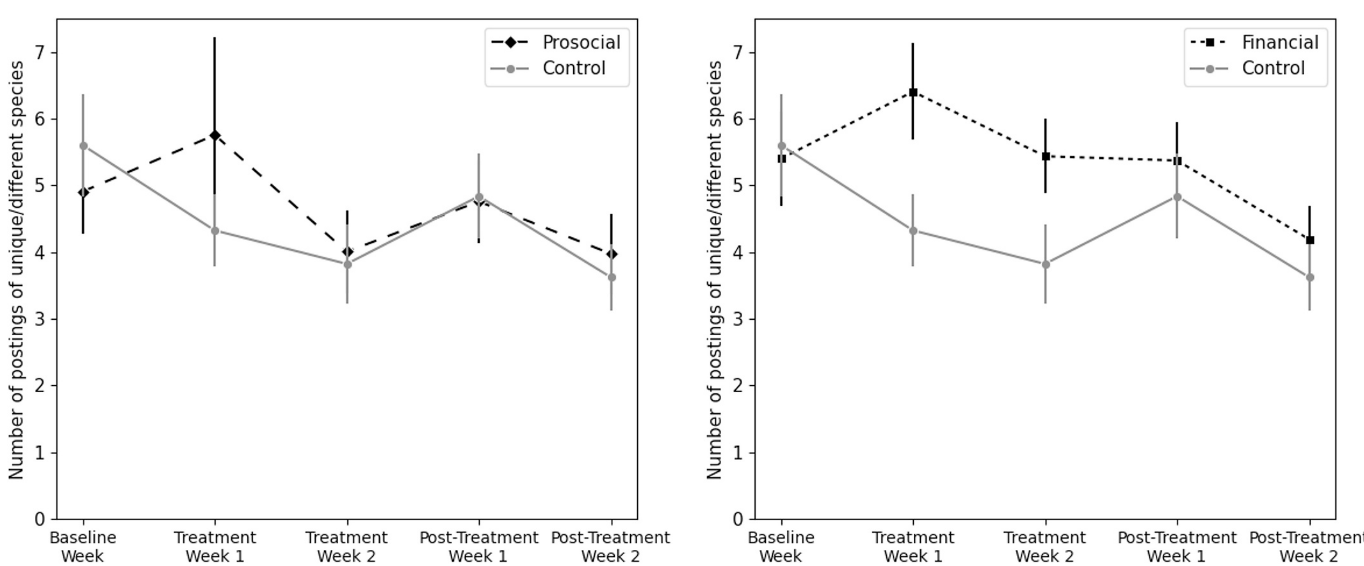

Fig. 2. Number of Posts of Unique, Different Species.
Note: We draw a vertical standard error bars at each data point.

Table 2, **Column 1** presents the regression results for posted photos of unique, different species. The prosocial incentive group showed a coefficient of 2.126 in the first treatment week, which was not statistically significant. The effect size decreased in the second treatment week. The financial incentive group yielded coefficients of 2.284 in week 1 and 1.817 in week 2, both statistically significant ($p < 0.05$). However, a direct comparison of the prosocial and financial incentive groups revealed no significant differences, likely due to the large variations of the prosocial incentive.

Column 3 presents the results for total number of species photo posts. The financial incentive group exhibited an increase in posts only during the first treatment week (2.476, $p = 0.028$).

Table 2
Basic Analysis: Effects on Number of Posts.

	(1)	(2)	(3)	(4)
Analysis sample:	Total			
Number of participants:	n = 830			
Number of observations:	n = 2490			
Dependent variable:	Number of posts of unique, different species photos		Number of posts of species photos	
Prosocial incentive*Treatment week 1	2.126	2.191	2.948	3.003
	(1.599)	(1.600)	(2.129)	(2.124)
Prosocial incentive*Treatment week 2	0.877	0.945	0.240	0.302
	(0.844)	(0.843)	(1.165)	(1.168)
Financial incentive*Treatment week 1	2.284**	2.202**	2.476**	2.312**
	(0.984)	(0.990)	(1.127)	(1.136)
Financial incentive*Treatment week 2	1.817**	1.731**	0.975	0.820
	(0.842)	(0.844)	(1.161)	(1.183)
Treatment week 1	−1.278*	−8.804	−1.396*	−11.770
	(0.680)	(7.166)	(0.750)	(9.823)
Treatment week 2	−1.780***	−10.906	−1.051	−13.735
	(0.643)	(8.876)	(0.989)	(12.195)
Time-varing attributes	NO	YES	NO	YES
Constant term	5.304***	26.979	6.046***	38.285
	(0.260)	(22.889)	(0.316)	(31.618)

Note: We use fixed-effects estimation and standard errors clustered at each participant; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

For robustness check, **Columns 2 and 4** additionally controlled for weather data (weekday averages of temperature, rainfall, and sunshine hours, their average deviations from the weekday averages, and number of sunny days during weekdays) for the participants' locations. This considers the changing conditions and environments in which they take and post photos. The results showed that the size and statistical significance remained largely unchanged.

In **Table 3**, we examined how each treatment effect varies with the pre-experimental frequency of unique, different species postings. We categorized the participants into three groups, including SMALL (the mean is 0.119), MEDIUM (the mean is 3.654), and LARGE (the mean is 27.937).[19] The findings indicated that the effect of financial incentives on increasing unique, different species posts was primarily observed in the MEDIUM group. The treatments' coefficients, including the one for the prosocial incentive, for the LARGE group were large but not statistically significant due to their large standard errors.

We performed another subsample analysis using the attribute variables. The estimated results in **Table B.1** showed that the financial incentive could be more effective for younger participants, women, those with lower education levels, and those working longer hours. Examining the constant term, excluding the educational level, people with these characteristics tended to have fewer posts during the baseline period, indicating that the financial incentive may have activated their posting behavior. The effect of the prosocial incentive was not found in most segments; however, it showed a 10 % level of significance in promoting posts among men during the first treatment week. In contrast, the effect on women was negative, making this a contrasting result. Men are more motivated to gather and post information on a wider variety of species when offered prosocial incentives.

As shown in **Tables B.2** and **B.3**, the increase in unique, different species posts due to the financial incentive was limited to weekdays during the treatment period. This effect did not last on the weekends or after the treatment period.

3.2. *Interpretation*

The result of **Table 2, Column 1** suggests a substantial impact of the financial incentive on the number of photo posts of unique, different species. Initially, its number averaged 5.304, according to the constant term. During the first treatment week, there was a decrease in the control group from 5.304 to 4.026 (a drop of 1.278). However, the financial incentive reversed this trend, increasing the number of posts by around 2.284 (from 4.026 to 6.310), or + 56.7 %. A similar pattern occurred in the second treatment week, with a rise of 51.6 %, highlighting the effectiveness of financial incentives in boosting posts of unique, different species photos.

Considering the effects of the financial incentives on total and unique, different species posting frequency in Table 2, we interpret the results as follows: In the first treatment week, the financial incentive led to an increase in total and unique, different species posts. However, in the second week, the total number of species posts did not increase, whereas that of unique, different species posts increased. This indicates that participants could become selective in their posts, likely influenced by their experiences in the first week.

Table 3 found contrasting seasonal trends between the SMALL and LARGE groups. The treatment week variables showed an upward trend in the SMALL group, indicating that inactive participants could be encouraged to post more simply due to their participation in the experiment. In the LARGE group, however, these week variables exhibited significant declines even after controlling for the effects of weather and temperature. Generally, posts tend to be higher in summer than in autumn or winter due to factors like summer vacations. Participants in the LARGE group could have taken advantage of this period to take more photos, resulting in a particularly high number of posts in summer, followed by a sharp decline in autumn. Given these patterns, the significantly increasing effects observed in the MEDIUM group, who did not have such seasonal trends, indicate that the financial incentives in this study could influence more typical participants without extreme behavioral patterns.

The results of **Tables B.1** and **B.2** in **Appendix B** imply that the increase in the number of unique, different species posts disappeared on the weekends and after the treatment period. This tendency has been observed in previous studies on financial and prosocial incentives in other contexts (Barte and Wendel-Vos, 2017; Epperson and Reif, 2019). These results also imply that no "boomerang effect" existed; species posts did not decrease on weekends or after the treatment period.[20] As this effect is a concern in behavioral intervention studies (Allcott, 2011; Scharf et al., 2022), the absence of this effect in our study is meaningful.

4. Supplementary analysis: effects on contents of posts

4.1. *Estimation results*

We examined how prosocial and financial incentives influenced the types of species posted. This was not pre-registered and thus a secondary analysis. The app categorized posted species into groups, including rare species (e.g., endangered and quasi-endangered species and species with limited information), non-rare species, and invasive species. The results showed that the prosocial incentive could increase posts on rare species. In contrast, the financial incentive could boost posts of less rare and

[19] The maximum number of unique, different species for which donation or monetary incentives were granted was set at 10. Therefore, we categorized the participants with over 11 pre-experiment postings as the Large group and then divided the rest of the participants into two equal groups (Medium and Small).

[20] **Table B.1** addresses the concern that participants may have been taking and saving photos of species on weekends and posting them during the weekdays to maximize their financial rewards. If this was the case, the number of weekend postings should has decreased in the financial incentive treatment group; however, we did not observe this phenomenon.

Table 3
Basic Analysis: Heterogeneity by Pre-experimental Number of Posts.

	(1)	(2)	(3)	(4)	(5)	(6)
Analysis sample:	SMALL		MEDIUM		LARGE	
Number of participants:	$n = 375$		$n = 344$		$n = 111$	
Number of observations:	$n = 1125$		$n = 1032$		$n = 333$	
Dependent variable:	Number of posts of unique, different species photos					
Prosocial incentive*Treatment week 1	0.013	0.016	3.449	3.072	4.716	5.765
	(0.568)	(0.560)	(3.240)	(2.834)	(5.023)	(5.307)
Prosocial incentive*Treatment week 2	−0.138	−0.132	0.321	−0.064	5.915	6.803
	(0.601)	(0.595)	(0.670)	(0.814)	(4.855)	(4.879)
Financial incentive*Treatment week 1	1.018	1.047	3.447**	2.893*	4.057	3.945
	(0.639)	(0.635)	(1.422)	(1.501)	(4.768)	(4.730)
Financial incentive*Treatment week 2	0.445	0.503	2.000***	1.580*	6.760	6.661
	(0.665)	(0.656)	(0.729)	(0.860)	(4.457)	(4.439)
Treatment week 1	1.561***	1.089	−0.188	−15.667	−14.444***	−43.644**
	(0.448)	(1.642)	(0.479)	(15.252)	(4.119)	(20.139)
Treatment week 2	1.332***	1.206	−0.504	−19.719	−16.472***	−52.336**
	(0.513)	(1.879)	(0.455)	(18.835)	(3.482)	(24.617)
Time-varing attributes	NO	YES	NO	YES	NO	YES
Constant term	0.119	−1.855	3.654***	49.014	27.937***	113.699**
	(0.146)	(4.370)	(0.424)	(50.214)	(1.108)	(53.754)

Note: We use fixed-effects estimation and standard errors clustered at each participant; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4
Supplementary Analysis: Effects on Contents of Posts.

	(1)	(2)	(3)	(4)	(5)	(6)
Analysis sample:	Total					
Number of participants:	n = 830					
Number of observations:	n = 2490					
Dependent variable:	Number of posts on rare species		Number of posts on less rare species		Number of posts on invasive species	
Prosocial incentive*Treatment week 1	2.084*	2.096*	0.860	0.894	0.020	0.024
	(1.246)	(1.243)	(0.928)	(0.925)	(0.120)	(0.119)
Prosocial incentive*Treatment week 2	0.824**	0.849**	−0.395	−0.366	−0.246	−0.242
	(0.371)	(0.378)	(0.906)	(0.904)	(0.250)	(0.251)
Financial incentive*Treatment week 1	0.654	0.547	1.496*	1.447*	0.250**	0.239**
	(0.444)	(0.464)	(0.778)	(0.773)	(0.116)	(0.116)
Financial incentive*Treatment week 2	0.215	0.122	0.699	0.650	−0.020	−0.034
	(0.418)	(0.431)	(0.911)	(0.924)	(0.246)	(0.253)
Treatment week 1	−0.775**	−6.644	−0.611	−4.702	−0.013	−0.451
	(0.304)	(5.933)	(0.500)	(3.700)	(0.068)	(0.485)
Treatment week 2	−0.789***	−7.776	−0.375	−5.635	0.147	−0.370
	(0.281)	(7.336)	(0.802)	(4.659)	(0.240)	(0.622)
Time-varing attributes	NO	YES	NO	YES	NO	YES
Constant term	1.304***	19.586	4.320***	17.026	0.356***	1.874
	(0.167)	(19.228)	(0.188)	(11.634)	(0.034)	(1.546)

Note: We use fixed-effects estimation and standard errors clustered at each participant; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

invasive species.

Table 4, **Column 1** presents the results for rare species posts. The prosocial incentive group showed a coefficient of 2.084 in the first treatment week, which was weakly statistically significant, at the 10 % level; the coefficient in the second treatment week was 0.824, which was smaller than for week 1 but achieved statistical significance at the 5 % level. The coefficients for the financial incentive were small for both weeks and not statistically significant.

Columns 3 and 5 present the results for less rare and invasive species posts. The financial incentive increased both indicators only during the first treatment week. The coefficient for the number of less rare species posts was 1.496 and statistically significant, albeit at the 10 % level. The coefficient for the number of invasive species posts was 0.250 and statistically significant at the 5 % level.

For robustness check, **columns 2, 4, and 6** additionally controlled for weather data (weekday averages of temperature, rainfall, and sunshine hours, their average deviations from the weekday averages, and number of sunny days during weekdays) for the participants' locations. The results showed that the effect size and statistical significance remained largely unchanged.

4.2. Interpretation

The result of Table 4**, Column 1** indicates a large impact of the prosocial incentive on the number of posted photos of rare species. Initially, its number averaged 1.304, according to the constant term. During the second treatment week, there was a decrease in the control group from 1.304 to 0.515 (a drop of 0.789). The prosocial incentive reversed this trend, increasing the number of postings by around 0.824 (from 0.515 to 1.339), or a substantial rise of 160.0 %.

Tables 2 and 4 show that although the number of posted photos of unique, different species in the prosocial incentive treatment group did not increase, the proportion of rare species photos increased. This result indicates the possibility that the increase in rare species posts may not be accidental due to taking and posting more photos. The participants likely knew the locations of rare species, and the prosocial incentive encouraged them to visit these locations and photograph the species.

The financial incentive treatment effect on the number of posted photos of less rare and invasive species was substantial. For example, the effect size for invasive species posts means to add 0.250 to the average number of posts of 0.356 at the baseline period, with an increase of +70.2 %.

Sections 3 and 4 suggest that the participants in the financial incentive treatment group likely posted more photos of less rare species that are often encountered. This indicates a behavioral pattern of taking and posting photos of species in their vicinity to maximize monetary rewards. However, this financial incentive could increase the number of posted photos of invasive species, which could substantially influence eco-systems. As the participants posted more photos of familiar, less rare species, they may have unintentionally encountered and submitted photos of invasive species. As the baseline mean of posted photos of these species was relatively low at 0.356, this increase could be meaningful.

5. Discussion, limitations, and conclusions

This study proposed two interventions to encourage people to report plant, insect, or animal species information, focusing on the conditions where posts typically decrease. One unique feature of our study was employing prosocial incentives, in which donations were made to biodiversity conservation activities in response to people' posts, in addition to financial incentives. We evaluated the effectiveness of these two interventions through a randomized controlled trial with 830 users of a Japanese smartphone app widely-used for posting species photos. The prosocial incentive did not increase the average number of species posts, whereas the financial incentive significantly increased the number of these posts. However, we found another tendency when looking at contents of the posted species information. The prosocial incentive increased the proportion of posted photos of rare species. In contrast, the financial incentive increased the number of photos of less rare and invasive species.

Our findings indicate that the prosocial and financial incentives could stimulate different motivations and encourage different posting behaviors. This suggests developing policies using different incentives schemes, while considering the species for which governments and practitioners need to collect information. This also suggests a concern that employing a single incentive could lead to the collection of unwanted information. This concern has been raised by Diekert et al. (2023), who found that financial incentives increased the number of species information posts but decreased the diversity of the posted species information. Although our results on financial incentives were similar to theirs, our findings highlight the potential of financial incentives to increase the number of posts on invasive species that could significantly impact the ecosystem, in addition to less rare species postings. Balancing the implementation of both prosocial and financial incentives could lead to more comprehensive biodiversity information collection.

In addition, our study contributes to advocating for behavioral intervention studies in biodiversity conservation. In this field, there have been limited cases of field experiments on conservation of threatened species (Walsh, 2021), water use management (Ferraro et al., 2011), and fundraising activities (Kubo et al., 2018; Kubo et al., 2023), partly due to the complexity of biodiversity metrics (Baylis et al., 2016). Exploring causal influence of financial and non-financial interventions through field experiments beyond the limited topics has significant potential to provide policy and practical implications for biodiversity conservation. Further studies should be encouraged to integrate ecological knowledge and findings of behavioral change research in other important topics, including food choice, transportation, recreation, wildlife trade, education, land use change, etc. (The Behavioral Insights Team, 2019).

This is the first study to conduct a field experiment exploring the impacts of prosocial and financial interventions to enhance citizen science in biodiversity conservation. However, this study has limitations. First, this study does not elucidate what mechanisms generate each treatment effect. For example, two behavioral pathways potentially exist. The first is that the incentives encourage participants to expand their activity range (e.g., visiting new locations), leading to an increase in the number of unique, different species photos posted. The second is that participants, without expanding their activity range, become more attentive to familiar locations, resulting in more posts. We conducted a follow-up survey after the treatment weeks, where 445 participants reported their weekday steps during the second treatment week (the valid response rate was 53.6 %).[21] The results showed a daily average of 6483 steps for the control group ($n = 151$), 6643 steps for the prosocial group ($n = 146$), and 6405 steps for the financial group ($n = 148$). While the prosocial group showed a slightly higher number of steps, no increase was observed for the financial group. Thus, the prosocial incentive may have increased rare species posts via the first mechanism, while the financial incentive may have increased less rare or invasive species posts via the second. However, the difference between the prosocial group and the control group was not statistically significant. Given the small sample size after attrition, this finding should be interpreted cautiously, and a more rigorous examination remains for future research.

In addition, this study does not clarify to what extent the treatments could reduce the bias of citizen-posted species information and to what extent the effect changes when users repeatedly receive the same incentive. Furthermore, the concern of external validity remains, because we obtained participants' opt-in informed consent and used their data for analysis. Considering the characteristics of our experimental participants, our findings may be limited to people who are more active and have a slightly higher interest in biodiversity conservation. These questions also should be examined in future studies.

Nevertheless, intervention studies on voluntary information provision by citizens for biodiversity conservation are an emerging line of research. Our study makes significant academic and policy contributions by providing new insights to this emerging literature using a controlled field experiment.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used DeepL and ChatGPT to improve the readability and proofreading of the English text we have written. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the manuscript.

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Ethical considerations

We obtained ex-ante approval from the ethics committee of The University of Osaka, Japan (2022CRER0901). We also registered the experimental design with the AEA RCT Registry (Sasaki and Kubo, 2022).

[21] When using participants who responded to the follow-up survey ($N = 445$), we found results consistent with those from the full sample ($N = 830$). Please see Table B.4.

CRediT authorship contribution statement

Shusaku Sasaki: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Takahiro Kubo:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Shodai Kitano:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis.

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.

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Appendix A. Experimental schedule

Recruitment with Baseline Survey: September 15–30

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Information Provision by Groups (1): October 11

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First Treatment Week: October 17–21

Information Provision by Groups (2): October 17

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Second Treatment Week: October 24–28

Information Provision by Groups (3): October 24

↓

First Post-Treatment Week: October 31–November 04

↓

Second Post-Treatment Week: November 07–11

Note: To consider equal opportunity among participants, we offered those in the control group the opportunity to receive a prosocial or financial incentive after November 8. Therefore, we did not use data after this date in the analysis.

Appendix B. Appendix

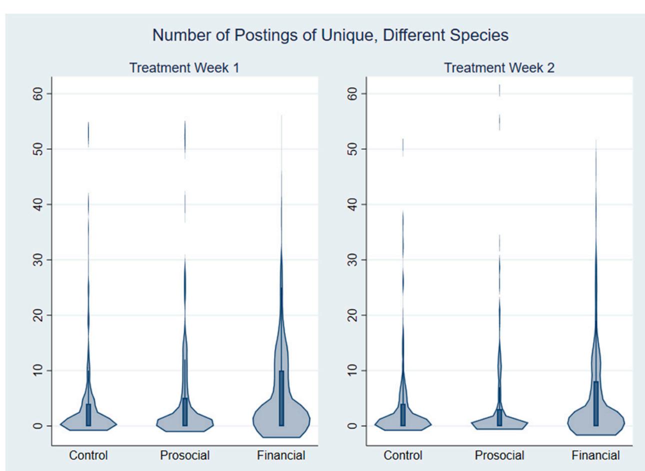

Fig. B.1. Distributions of Number of Posts of Unique, Different Species Photos during Treatment Weeks.
Note: The maximum number of unique species posted during the treatment period was 375 in the prosocial incentive group and 138 in the financial incentive group. This figure does not display the two extremely high values for clarity.

Table B.1
Heterogeneity by Attributes.

Dependent variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of posts of unique, different	Age (Median:47)		Gender (binary)		Educational level (binary)		Economic level (Median:6)	
species photos	Older	Younger	Female	Male	With Bachelor	Wihtout Bachelor	Higher	Lower
Prosocial incentive*Treatment week 1	1.006	3.277	−0.803	5.174*	2.144	1.768	1.566	2.396
	(1.117)	(3.125)	(1.050)	(3.025)	(2.249)	(1.702)	(1.606)	(2.260)
Prosocial incentive*Treatment week 2	1.284	0.428	0.367	1.476	1.058	0.340	2.236	0.181
	(1.250)	(1.138)	(0.996)	(1.405)	(0.878)	(1.737)	(1.614)	(0.971)
Financial incentive*Treatment week 1	0.723	3.748**	1.837*	2.823	0.854	4.596**	2.028	2.420**
	(1.227)	(1.520)	(0.981)	(1.769)	(0.987)	(2.015)	(1.755)	(1.186)
Financial incentive*Treatment week 2	1.023	2.577**	2.361**	1.261	0.853	3.376**	3.050*	1.189
	(1.332)	(1.049)	(0.938)	(1.442)	(1.033)	(1.438)	(1.776)	(0.889)
Constant term	6.329***	4.309***	5.035***	5.594***	4.819***	6.130***	6.580***	4.655***
	(0.303)	(0.421)	(0.247)	(0.470)	(0.334)	(0.412)	(0.424)	(0.328)
Number of participants	409	421	430	400	523	307	280	550
Number of observations	1227	1263	1290	1200	1569	921	840	1650
Dependent variable:	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Number of posts of unique, different	Working hours (Median:40)		Prosocial motivation (Median:7)		Attitude for biodiversity conservation (Median:4)		Number of sunny day (Median:4)	
species photos	Longer	Shorter	Higher	Lower	Higher	Lower	More	Less
Prosocial incentive*Treatment week 1	4.043	−0.412	2.176	2.016	0.788	3.098	4.128	0.011
	(2.628)	(1.274)	(2.625)	(1.244)	(1.642)	(2.472)	(2.942)	(1.052)
Prosocial incentive*Treatment week 2	1.764	−0.288	0.908	0.851	1.818	0.244	1.742	−0.034
	(1.133)	(1.285)	(1.112)	(1.296)	(1.558)	(0.958)	(1.336)	(1.026)
Financial incentive*Treatment week 1	3.052**	1.335	1.456	3.355**	3.849*	1.138	3.153*	1.478
	(1.448)	(1.285)	(1.422)	(1.305)	(1.964)	(0.936)	(1.790)	(0.969)
Financial incentive*Treatment week 2	2.254**	1.279	1.782	1.868	2.210	1.557*	2.177	1.467
	(1.137)	(1.261)	(1.104)	(1.304)	(1.601)	(0.890)	(1.448)	(0.905)
Constant term	4.266***	6.614***	5.840***	4.598***	6.200***	4.674***	5.383***	5.229***
	(0.395)	(0.312)	(0.396)	(0.304)	(0.394)	(0.347)	(0.466)	(0.248)
Number of participants	463	367	472	358	343	487	405	425
Number of observations	1389	1101	1416	1074	1029	1461	1215	1275

Notes: We use fixed-effects estimation and standard errors clustered at each participant; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The estimations do not include time-varying attributes. The table does not display the parameters of Treatment weeks 1 and 2 for clarity. We do not include the subsample analysis of cohabiting partners, as the estimation is not concluded due to the small proportion of participants without cohabiting partners. In the subsample analysis based on the number of sunny days, we divide participants into two groups using the median of the average values for the two treatment weeks.

Table B.2
Effects on Number of Posts on Weekends During the Treatment Period.

	(1)	(2)	(3)	(4)
Analysis sample:	Total			
Number of participants:	n = 830			
Number of observations:	n = 2490			
Dependent variable:	Number of posts of unique, different species photos on weekends		Number of posts of species photos on weekends	
Prosocial incentive*Treatment week 1	−0.656	−0.603	−0.617	−0.554
	(0.604)	(0.605)	(0.695)	(0.693)
Prosocial incentive*Treatment week 2	−0.435	−0.391	−0.370	−0.318
	(0.572)	(0.571)	(0.630)	(0.628)
Financial incentive*Treatment week 1	0.393	0.411	0.474	0.497
	(0.684)	(0.682)	(0.788)	(0.784)
Financial incentive*Treatment week 2	0.256	0.273	0.208	0.227
	(0.615)	(0.614)	(0.679)	(0.678)
Treatment week 1	−0.609	0.178	−0.676	0.063
	(0.473)	(1.559)	(0.562)	(1.793)
Treatment week 2	−1.402***	−0.022	−1.520***	−0.277
	(0.481)	(2.009)	(0.525)	(2.290)
Time-varing attributes	NO	YES	NO	YES
Constant term	3.578***	0.671	4.122***	1.426
	(0.147)	(4.556)	(0.163)	(5.108)

Table B.3
Effects on Number of Posts After the Treatment Period.

	(1)	(2)	(3)	(4)
Analysis sample:	Total			
Number of participants:	n = 830			
Number of observations:	n = 2490			
Dependent variable:	Number of posts of unique, different species photos		Number of posts of species photos	
Prosocial incentive*Post-Treatment week 1	0.617	0.634	0.457	0.445
	(0.863)	(0.862)	(0.994)	(0.986)
Prosocial incentive*Post-Treatment week 2	1.048	1.000	1.259	1.182
	(0.840)	(0.843)	(0.943)	(0.940)
Financial incentive*Post-Treatment week 1	0.739	0.761	0.207	0.225
	(0.930)	(0.924)	(1.057)	(1.051)
Financial incentive*Post-Treatment week 2	0.773	0.809	0.530	0.578
	(0.883)	(0.883)	(0.964)	(0.966)
Post-Treatment week 1	−0.765	1.611	−0.400	2.854
	(0.720)	(2.331)	(0.834)	(2.597)
Post-Treatment week 2	−1.980***	1.099	−1.844**	2.116
	(0.675)	(2.527)	(0.741)	(2.846)
Time-varing attributes	NO	YES	NO	YES
Constant term	5.304***	−2.818	6.046***	−3.591
	(0.213)	(5.339)	(0.236)	(5.967)

Note: We use fixed-effects estimation and standard errors clustered at each participant; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table B.4
Analysis with Follow-up Sample: Effects on Number of Posts.

	(1)	(2)	(3)	(4)
Analysis sample:	Total			
Number of participants:	$n = 445$			
Number of observations:	$n = 1335$			
Dependent variable:	Number of posts of unique, different species photos		Number of posts of species photos	
Prosocial incentive*Treatment week 1	4.091	4.137	5.767	5.811
	(2.851)	(2.832)	(3.858)	(3.822)
Prosocial incentive*Treatment week 2	0.949	1.115	−0.256	−0.012
	(1.307)	(1.329)	(1.940)	(1.962)
Financial incentive*Treatment week 1	4.570***	4.150***	4.970***	4.267**
	(1.521)	(1.587)	(1.826)	(1.930)
Financial incentive*Treatment week 2	3.250***	2.909**	1.569	1.047
	(1.223)	(1.259)	(1.888)	(1.988)
Treatment week 1	−1.553	−19.939	−1.795	−26.756
	(0.994)	(15.573)	(1.126)	(21.407)
Treatment week 2	−1.685*	−24.629	−0.278	−31.490
	(0.964)	(19.382)	(1.669)	(26.653)
Time-varing attributes	NO	YES	NO	YES
Constant term	6.464***	62.708	7.584***	88.299
	(0.425)	(50.531)	(0.536)	(69.921)

Note: We use fixed-effects estimation and standard errors clustered at each participant; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2024.108506.

Data availability

The data that has been used in this study is confidential under the agreement with Biome, Inc. We have uploaded the program code as a supplementary file.

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