Experimentation

Co_Lab

UNDP Argentina accelerator lab

Environmental Citizen Science and its Effects on Participants, Governance, and Innovation

Evidence of Two Small-Scale Experiments

Index

UNDP acknowledges the relevance of inclusive language to make gender diversity visible. Thus, the generic masculine and female forms are alternately used in this report.

Summary

Climate change is accelerating its impact on development. This is a complex problem with individual and institutional dimensions that must be addressed from a systemic perspective. This report presents the results of two experiments in which we tested two environmental citizen science solutions, which demonstrate the potential of this approach to address this problem. The first was an initiative to separate household waste to evaluate its effects on the commitment and predisposition of people to care for the environment. Throughout the experiment, there were indications of a positive correlation between age, educational level, and the existence of pro-environmental behaviors in the participants prior to treatment. Although there were no effects observed in the variation of post-treatment environmental engagement, this can be linked to the self-selection bias of the volunteers who participated. Unlike what was expected, the control group showed an increase in their environmental engagement. This increase may be related to the participation of both groups in a survey on environmental issues which, given the lower pro-environmental bias of the control group, could have had an effect in this regard. Another result suggests correlations between education, age, and the increase in post-treatment environmental engagement, but the evidence was not conclusive. The second experiment was a crowdsourcing experience in aquatic ecosystems, using a mobile app that creates georeferenced environmental quality indicators. This sought to learn about the effects of citizen science on environmental governance, on increasing the quantity and quality of information obtained, and on promoting innovation in local environmental policies. In all three cities where the app was deployed, it helped collect valuable information about the state of their aquatic ecosystems. In addition, we obtained qualitative evidence of greater coordination across government areas to work on these policies. In the city where citizens took part in the mapping, the resulting data reflected a greater diversity of views and experiences on the natural environment.

These results leave the following lessons about the possibilities and limitations of environmental citizen science at individual and governance level:

1. It can be a tool to promote individual changes as long as it includes people with different levels of information and motivation regarding the issue in question.
2. It can be more effective if it is used in a segmented way and is targeted to different groups of participants —with diverse ages, genders, and education levels— and combines them. It also has different effects depending on the degree of interest of the participants in question.
3. It helps shape a more systemic approach to environmental issues in their different dimensions for governments.
4. It encourages innovation and coordination across areas and stimulates the undertaking of new actions and policies.
5. Its tools are user-friendly and easy to adopt both for participating citizens and officials.
6. It involves officials in the tool design process; thus, tools can be customized to meet their needs.
7. It helps officials to produce a greater amount of more plural and accurate information with less effort.
8. The diversity of data it provides allows a more thorough understanding of citizens' needs.
9. It creates new spaces for interaction and dialogue with citizens, even with those who do not participate in other spaces.
10. It allows a greater mutual understanding between government and citizens.

I . Introduction

Climate change is accelerating its impact on development. This is a complex problem with consequences of different dimensions that can be approached from several perspectives, such as incentives for governments to act in a timely manner or the promotion of citizen behavior and awareness that result in compliance with these policies. However, these strategies can sometimes end up competing or contradicting each other unless they are carried out with an overall vision aligned with the systemic nature of the effects of climate change. At the Co_Lab of UNDP Argentina, we learned that citizen science is a very versatile tool that can be useful to tackle different aspects of environmental issues, avoiding the potential tensions that may emerge from fragmented and isolated interventions. We identified different citizen science solutions (**MINCYT & UNPD 2022, 2022**) with the potential to operate on these different dimensions: on the one hand, on the environmentally friendly predispositions and engagement at the individual level, and on the other, on the governance of environmental issues, especially, in relation to the data generating process and policy innovation to address them. Specifically, citizen science fosters environmentally friendly predispositions and engagement. It helps to generate valuable information for its quality and quantity. This, and the tools used to collect information, encourages government innovation and environmental policies. Citizen science is also a means of social and political inclusion because it facilitates the participation of citizens with important governance implications (Göbel *et al.*, 2019; Mattijssen, T., 2022; Nascimento, S. *et al.*, 2018; Pelacho *et al.*, 2021; Schade *et al.*, 2021; van Noordwijk, 2021). Moreover, digital environments and tools have refunded citizen science expanding its reach to the unimaginable (e.g. **iNaturalist Project** or **eBird**). They allow crowdsourcing of more information even from remote and no accessible places. These conclusions arise from two small-scale experiments framed in our learning loop and portfolio on environmental citizen science.

Both experiments were carried out following a model of work that relies on partnerships. We did both of them along with scientists who were already in charge of citizen science projects. We also partnered with local governments that helped us to conduct experiments and adopted the solutions as theirs (**Moscovich, 2022**).

To explore the effects of citizen science on predispositions, we conducted the first experiment called *Laboratorio de residuos* (Waste Lab). A group of neighbors filled in a survey about their habits, beliefs, and knowledge regarding environmental issues and domestic waste management. One-third of them also weighed their domestic waste. A week later, all the participating neighbors completed the same survey again. Our main question here was if taking part in a citizen science experience affects their environmentally friendly predispositions and engagement with the care of the environment. We found a positive correlation between the engagement of some groups of participants, according to their age and educational level. The effects on predisposition were less clear as the volunteers who took part in this citizen science

experience had preexisting high levels of awareness before the experiment. We also found that, before treatment, education and age were positively correlated with higher levels of environmentally friendly behaviors, meaning that older and more educated citizens have more pro-environmental habits linked to their waste management.

Citizen science can also favor the governance of environmental issues. It provides evidence for policy formulation and innovation to address these problems, and it generates new information, everything with less effort from public officials. This information, generated by people with different backgrounds and interests, is more plural and diverse. The participatory nature of citizen science has very important governance implications. It allows citizens to express their opinions and points of view, giving policy-makers a more nuanced understanding of how they experience environmental issues. Likewise, digital tools broaden the reach of citizen science and allow governments to adopt this type of innovation easily. Thus, in our second experiment, we invited three local governments in Buenos Aires, Argentina, to participate in the mapping of aquatic ecosystems using a mobile app called *PreserVamos* (WePreserve). Here, since the app gathers georeferenced data and creates environmental quality indicators for freshwater ecosystems, we wanted to explore if citizen science experiences could encourage local governments to adopt a policy innovation and generate and use new evidence.

In the Co_Lab, we aim at accelerating our knowledge of complex problems that hamper development and building meaningful learnings that can be used by governments and other stakeholders in their development strategies. In doing so, we use a very specific source of evidence: grassroots solutions –that is, what people do on a daily basis in their territory– because people experiencing their own problems become experts in dealing with them, and the solutions they find can teach us valuable lessons. In our learning loops, including the citizen science loop, **we explore future problems and opportunities to identify frontier challenges** (Acosta *et al.*, 2022), **we identify, and map grassroots solutions** (MINCYT & UNPD 2022, 2022), and **we test in a model that harnesses its scalability** (Moscovich, 2022).

The rest of this report is organized as follows: in the second section, we will explore previous theories and findings that support our hypotheses linking the effects of citizen science at the individual and institutional levels. In the third section, we will lay out the *Laboratorio de residuos* experiment, used to test our first set of hypotheses on citizen science and environmental predispositions and engagement, and elaborate on its results. In the fourth section, we will turn our heads to the institutional and governance implications of citizen science, explored by the second set of hypotheses. We will also focus on data generation and innovation in environmental policies, tested using the *PreserVamos* app to map aquatic ecosystems, and describe our findings. In the fifth section, we will discuss the implications of the results and the lessons learned, and elaborate on our findings, which will be summarized in the sixth and final section.

II. Policy and Individual Level Effects of Environmental Citizen Science

Citizen science is a participatory process in which citizens help to collect data in a systematic way or take part in any other stage of the knowledge-building process, usually, but not exclusively, along with scientists. This versatile approach has been proven a useful tool to address different development problems (Fritz *et al.*, 2019), in particular, to different dimensions of environmental issues (Pierini *et al.*, 2021), at the individual and institutional levels (San Llorente Capdevila *et al.*, 2020). There is evidence of the effects of citizen science on the promotion of environmental awareness and engagement, policy-making (Hecker *et al.*, 2019), the generation of new evidence with rigor (Van Brussel & Huyse, 2019), environmental habits (Pierini *et al.*, 2021), and awareness (Jordan *et al.*, 2011; Mitchell *et al.*, 2017; Pierini *et al.*, 2021; Requena-Sanchez *et al.*, 2022; San Llorente Capdevila, 2020), and also on the collaboration between different government areas, and among citizens, governments, and scientists (Pierini *et al.*, 2021; Conrad & Hilchey, 2011).

II.a Citizen science and its potential effects on predispositions and engagement

H.I.a Taking part in a citizen science project positively affects the willingness and predisposition to adopt environmentally friendly behaviors. Volunteers who participated in the citizen science initiative are expected to have a more environmentally friendly predisposition compared to those who did not.

Citizen science allows for generating new data and raising environmental awareness of its participants at once (Pierini *et al.*, 2021). It affects behavior and predisposition by different means. One of the main drivers to take part in citizen science activities is the interest in and commitment to the issues it addresses; and results have shown that these activities can reinforce both (Mitchell *et al.*, 2017). Moreover, at some point, most citizen science activities involve interaction with other participants or the leaders of the initiatives, either when going to the field to gather data or when being trained to do so. This interpersonal interaction can result in

changes in behavior through motivation, imitation, or peer effect (Varotto & Spagnolli, 2017). Whether patterns of whales' migration or the features of certain birds or mosquitos (MINCYT & UNPD 2022., 2022), participants acquire new information and knowledge related to the topic being addressed in the citizen science activity (Pierini *et al.*, 2021; *Santori et al.*, 2021). In addition, participants also learn from experience (Van Noordwijk *et al.*, 2021). They can realize how rains impact flooding or evaluate aquatic ecosystems, and through these experiences, they become aware that they are able to adopt new environmentally friendly habits (Steg & Vlek, 2009).

H.I.b Citizen science will have a positive reinforcing effect on the engagement of citizens that, after taking part in these experiences, will be more willing not only to undertake more environmentally friendly actions but also to advocate for these issues with their social circle.

According to previous findings (Mitchell, 2017; San Llorente Capdevila *et al.*, 2020), individual awareness of citizen science topics is positively related to the willingness to participate in these activities. Given this fact, those who choose to participate may usually be the most interested in and concerned about the issues. This is known as self-selection bias and means limitations in assessing the effects of citizen science on these individual and subjective dimensions. However, citizen science may have other effects, even among the most concerned, such as reinforcing these predispositions in the first place, but particularly the possibilities of "spreading the word" about environmentally friendly habits.

It is also interesting to assess if these predispositions to participate, the level of participants' environmental concerns, and the post-treatment effects of citizen science are somehow linked with different personal characteristics, such as gender, educational level, or ethnicity (Varotto & Spagnoli, 2017). Previous findings show evidence of the differential effects according to previous knowledge and experience, degrees of environmental awareness, socio-economic backgrounds (San Llorente Capdevila *et al.*, 2020), pro-environmental motivations (Sharpe *et al.*, 2021), age and gender, as well as other psychological variables (Swami *et al.*, 2011) of participants.

In all, citizen science has several potential effects on participants, such as promoting environmentally friendly opinions and habits, and reinforcing citizen engagement through new learnings and practices (Jordan *et al.*, 2011). These effects may come up from the new knowledge and information they get, but also by experiential learning and by the effect that peers have on their behaviors (Jordan et al., 2011; Schultz, 2014; Shultz & Kaiser, 2012).

II.b Citizen science as an environmental governance input and outcome

Not only does citizen science allow people to go through a learning and awareness process, but, at an institutional level, it can also help to generate and adopt new data and tools by the governments and promote citizen participation enhancing environmental governance at the same time (Conrad & Hilchey, 2011; Mattijssen, 2022; World Bank, 2016). The possibilities of citizen science to contribute to data generation and policy innovation in environmental areas are related to the multiple resources that citizen science can provide governments, which many times lack them. According to the European Citizen Science Association (ECSA, 2015), citizen science can influence policies, foster innovation, and promote participation; in this last sense, citizen science can be a means for social and political inclusion. Because citizen science is usually open to all kinds of people, with or without previous knowledge, citizens with different levels of education, interests, and social backgrounds can get involved in citizen science activities. These people may not be the ones who usually join other participatory instances at the local level. In this sense, these activities allow a more plural approach, with different interests and points of view, and a broader set of voices to emerge and express themselves. It gives people the possibility to be listened to and included in the public agenda, and influence decision-making as well (Conrad & Hilchey, 2011). Plus, it gives a common ground for discussion and consensus building among government officials, citizens, and scientists, and more generally different stakeholders, about different problems and priorities, such as environmental issues (Acosta *et al.*, 2022; Aceves-Bueno *et al.*, 2015; Newman *et al.*, 2017; World Bank, 2016).

Moreover, as we will see, citizens may have different points of view and experiences (Schade *et al.*, 2021) in relation to flooding, waste management, the use of watercourses, and other topics of citizen science, which may translate into different assessments of the evidence they collect. When citizens collect the information, they also share their perspectives arising from their experience. In the example of the water bodies' datasets, built with the information collected by the citizens, "it provides not only water quality conditions throughout the study area but the type of water use, locations of water sources accessed, the timing of use, seasonality patterns of water use, and so on" (World Bank, 2016:10). This information is very difficult, not to say impossible, and expensive to gather by other means. In this sense, citizen science results in datasets reflecting a more diverse set of interests and experiences in relation to its object of study. It gives policy-makers a more nuanced understanding of the issue under analysis and how this is impacting citizenry, and thus facilitating the citizens' agreement and compliance with the policy, they undertake to address the issue (Irwin, 1995; Hecker *et al.*, 2019).

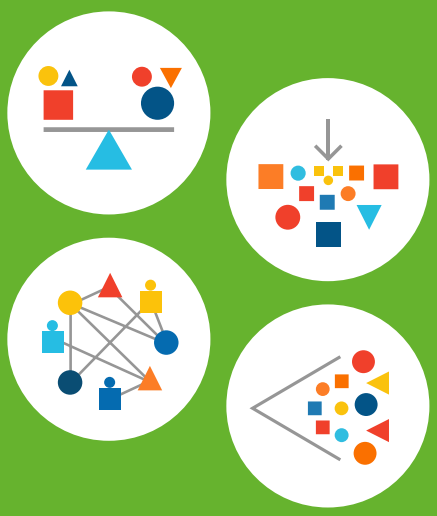
II.c The contribution of citizen science to data gathering and policy innovation

Since citizen science activities are most of the time designed and led by scientists, they gather evidence in a systematic way. This guarantees that the evidence generated through a variety of activities —with

appropriate preparation— meets basic standards of quality (Cochero 2018; Theobald *et al.*, 2015; Werenkraut *et al.*, 2020). Some argue that even if accuracy and bias are a challenge, many strategies –before, during, and after the projects' deployment– can be carried out by scientists to address this issue. These strategies are related to participants, like the careful training of the citizens (Koo *et al.*, 2022) or relying on more experienced participants because evidence shows the longer participants take part, the higher the quality of the information they gather (Dickinson *et al.*, 2010). Other strategies focus on the quality check of the data. Such strategies can be using sub-samples gathered by scientists to use as baselines to compare with the samples collected by citizens (Aceves-Bueno, 2017), validating the data in different iterations (Kosmala *et al.*, 2016), applying different statistical tools (Koo *et al.*, 2022; Dickinson *et al.*, 2010), supervising the collection process, applying cross data controls or submitting it to peer review (Freitag *et al.*, 2016), among others (Lukyanenko *et al.*, 2016). However, governments are reluctant to trust and use this data. Common reasons usually given for resisting the use of this information are related to the lack of an experimental design, sample size, data fragmentation, and issues regarding the objectivity of citizens, among others (Conrad and Hilchey, 2011). One of the main challenges of citizen science is to reach decision-makers so they can use the evidence and lessons learned to set their agendas and design policies (Schade *et al.*, 2021).

This evidence is very valuable in developing countries, where the lack of resources (Pierini *et al.*, 2021), and sometimes specific expertise (Conrad & Hilchey, 2011), generates a subsequent lack of information for decision-making. The new information gathered by citizens can reduce the effort needed by officials to generate it (Dickinson *et al.*, 2010; Fritz *et al.*, 2019; Nascimento *et al.*, 2018), and more broadly, influence policy-making (Conrad & Hilchey, 2011).

The second set of hypotheses (H.II) is related to the effects of citizen science on environmental policy-making. Citizen science initiatives can:



- ***create valid and rigorous evidence that can be used to define and design public policies at a local level. H.II.a***
- ***reduce the effort of public officials to generate the evidence needed for the follow-up of several environmental issues. H.II.b***
- ***provide different assessments in the production of data generating evidence in a more plural way. H.II.c***
- ***foster innovation by facilitating the adoption of new tools for data gathering. H.II.d***

Not only can citizen science contribute with new data but also with **innovative tools** not formerly used by the government (Acosta *et al.*, 2022; Schade *et al.*, 2021), particularly at the local level. Digital tools have both lowered the cost of data gathering and expanded the reach of citizen science (Pierini *et al.*, 2011) which became crowdsourcing. **Crowdsourcing** is an activity made by a large number of people who volunteer to gather or share information (or give their time or services) with digital tools or in digital environments to put up a project or task (Oxford Dictionary, 2015). The use of mobiles and apps (Lemmens *et al.*, 2021) allows citizens to search in different places, **expanding the geographical reach of this data gathering and facilitating its endurance** over time (Conrad & Hilchey, 2011; Pierini *et al.*, 2021; World Bank, 2016). These technological advances also facilitate citizen science: increase the likelihood of participation and reinforce engagement in a **virtuous circle between the individual, and policy/governance dimensions** (Newman *et al.*, 2012).

Table 1. Hypotheses and experiments on the contribution of citizen science to address different dimensions of the environmental problems

Dimension under analysis	Hypotheses Citizen science...	Experiment/CC experience	The Colab partnered with
Individual Level	Positively affects the willingness and predisposition to adopt environmentally friendly behaviors and reinforces engagement on these issues.	*Laboratorio de Residuos* Domestic waste weighting	City of Quilmes, (located in the province of Buenos Aires, Argentina) Lab Ciudadano (University of Buenos Aires)
Governance/Policy Level	Creates valid and rigorous evidence useful for policy making. Reduces the effort of public officials to generate evidence. Produces evidence in a more plural way. Fosters policy innovation.	*PreserVamos* App to map aquatic ecosystems	Cities of Mercedes, Balcarce, San Antonio de Areco (located in the province of Buenos Aires, Argentina) AppEAR (University of La Plata)

Source: Own elaboration

With these findings in mind, we designed two small-scale experiments. We aim at learning more about the effects of citizen science on individuals, through changes in their predispositions, and on governance and environmental policy, through producing more diverse data with less effort, which could be used as input for public policy-making and policy innovation. Table 1 sums up our hypotheses on citizen science regarding environmental issues on these levels and the experiments designed to test them.

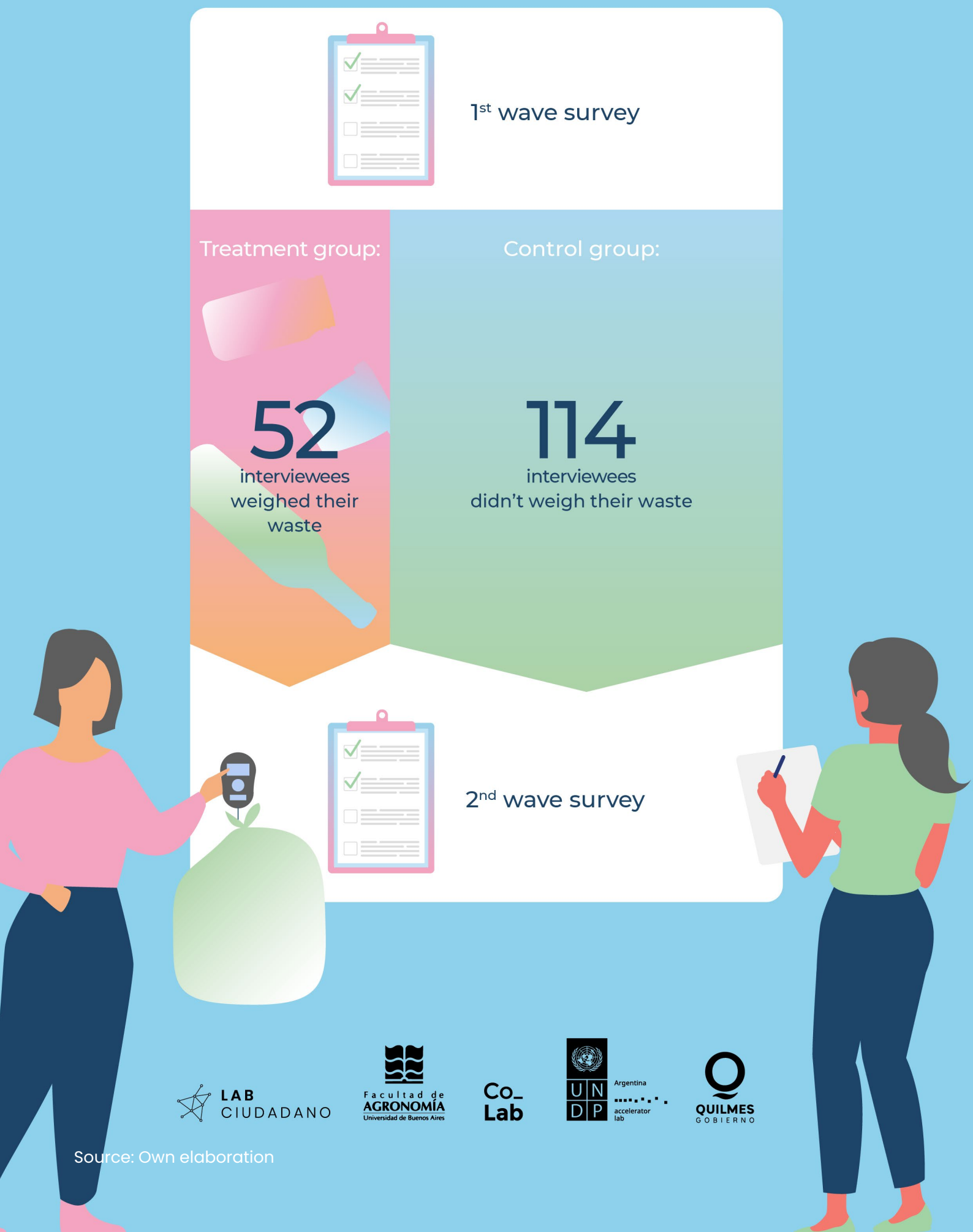
III. Experiment I. Citizen Science Effects on Environmental Predisposition

III.a *Laboratorio de residuos*: A waste weighing experience

The experiment lasted three weeks and replicated the model developed by *Lab Ciudadano* (see Pierini *et al.*, 2021). During this period, 166 neighbors filled in a survey (some of them in person, others online using a QR code). The survey inquired about their habits, opinions, beliefs, and knowledge regarding environmental issues and domestic waste management, and their predisposition to engage in several environmentally friendly activities in the near future, alongside their socio-demographic background. The treatment group was composed of 52 interviewees, who volunteered to separate and weigh their household waste using personal scales for a week. To do so, they were given instructions by the *Laboratorio de residuos*' team to separate their waste into three main categories – organics, recyclables, and others – and to weigh them. After a week, they were surveyed again to evaluate if participating in the *Laboratorio de Residuos* experiment had any effect on the participants' views on several environmentally friendly habits and their predisposition to engage in them.

In the first survey, participants replied to questions regarding their views on different environmentally friendly behaviors and issues, and their willingness to engage in them. They also stated their willingness to participate in a second stage of the experiment, weighing their own household waste for a week (treatment group). Those who agreed were given weighing scales, and informational brochures and a team member was assigned to follow up on their progress through WhatsApp. On the other hand, those who did not agree to participate (control group) were only reminded that they would be receiving a second survey after 7 to 10 days. All participants, whether in the treatment or control group, answered the questionnaire twice, with a week of difference. The only difference between groups was their participation (or not) in the weighing experiment. Those who took part in the weighting experience also registered specific information and results regarding their experience (treatment group).

Figure 1: Design of the *Laboratorio de residuos* experiment



Source: Own elaboration

III.b Results of the *Laboratorio de residuos* experiment

1st wave

314 people answered the first survey

2nd wave

166 people completed it again a week later out of which, 52 were part of the treatment group (31%)

We focused on this group of 166 people who completed both questionnaires to compare the results of the experiments, as well as the predispositions and commitment of the treatment and control groups.

When analyzing the composition of the sample groups, we see that there were imbalances, particularly referring to age and gender. For instance, elder people (80+) did not take part in the experiment, so we could not observe any kind of behavior or result for this group. Young people (20-39 years old) were the majoritarian group (60%), followed by adults from 40 to 59 years old (23%), and then children (11%). Also, 81% of the participants were women. Only 17% of them identified themselves as males, and 1.8% did not provide a specific answer to this question. This imbalance in gender did not allow us to perform any statistical analysis that could give meaningful insights. Different studies on environmental psychology find that women exhibit a higher environmental awareness or personal involvement in environmentally friendly habits when compared to males (see Casaló Ariño & Escario, 2018), which could account for a lacking representation of males in our sample and points out the need to increase this group's representation in following studies. When analyzing the level of education in the sample, most participants have secondary education (56%), followed by undergraduate/ tertiary and primary education, with 32.8% and 10.8% respectively.

For this experiment, we wanted to test whether participation in the measuring experience had any effect on the participants' predispositions and engagement with environmentally friendly behaviors. To do so, we put together a questionnaire that gathered participants' responses in relation to their environmentally (friendly or unfriendly) behaviors in the past week, such as composting,

separating waste, reading about the environment, talking to their friends regarding these topics – on the positive –, as well as throwing their waste on the street or in a single bag – on the negative. We also asked them how likely they thought it would be for them to do these activities the following week. Finally, we asked them how much they agreed (or not) with a series of phrases, such as "I care about what happens to my waste after I take it out". With these responses, we assigned them values using a Likert scale and created an index that summarized the participants' responses on these three aspects: habits, likelihood to adopt these habits, and affinity. The environmental predispositions index (see details in Appendix I) for each participant looks as follows:

$$Environmental\ Pr\ Predispositions_i = Habits_i + Likelihood_i + Afinity_i$$

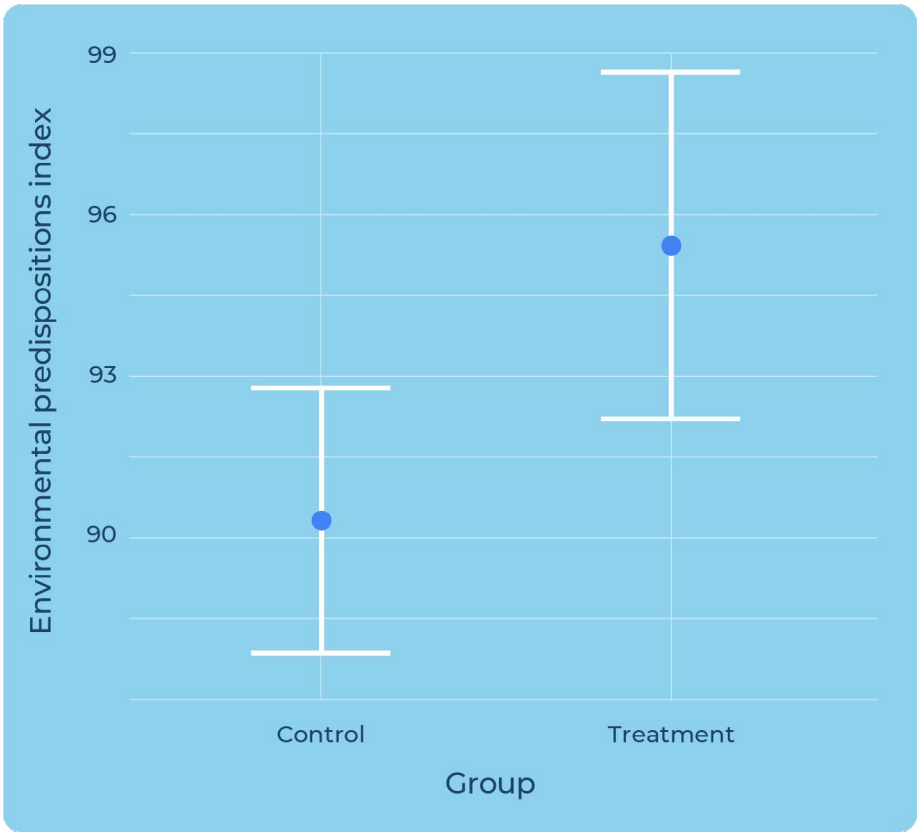
Our index takes values from 0 to 125, with higher numbers representing more environmentally friendly behaviors, beliefs, and predispositions. Our assumption was that people in both groups, treatment, and control, would have similar levels on this index before treatment. To verify this, we performed an inferential analysis. Our first hypothesis was that the values of this index would increase more in the participants of the treatment group than in the control group (we analyzed predispositions because the short time between both surveys limited the assessment of changes in habits and behaviors). The second hypothesis was related to the effects on engagement, whose proxy was the predisposition to inform friends and family about issues related to waste.

For the first hypothesis, we compared the environmental predisposition index between participants belonging to the control and treatment groups using a t-test. To rule out if differences were random, our first analysis aimed at evaluating if there was a statistically relevant difference in the participants' index across groups. Our results indicate that there was indeed a statistically significant difference in the index of the participants that belonged to the treatment group, with a mean index value of 95.44, while the volunteers in the control group had a mean index value of 90.33. This contradicts our assumption that both samples had the same index of environmental predisposition. This means the volunteers that decided to separate their waste already had a higher level of environmentally friendly behaviors and beliefs than the ones who did not volunteer. These results are in line with previous findings in the literature that argue that higher levels of environmental awareness are correlated with a willingness to participate in citizen science activities (Mitchell, 2017; San Llorente Capdevila *et al.*, 2020).

Unlike the expectation, when analyzing the difference in the index in both groups before and after the experiment, we found that participants in the control group had a mean increase in their index of 3.31 points, higher than the treatment group, which showed an increase of 1.80 points. It is important to recall that higher numbers account for more environmentally friendly predispositions. These findings could show a positive effect of the act of filling in a questionnaire

asking about environmental issues on the participant's attitudes and beliefs, independent of the act of participating in the treatment. Also, the milder effect on those who weighed their household waste can be explained by the fact that pre-treatment in this group already shows higher levels in the index of environmentally friendly predispositions.

Figure 2: Participants' environmental predispositions index before treatment across groups



Note: Own elaboration. Mean and confidence intervals for participants' environmental predispositions index across groups

Considering these results, we decided to run linear regressions to assess if the predispositions index prior to the treatment was explained by different sociodemographic variables – the age category of the participants, their maximum level of education, their gender, and if they had decided to participate in the treatment (Varotto & Spagnoli 2017; San Llorente Capdevila *et al.*, 2020; Swami *et al.*, 2011). We decided to include this last variable since enrollment was voluntary. The results of the regression can be found in Table 2.

Table 2: Determinants of environmental predispositions index before treatment

Variables	Coefficient	p-value
Age Bracket		
Under 20 years	-	
20 - 39 years	1.0	0.800
40 - 59 year	3.9	0.300
60 - 79 years	-1.0	0.900
Group		
Control	–	
Treatment	5.0	0.021
Level of education		
Incomplete Primary	–	
Complete Primary	-0.3	0.981
Incomplete Secondary	-3.2	0.735
Complete Secondary	2.5	0.776
Incomplete Tertiary	0.7	0.943
Complete Tertiary	4.3	0.641
Incomplete Undergraduate	4.2	0.640
Complete Undergraduate	7.4	0.416
Incomplete Graduate	21.0	0.058
Complete Graduate	14.0	0.142
Gender		
Female	–	
Masculine	-3.3	0.200
Does not specify	7.0	0.300
*** p<0.01, ** p<0.05, * p<0.1		

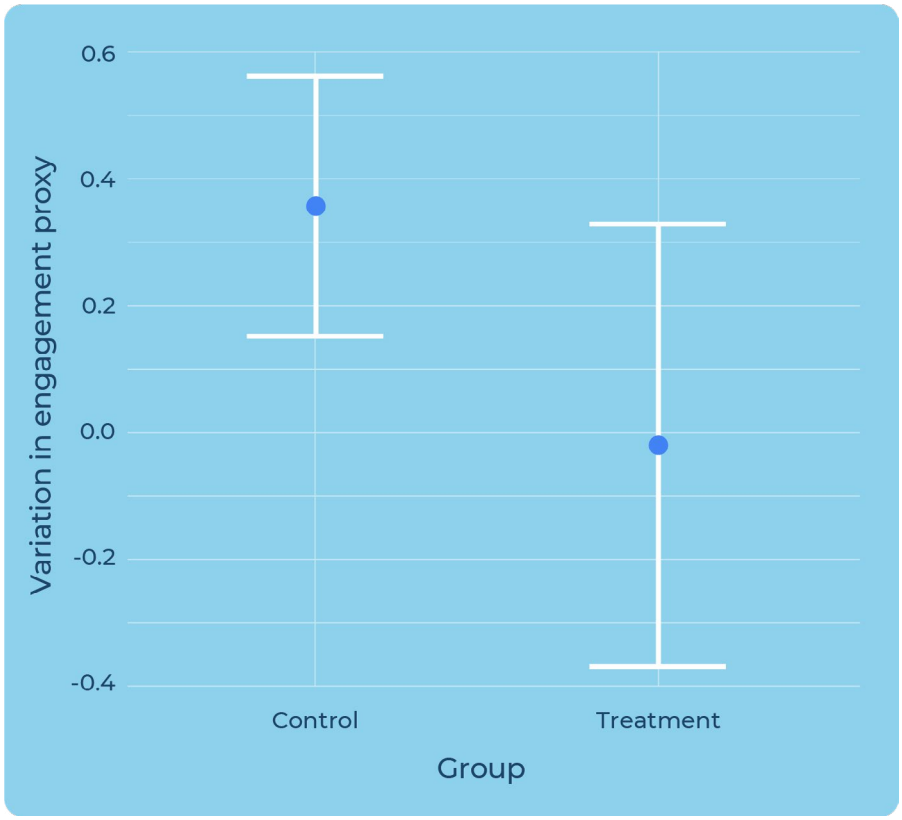
Note: Own elaboration. Linear regression —Ordinary Least Squares (OLS)— on the effects of several sociodemographic variables on participants' index of environmental predispositions before treatment

We found a positive relationship between the maximum level of education achieved and the environmental predispositions index before treatment, with a statistically significant correlation in participants with an incomplete graduate education, who had an index 21 points higher than the base category (incomplete primary). This coefficient is statistically significant at 10%. The fact that the effect of the correlation is smaller in the complete graduate category is worthy of attention, but since this coefficient is not statistically significant, the possibility that this result may arise from random effects cannot be ruled out. These results are in line with previous findings that indicate a positive correlation between pro-environmental behavior (Sharpe *et al.*, 2021) and education (there are mixed findings in relation to education (Casaló Ariño & Escario, 2018; Hornsey *et al.*, 2016)). We did not find statistically significant effects for age or gender. The variable that explains variation in the index with statistical significance is the decision to take part in the weighting experience. We found that volunteers that agreed to participate in the treatment had a value for the index 5 points greater than the ones who did not before treatment. This result is statistically significant at 5%. Therefore, it reinforces the theory that people with greater environmental awareness have a greater tendency to participate in citizen science experiences.

As mentioned earlier, the questionnaires had an array of questions aimed at gathering information about the participants' beliefs, habits, and willingness to adopt some environmentally friendly behaviors. We expected citizen science to have a reinforcing effect on the engagement of participants with environmental issues and concerns. For that, we ran a linear regression to measure the difference between pre- and post-treatment in the participants' responses to one question in particular – their willingness to inform their friends and family about the waste-related issues in the following week – which was used as a proxy for engagement.

Figure 3 illustrates the change in the predisposition to inform friends by group, showing that the treatment group had a slight negative variation in their predisposition, while the control group overall had an increase in their predisposition to inform their friends. We also estimated the effects our variables had on this variation with a linear regression, the results of which are illustrated in Table 3.

Figure 3: Changes between surveys in the participant's predisposition to inform their friends about waste-related issues in the following week, across groups



Source: Own elaboration. Mean and confidence interval depicting the variation in participants' predisposition to inform their family and friends about waste issues

Table 3: Estimation of determinants of differences in participants' engagement proxy between surveys

Variables	**Coefficient**	**p-value**
Group		
Control	–	
Treatment	-0.3	0.100
Age Bracket		
Under 20 years	–	
20 - 39 years	-0.4	0.266
40 - 59 year	0.1	0.685
60 - 79 years	-0.2	0.754
Gender		
Female	–	
Masculine	-0.1	0.600
Does not specify	0.1	>0,9
Level of education		
Incomplete Primary	–	
Complete Primary	1.7	0.073
Incomplete Secondary	0.6	0.470
Complete Secondary	0.9	0.195
Incomplete Tertiary	1.4	0.054
Complete Tertiary	0.9	0.231
Incomplete Undergraduate	0.7	0.320
Complete Undergraduate	0.9	0.201
Incomplete Graduate	0.1	0.902
Complete Graduate	0.6	0.432
*** p<0.01, ** p<0.05, * p<0.1		

Note: Own elaboration. Linear regression (OLS) on several sociodemographic variables' effect on the changes in participants' stated predisposition to inform their friends and family about waste issues between surveys

The results of the regression indicate a mild decrease in the engagement proxy for individuals belonging to the treatment group when compared with the control group; this coefficient is statistically significant at 10%. This finding could be aligned with other sources (see Gomera Martinez, 2008, and Mitchell *et al.*, 2017) that indicate that a person's motivation is defined by both their attitude and the social norm. It is possible that volunteers did not consider it was their responsibility to inform others.

Additionally, since participation in the treatment —which involved a full week of waste sorting, weighing, and recording— was voluntary, the fact that there is a self-selection bias cannot be ruled out. This bias may limit our ability to assess the impact of this citizen science experiment. Again, although not all the coefficients are significant, we notice a positive correlation between educational level and greater environmental engagement. The control group experienced an increase in their environmental engagement. This is an intuitive result since the marginal changes in the group with a lower pro-environmental predisposition (control group) are expected to be greater than those of the group with a higher pro-environmental predisposition (treatment group), even when the latter only answered the questionnaires and did not weigh their waste.

It is worth noting that this survey was complemented by 10 qualitative in-depth interviews with 5 participants from each group after the experiment was finalized. In the interviews, people who participated in weighing their waste manifested a willingness to change their everyday behaviors toward recycling. People from both groups highlighted the influence the experiment had had on them at a personal level. Comments such as "I feel it has shown me the importance of recycling and made me aware of how much my waste weighed. I was surprised by the weight" or "I learned to separate waste, I used to throw everything in the same bag. [I separated] cardboard and bottles and gave them to a man the other day" (own translations) show that there is an ongoing learning and awareness process in these participants.

People from both groups stated that they were more aware of the consequences of their environmental behaviors after the experiment. This was especially remarkable in the treatment group, suggesting that participating in the experience of weighing their household waste might have been a decisive factor towards this change (in perception).

III.c Limitations of the Experiment

While we have gathered valuable insights from this experiment, there were also limitations when analyzing its results. The first would be the small sample size and the fact that it was imbalanced in terms of gender. The second is related to the small-scale and short-term nature of the intervention, which hinders our ability to observe long-term effects on behaviors and beliefs. These two could be addressed in a future implementation aiming at increasing the sample size and taking a longer timespan between measurements. A third limitation arose by design. The fact that enrolment in the experience was voluntary led to a self-selection bias. That is, participants in the treatment group already had a high index of pro-environmental predisposition before the experiment. This fact hampered our ability to isolate its effects.

This could be addressed by randomizing what treatments participants get. Finally, the last limitation we see in this design is that it is based on self-reported beliefs and behaviors, which biases replies in the sense of complying with what is socially expected from environmentally friendly behaviors or predispositions.

IV. Experiment II. Citizen Science and Environmental Governance, Policy-making, and Innovation

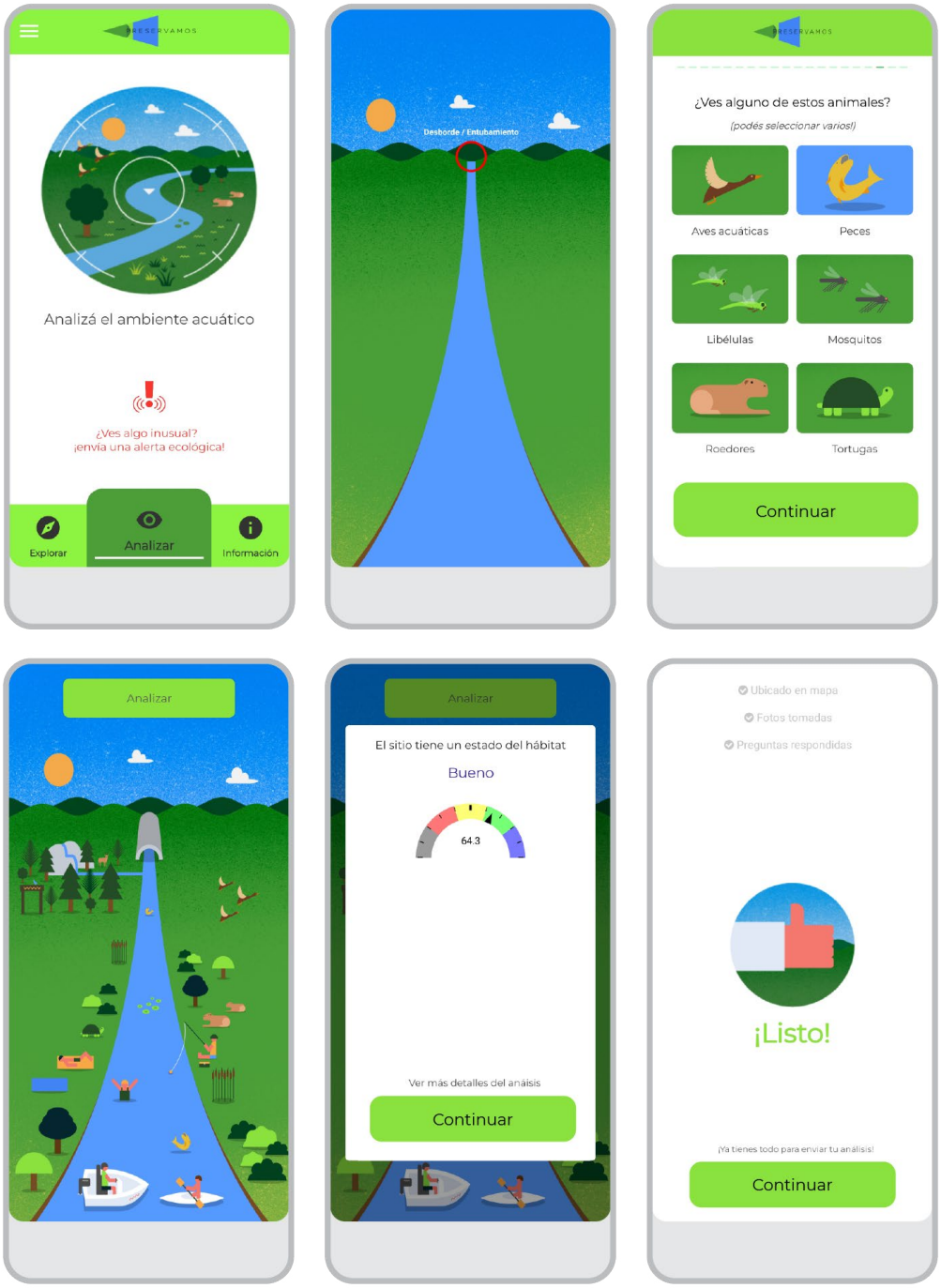
IV.a *PreserVamos*: An app to monitor aquatic ecosystems

Download the app

In the solutions mapping, conducted along with the Ministry of Science and Technology, (MINCYT & UNPD 2022, 2022), we met Marcelo Garcia, a scientist working in the City Government of the province of Córdoba, Argentina, who organizes citizen science activities to produce evidence on topics such as floods, bodies of water, or rains, that informs the actions and policies of his team. To our best knowledge, this experience embodied the gold standard of citizen science: being embedded in the government and impacting on public policies. Therefore, we decided to test its scalability. However, it was far beyond our scope to replicate this model in a reasonable time span, given the laws and bureaucratic structures that rule governmental agencies' work in Argentina. Thus, we developed a minimum viable product: "Community-based monitoring where citizens, scientists, and government can collaborate to monitor, track and respond to issues of common community environmental concern" (Whitelaw *et al.*, 2003, in Conrad and Hilchey, 2011). This initiative would allow us to explore the effects of citizen science on the governance of environmental issues at the local level. In addition, we would be able to provide evidence on its potential for gathering data, saving governmental efforts, increasing diversity in the assessment among citizens and governments, and possibly even fostering policy innovation.

In partnership with three local governments from Buenos Aires, Argentina, San Antonio de Areco, Mercedes, and Balcarce, and with the scientists running AppEAR (see details of this initiative in Cochero, 2018); we co-designed a small-scale experiment. Officials from the three local governments participated in a mapping of aquatic ecosystems using *PreserVamos*, a new version of the original mobile app AppEAR. The logic behind this experience is that, while visiting local lagoons or rivers, users can follow the instructions of the app, which asks them questions about what they can perceive in their environment and asks them to take photos of what they see. The questions are aimed at evaluating the environment, with prompts like "Do you see any of these animals?", "Is there garbage on the riverbank?", "Is there garbage in the water?", "Does the water smell bad?". Based on the responses, the app calculates an environmental index (with values between 0 and 100) for that georeferenced mapping. It also has information about the initiative and visual resources to help users in the mapping process, such as images of invasive plant species.

Figure 4: Images of the *PreserVamos* app



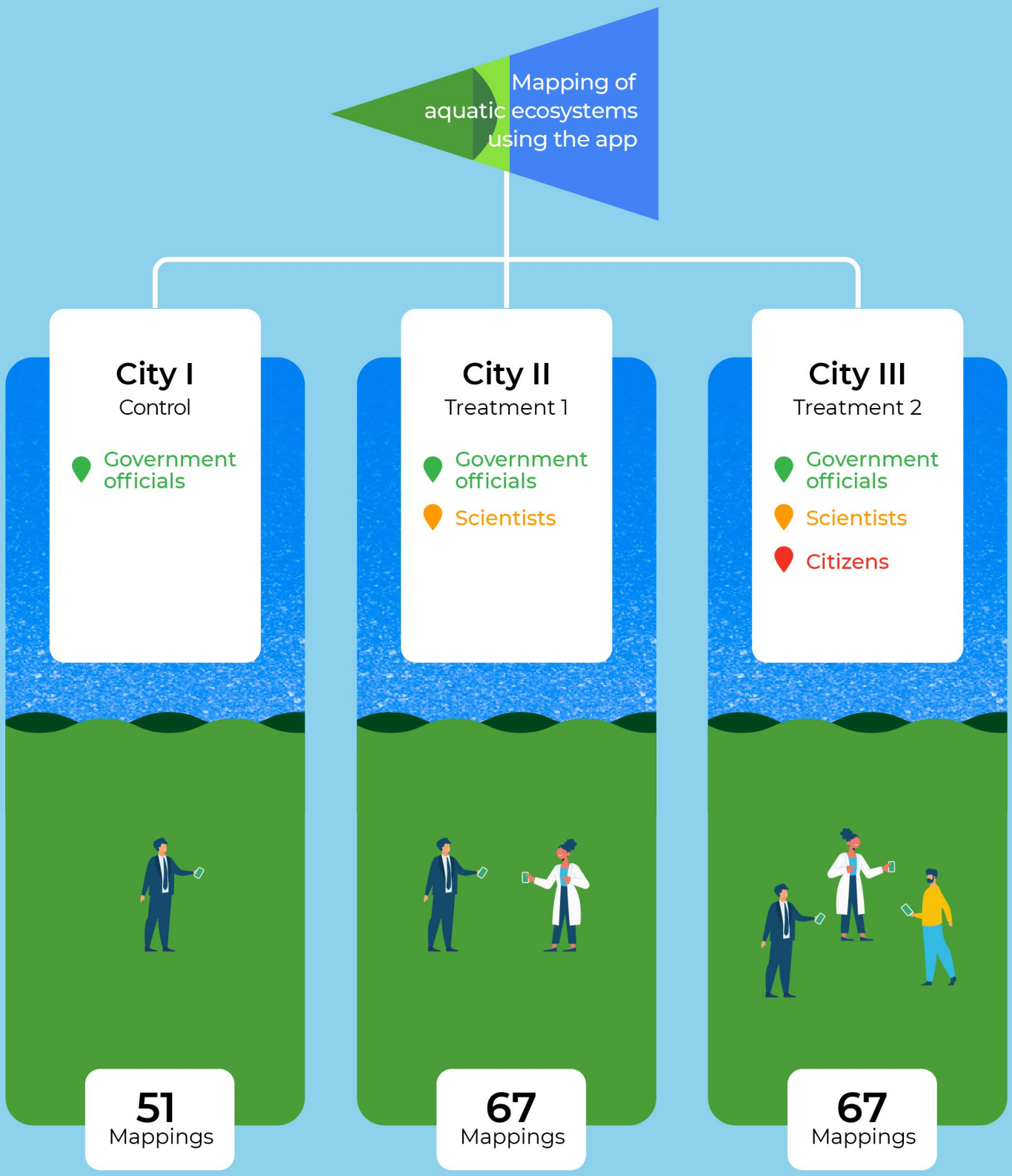
Source: Own elaboration

The app yields an indicator that has scientific validity (Cochero, 2018). The questions were designed by the AppEAR team, made up of biologists from the University of La Plata, Buenos Aires, Argentina, who are researchers specialized in water ecosystems. Local officials were invited to participate in a beta testing of this new version of the app, which they helped to co-create by including questions and issues of their interest. The beta testing included the usage of the app for two weeks, creating as many mappings around their aquatic environments as they could within that timespan.

The implementation of the *PreserVamos* project took almost 7 months, beginning with several meetings and collective intelligence activities with the AppEAR team to discuss the co-design of the experiment. The next step was several in-depth interviews with key informants responsible for the environmental areas of eight cities of the province of Buenos Aires, in Argentina. It allowed us to have a more nuanced understanding of the approaches, needs, and other dimensions of the management of aquatic ecosystems. In addition, we could get an overview of the environmental governance and policies that needed to be adjusted for community-based monitoring, and of the updates the new version of the app needed to meet all of these requirements. This pre-production work covered the dimensions suggested by the World Bank (2016) for the successful implementation of this kind of project. We invited three local governments from that pool to participate in the pilot testing of the app. And they also took part in the final stage of production, which included the design of promotional and informational materials to spread the use of the app within each group participating in the mapping, according to the experiment design in each city (see infographic). The guest cities share similar demographic characteristics. This made them comparable in terms of size and resources. They all had water bodies resources, and these water bodies were explicitly in the environmental management agenda of the city. Plus, they had, or were in the process of creating, a protected area or nature preserve, which was taken as a proxy of a baseline in the environmental management of local natural resources; and their water bodies were comparable.

The experiment took place between March 3rd and 20th, 2022. Four additional days to the first ending date, March 16th, were needed due to severe thunderstorms in the area. In each city, the degrees of participation of scientists and citizens in the use of the app varied (see the infographic). This would allow us to assess the potential effects of citizen science in the generation of new evidence and the effort associated with these tasks, the diversity in the generated data, the use of this innovation, and the strategies that each local government used to manage their water resources.

Figure 5: *PreserVamos* experiment design



Source: Own elaboration

In the first city of treatment, both citizens and scientists took part in the 2-week mappings along with the government officials. To that end, there were public campaigns on social media inviting citizens to take part in the mapping and materials developed ad hoc to be shared in the public campaign. In the second city, only the scientists participated with the government officials. They visited the city during the mapping and coordinated mappings together. Although regular meetings with local officials before and after the experiments were held in the three cities, the third one was the control city. In the latter, only government officials carried out the mapping along the same two weeks as the rest of the cities, and they could ask the scientists team for technical assistance. This approach was intended to help us observe in the experiment's results, the incremental effect (or the lack thereof) of the different actors involved.

In addition to the data produced using the application, we designed a matrix to collect additional information requested by local officials in interviews and systematized it in four dimensions. Each dimension focused on a specific relevant aspect that we wanted to evaluate: the tool's adoption, the amount and quality of the evidence gathered, water resource management policies implemented or planned by the local government, and citizen engagement. We used this matrix to analyze the whole cycle of the action - the situation in each city before, during, and after the experiment - to assess the potential effects of officials' approach to environmental policies, specifically the management of water and aquatic ecosystems.

Creating the matrix required further research, such as looking for more information on water resource management in the cities and running several interviews (two months after the mapping exercise) with key informants working in the Environmental Departments of each city.

IV.b *PreserVamos* results. Citizen science effects on data generation amount, effort, and diversity, and on policy innovation

We aim at assessing the effect of *PreserVamos* on the data generated (amount and diversity) in the relative effort made by citizens vs. public officials to gather environmental data, and in the approach to environmental governance and policies implemented by each local government. In relation to the amount of data, we will analyze the number of mappings gathered in each city (with and without citizen participation) during the test. For the second and third aspects, we will evaluate the results using inferential analysis. Data diversity will be studied by comparing the scores of mappings reports made by each type of user, i.e., scientists, government officials, and citizens, while the impact on the effort needed to generate information will be tested using the amount of data gathered by type of users compared to the total mappings. Finally, the app use of innovation in local policies will be analyzed using qualitative data gathered in our environmental governance and policies matrix.

During the three weeks of the experiment, the **app was downloaded 72 times**, **61 persons signed up** (including 4 from AppEAR), and it collected a total of **185 'reports' among all municipalities**. Civil servants from the three cities used the app to collect information, with similar results - **51 reports for the 'Control city'**, and **61 for the Treatment 1 city**. In **Treatment 2**, we observed a low app use by civil servants when compared to the other cities, explained by adverse weather conditions and the resignation of the Environment Area Director a few days prior to the start of the action. However, the final number of reports collected (**60**) was similar, thanks to the citizens' engagement.

The mean values for the **environmental index obtained** were **70.9** for the Control group, **79.4** for Treatment 1 (scientists and local officials), and **66.8** for Treatment 2 (all three actors).

These results are summarized in Table 4 below.

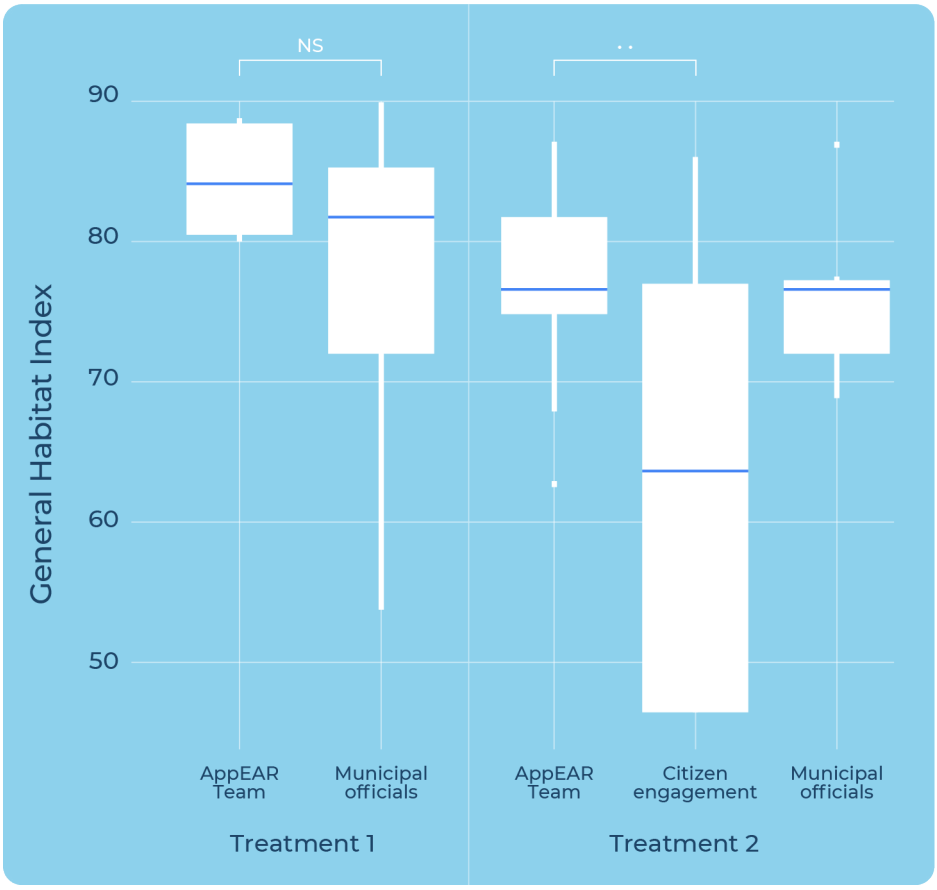
Table 4: *PreserVamos* usage statistics throughout the experiment

Treatment	User Type	Reports	Participants
Control *Balcarce*	Government officials	51	5
	Totals	**51**	**5**
Treatment 1 *Mercedes*	Scientists	6	4
	Government officials	61	6
	Totals	**67**	**10**
Treatment 2 *San Antonio de Areco*	Scientists	11	4
	Citizens	50	47
	Government officials	6	3
	Totals	**67**	**54**
TOTALS		**185**	**69**

Source: Own elaboration.

The next step was analyzing these reports in-depth to see if there was a difference between the mapping done by the different types of users - scientists, represented by the AppEAR team, local government officials, mostly from areas involved in environmental policies, and citizens. For this, we used an analysis of variance (ANOVA) to calculate the difference between mapping scores done by these different groups in Treatments 1 and 2 (the Control city was not used because it only had mappings from local government officials). Our results are shown in Figure 6.

Figure 6: Urban Stream Habitat Index results across user types



Note: Own elaboration. Boxplot for environmental index obtained for Treatments 1 and 2, comparing each type of user - AppEAR team, local government officials, and the general public. The * indicates statistically significant differences between groups, while NS indicates no statistically significant differences.

It can be observed that both in Treatment 1 and 2 the average index produced similar results between scientists and local government officials. In Treatment 1, the average index value was 78.8 among local government officials and 85.2 among scientist users. In Treatment 2, this value was 76.0 for the first group and 77.1 for the second. When looking at the average index obtained by citizens, we can see that it is not only significantly lower (63.2) than the ones corresponding to the other types of users, but it also shows an increased variability, which could indicate that citizens have a more critical view of their environment on average, with widely differing perceptions (see Figure 7). These results point in the direction of citizens having a different perception of what constitutes a healthy natural environment, increasing the diversity of environmental data collected and its rigor.

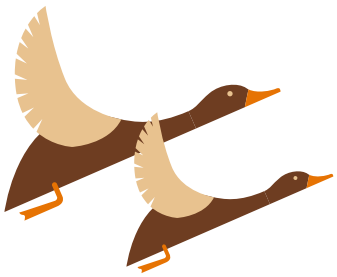
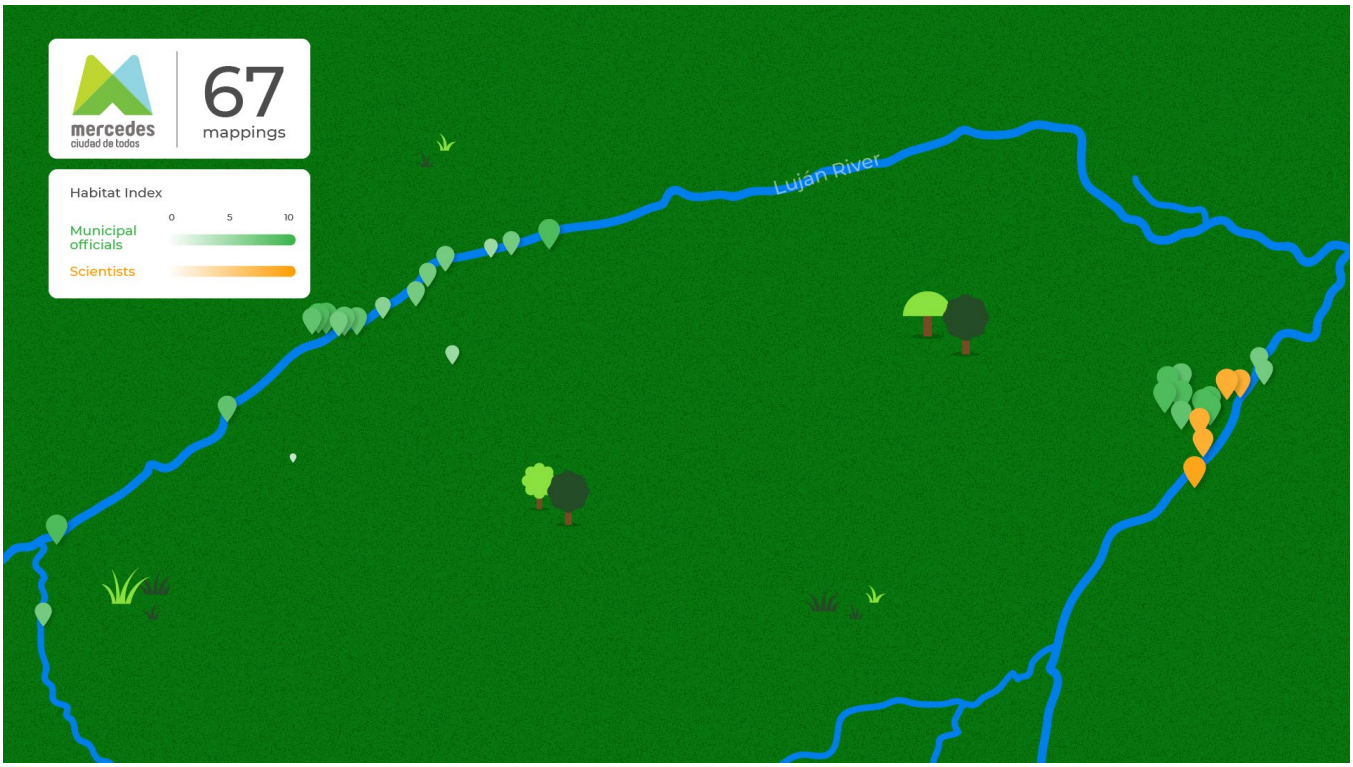


Figure 7: Mappings done in Treatment 1 and 2 by the different types of users



Note: Own elaboration. Each pin indicates a report with a different color according to the user that made it. The pins also change in size and in color intensity based on the resulting index.

Next, in order to measure the effort needed to create the mappings, we evaluated the number of mappings done per capita in each city. A lower number means that each person conducted fewer mappings, which implies a lower sampling effort. In Treatment 2, where citizens were actively engaged in the mappings, a similar number of total mappings was reached with less effort per person. The Control group had a mapping effort of 10.2 mappings per capita, while Treatment 1 had a value of 11.17. Treatment 2 showed the lowest value, with 2.91 mappings per capita. A Kruskall-Wallis test proved that the mapping effort was significantly different across all groups and that the involvement of citizenship in Treatment 2 lowered the effort needed to create useful evidence for the government by threefold ($p\text{-value} < 0.05$).

Lastly, through in-depth interviews and qualitative data, we assessed the potential impact that the participation of these three cities in the *PreserVamos* mapping had on their public policies, and if the app had created inputs for their formulation. While the timespan of the action limits our capacity to observe long-term results, such as the implementation of public policies related to *PreserVamos*, we found widespread interest and willingness to continue using the app. Throughout the interviews, the local informants identified a potential use of the app in generating a channel of communication between the local government and their citizens, as an educational tool, particularly in schools, and as an alert system for ecological events. After their comments and insights, upon the officials' request, two functionalities were added to the app – an alert system for algal blooms, the appearance of high numbers of dead fish, and industrial spills, as well as the integration of the app with ArgentiNat, an app that provides a guide on flora and fauna, and allows participants to recognize and identify species close to their location. It should be noted that these effects were observed regardless of the level of citizen participation in the experience, which would indicate that this result would be based on the tool acceptance, and not on the citizen participation aspect of the experiment.

In addition to these effects directly related to the app and its use in local government's policies, we observed some indirect effects of the implementation of the initiative in other aspects related to its impact on public policy. In all the participating local governments – regardless of the treatment assigned to them - we found evidence of a positive impact on the coordination across government areas that, before the experiment, did not work together on water management. In one of the cities that had reported not gathering information on their hydric resources in a systematic way, in one interview before the experiment, officials shared that they were planning to do so after the experiment, alongside environmental quality indicators using the app. In that same city, we observed that new collaborations were undertaken between the environmental area of the government and the National Institute of Agricultural Technology (INTA, by its Spanish acronym) to participate in the mapping effort. In another city, we identified a renewed interest in taking samples of water quality and habitat (the latter with the

PreserVamos app) more frequently, in the pre-treatment interviews informants stated that these controls were mainly in charge of the provincial government. To that end, they planned a water quality sample collection schedule every three months. This task would be carried out jointly by the city Early Warning Area and the Environment Department.

IV. c Limitations of the *PreserVamos* experiment

The main challenge to conducting the experiments was inclement weather at the beginning of the mapping period, which was particularly severe in the city assigned to Treatment 2, where citizens took part in the experience. The appearance of severe thunderstorms left several fallen trees and meant that the team of local government officials that had committed to engaging in the mapping effort had to attend to these issues instead. Consequently, we had to extend the mapping an additional week in the three cities. However, this event was coupled with the resignation of the Environment Area Director, which meant that there were even fewer people dedicated to the effort. This is shown in Treatment 2 usage numbers, where we can see that they ended up with a similar number of total mappings even though they had more actors involved. Interestingly, this unfortunate occurrence led us to observe the role of the citizenry in providing data the local government could not gather, and it reflects in a lower mapping effort in that city.

Another limitation of this experiment – aligned with the ones observed in the *Laboratorio de residuos* – is the effects of a small-scale short timespan on the experiment's capacity to show effects related to our hypothesis – creation of evidence that is useful, diverse, and that requires low effort by public officials and its influence on public policy-making and innovation.

V. What We Learned

Citizen science has diverse effects on the participants' predispositions and commitment to the environment. In this regard, our results were mixed. This can be a consequence of the short period of the treatments, the small size of the sample, or the self-selection of the participants who volunteer in these initiatives. As people who participate have high levels of interest in the topic, it is sometimes difficult to estimate the impact of citizen science.

The fact that predispositions and commitment vary according to education and age before the citizen science experience suggests the need to promote strategies aimed at different groups.

In the case of *PreserVamos*, the results show that citizen science provides resources for environmental policies, either because citizens reduce the effort to generate data, or because officials use these tools themselves, positively connecting this practice with the adoption of new technologies for data crowdsourcing and managing aquatic ecosystems. The app proved to be useful to generate valuable evidence on the state of the freshwater ecosystems of the cities. There was a threefold decrease of the effort required to produce the evidence in the city where the three types of participants were involved: citizens, scientists, and local government. The tools created for citizen science are user-friendly and intuitive for people with or without scientific knowledge, thus they are also easily adopted by local governments regardless of the citizen participation.

This experience also shows some indirect effects of citizen science on the inclusion of this agenda in the environmental areas of local governments. For example, there were plans to increase the number of water quality measurements in cities that were already measuring it, and to start where they were not doing so. The eagerness to introduce new environmental management tools led officials to ask for an app update that would include customized features to meet their needs. Furthermore, they came up with new usage ideas, such as using the app in schools and other educational programs. The three governments were willing to include the tool in their public policies. Interestingly, one city expressed that it wished to start implementing new water quality controls that in the past were in the hands of the provincial government. This suggests that with the right tools, governments can take on new responsibilities.

The Lessons of Environmental Citizen Science

• Citizen science activities are voluntary which means that its **participants self-select**. This posits a problem to test the effects of its activities and should lead to strategies to **include different kinds of people**.

• These are participants with varied sociodemographic characteristics, such as age or educational level. This suggests that it would be better to adopt **segmented strategies to harness all the potential of citizen science**, directing them towards certain groups or allowing the groups to interact and encourage each other.

• Citizen science activities may shape the **approach to the issues** being addressed. In one of our experiments, the system approach to aquatic ecosystems opened the door for greater coordination across government areas that deal with specific issues of aquatic ecosystems.

• Citizen science encourages **policy innovation** for taking on **responsibilities** in preserving aquatic ecosystems; these duties being shared with other government levels.

• Developing user–friendly tools for citizens, with or without previous knowledge, to gather data makes their adoption by **governments highly probable regardless of citizen participation**. Providing these tools to governments can be helpful for their daily activities. Officials get involved in the tool design process; thus, tools can be customized to meet their needs.

• Citizen science **reduces government's efforts** to produce new data.

• Data collected by citizens is more diverse since it reflects their concerns and experiences with the topic of the citizen science activity. Thus, this information **gives governments a more thorough understanding** of how these problems affect citizens and how they experience them.

• Citizen science is a channel for participation that may be used by citizens who do not use other channels. It gives governments a different **ground for dialogue and mutual understanding to listen to citizens' points of view and demands** regarding the issues being addressed by the citizen science activities.

The data collection instrument can shape the way in which the data is constructed. On the one hand, this means a systemic view for the analysis of aquatic ecosystems as a whole, including data on animal and plant species, floods, type of water use, and general state of water, among others. In fact, using the app can provide an approach that goes through the silos of bureaucracies of the agencies that address these issues, often in isolation and without incentives or opportunities to collaborate with each other. This was seen post-treatment in the greater predisposition to articulate among these different areas that deal with water and its environment.

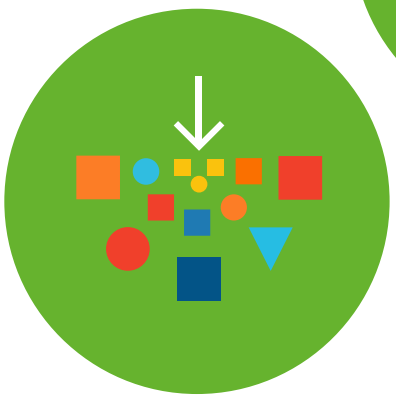
On the other hand, the fact that citizens and officials use the same data collection instrument shows that citizens have very different perceptions of the state of their environment, with a tendency to have more pessimistic visions, which increases the diversity of opinions in the data available to local governments

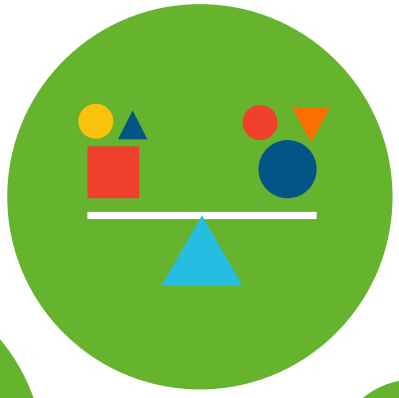
VI. Conclusion

At Co_Lab, we learned that citizen science is a powerful and versatile tool that allows a system approach that overcomes the problems of fragmented strategies addressing different dimensions, individual and institutional/governance, of environmental problems.

We identified different citizen science solutions with the potential to address these dimensions: individual-level environmentally friendly predispositions and engagement, and social inclusion for the governance of environmental issues, specifically data generation and policy innovation to address them. To that end, we partnered with two citizen science initiatives and four local governments, to design and implement two small-scale experiments.

To explore the effects of citizen science on predispositions, we conducted the first experiment, called the *Laboratorio de residuos*. Neighbors filled in a survey about their habits, beliefs and knowledge regarding environmental issues and domestic waste management. One-third of the neighbors also weighed their domestic waste on personal scales. Our main question here was whether participating in a citizen science experience affects environmental predispositions and commitment. We did not find clear effects on predisposition, which may be explained by the fact that those who volunteered to participate in this citizen science experience already had high levels of interest in the topic before taking part in the experiment. However, we observed that the control group experienced an increase in their commitment, measured as the predisposition to inform their friends about pro-environmental behaviors. This can be linked to their lower pro-environmental predisposition before treatment. The simple task of completing the surveys on these issues produced a marginally greater change in this group compared to the treated group which already had a higher environmental awareness to begin with. We also found evidence of a positive correlation between age and educational level and pre- and post- treatment pro-environmental predispositions.

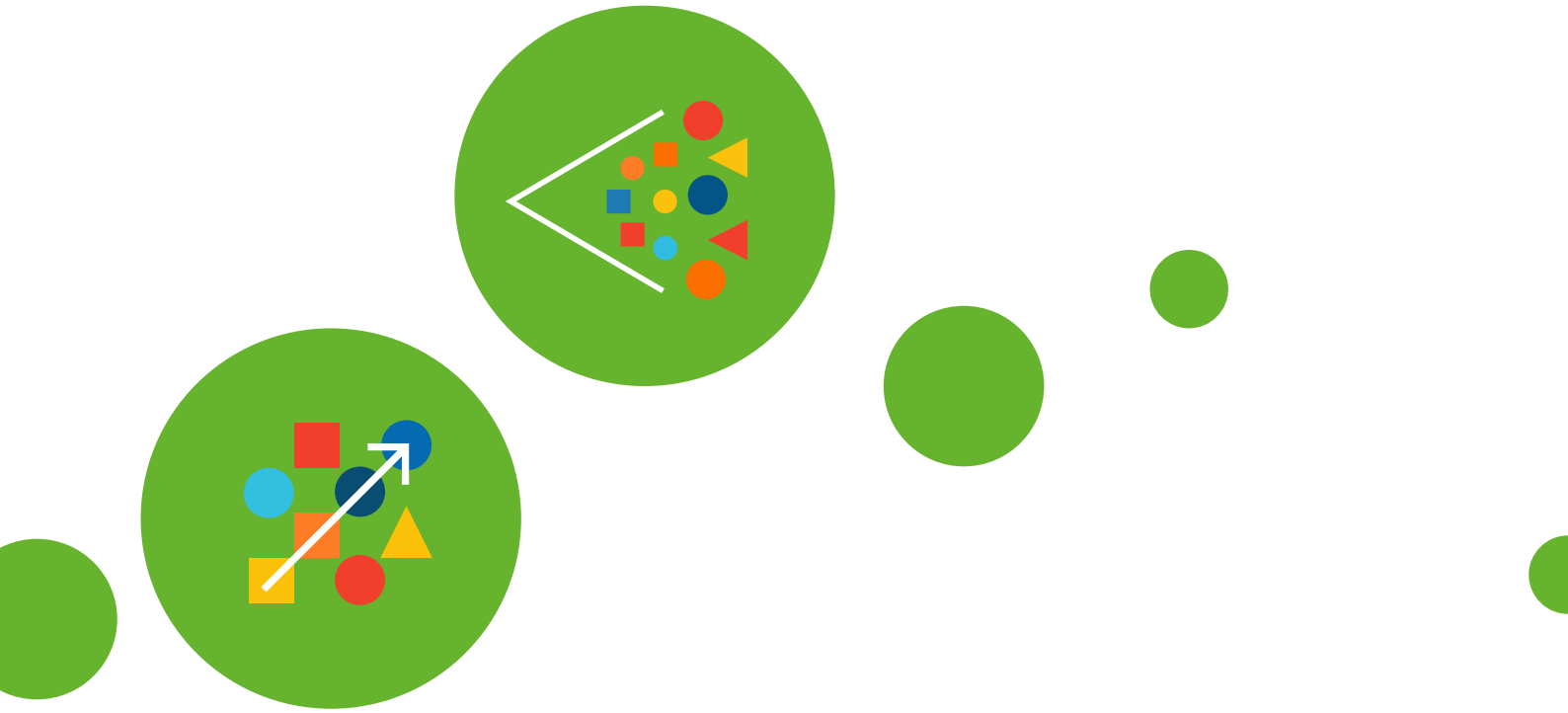




In our second experiment, we invited three local governments in Buenos Aires, Argentina, to participate in the mapping of aquatic ecosystems using a mobile app called *PreserVamos*. Here, since the app gathers georeferenced data and creates environmental quality indicators for freshwater ecosystems, we wanted to explore if citizen science experiences could encourage local governments to adopt an innovation and generate new evidence. We found that as a result of the mapping effort, all cities gathered valuable information on the state of their environment. We also found qualitative evidence of increased coordination across government areas to work on these policies. In the city that had implemented a mapping alongside citizens, we found that the data gathered was also more diverse, reflecting their different views on their environment.

Small-scale experiments allow us to test grassroots solutions fast, producing valuable inputs for policy-making and development strategies. As such, these experiments provide several possibilities, but they also pose limitations. Our strategy of collaborative work allows us to leave, at the end of our experiments, partnerships in place with relevant stakeholders that collaborated in the initiative who were trained and are willing to scale the solution tested. Moreover, the small scale makes the experiments a feasible low-cost method to replicate. On the other hand, they pose limitations linked to the fact that they are usually conducted in a short timespan, which hinders our ability to gather more data and to assess long-term effects.

Furthermore, in both experiments, the process of co-creating the pilots and their implementation led to a more inclusive conversation that involved governments, scientists and citizens, and different stakeholders interested in the environmental issues addressed in each experiment.



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