Attitudes toward Engagement in Citizen Science Increase Self-Related, Ecology-Related, and Motivation-Related Outcomes in an Urban Wildlife Project

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Citizen science projects are crucial for engaging citizens in conservation efforts. Although attitudes toward engagement in citizen science were mostly considered an outcome of citizen science participation, citizens may also have a certain attitude toward engagement in citizen science when starting with a citizen science project. Moreover, there is a lack of citizen science studies that consider changes over longer periods of time. Therefore, in this research, we present two-wave data from four field studies of a citizen science project about urban wildlife ecology using cross-lagged panel analyses. We investigated the influence of attitudes toward engagement in citizen science on self-related, ecology-related, and motivation-related outcomes. We found that positive attitudes toward engagement in citizen science at the beginning of the project had positive influences on the participants' psychological ownership and pride in their participation, their attitudes toward and enthusiasm about wildlife, and their internal and external motivation 2 months later. We discuss the implications for citizen science research and practice.

Keywords: citizen science, conservation, wildlife, attitudes, cross-lagged panel analyses

Human activities have profound effects on the environment and nature (e.g., Tracewski et al. 2016, Selinske et al. 2020). As a consequence, biodiversity is currently declining at unprecedented rates. Many species have become extinct or are seriously threatened with extinction (www.iucnredlist.org; Ceballos et al. 2015, Lees and Pimm 2015, Tracewski et al. 2016, Knapp et al. 2020, Eriksson 2021, Cowie et al. 2022; see also Pimm et al. 2006). To deal with this biodiversity crisis and to protect nature and ecology, political, societal, and collective civic initiatives and efforts to change behavior may be necessary. In this regard, the engagement of citizens could be one of several avenues needed to achieve these goals (e.g., Shirk et al. 2012; see also Kusmanoff et al. 2020). One way to increase citizens' awareness for conservation (see also Toomey and Domroese 2013, Haywood et al. 2016) is to engage them as volunteers in citizen science projects. These are scientific research projects in which volunteering citizens and professional scientists collaborate with each other (Heigl et al. 2019). In the research presented in the present article, we focus on citizen science projects on wildlife monitoring (e.g., www.ispotnature.org; Silvertown et al. 2015; see also Swanson et al. 2016, Greving et al. 2022).

Not surprisingly, a central goal of citizen science research has been to demonstrate improvements in citizens' ecological knowledge and attitudes toward conservation and science as outcomes of citizen science projects (e.g., Brossard et al. 2005, Crall et al. 2012, Toomey and Domroese 2013, Bela et al. 2016). However, the research findings on citizen science project outcomes are mixed. Although some research showed that citizens' knowledge (Brossard et al. 2005, Jordan et al. 2011, Crall et al. 2012) and proenvironmental attitudes increased (Toomey and Domroese 2013), other results showed no changes in attitudes (e.g., toward the topic of the citizen science project, citizen science in general, or science in general; Trumbull et al. 2000,

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Brossard et al. 2005, Crall et al. 2012) or behavior (Jordan et al. 2011).

Furthermore, most citizen science research to date has conducted cross-sectional studies (e.g., Haywood et al. 2016), whereas studies that capture changes and influences over time are lacking (Merenlender et al. 2016, Phillips et al. 2018), despite their undisputed necessity (e.g., Wells and Lekies 2015, Stylinski et al. 2020). In such studies, researchers investigate effects between one variable and another across a certain timeframe and, therefore, they may be a good means to examine cause–effect relationships that only unfold over a longer period of time (e.g., Kenny 1975, Kenny and Harackiewicz 1979). Finally, the measurement approach in past research may have been limited. For example, some researchers haver used only single indicators (e.g., interest) for variables such as attitudes (Rotman et al. 2012, 2014, Toomey and Domroese 2013, 2014; see also Phillips et al. 2018, Peter et al. 2021), and other researchers have used scale measures with rather low internal consistencies (Brossard et al. 2005, Crall et al. 2012). Therefore, we argue that citizen science research can benefit from studies that consider cause–effect relationships over time with clearly defined concepts and rigorous, standardized measurement approaches (see also Toomey and Domroese 2013, Phillips et al. 2018).

As an underlying model for investigating cause–effect relationships over time, we focused on the framework for public participation in scientific research (Shirk et al. 2012). This framework postulates that during the participation in a scientific project, participants bring certain *inputs* with them when they start participating. Then during the course of participation, they perform certain *activities* and make certain observations and have experiences that are referred to as *outputs*. At the end of the project, their participation results in certain individual participants' *outcomes*. These outcomes may ultimately transform into more general *impacts*, such as conservation, resilience, and sustainability. Importantly, the individual participants' outcomes refer back to the inputs in a feedback loop and may also motivate further engagement. In the present article, we focus on the inputs and outcomes that are relevant for engaging in citizen science.

According to psychological theorizing on behavioral change (e.g., Bandura 1977, Heckhausen and Gollwitzer 1987, Ajzen 1991, Fishbein and Ajzen 2010, Bamberg 2013), the initiation of behavior does not come easily, but several preconditions need to be fulfilled first. This may also be the case for the ultimate initiation of conservation behavior or any step toward that behavior. Following such theorizing, we argue that actual conservation behavior is more likely, successful, and sustainable, the broader the preconditions and antecedents of such behavior are. This is why the outcome variables of citizen science projects should take several concepts into account. Regarding such concepts, researchers have considered several outcomes (Rotman et al. 2014, Phillips et al. 2018, Peter et al. 2019, Aristeidou and Herodotou 2020). For example, the framework of individual learning outcomes from participation in citizen science (Phillips et al. 2018) and the dimensions of engagement framework (Phillips et al. 2019) have included both cognitive and affective dimensions (e.g., self-efficacy, motivation, Phillips et al. 2018, affective or feelings, Phillips et al. 2019) as outcomes. As much citizen science research has already focused on the cognitive dimensions (Brossard et al. 2005, Jordan et al. 2011, Crall et al. 2012) and also on behavior (Jordan et al. 2011, Phillips et al. 2019), we aimed to address the affective dimensions of the frameworks. Accordingly, we identified those three affective outcomes that were specifically stated in the frameworks by Phillips and colleagues. These are self-efficacy; interest, affective, or feelings; and motivation. We then related these three dimensions to our research in the present article in the context of wildlife ecology and further elaborated on them. We argue that it is of interest to the citizen science community what citizens take from the project for themselves, what their excitement and affective evaluation is regarding wildlife ecology, and how they are motivated to participate in citizen science. Therefore, we focused on self-related outcomes, ecology-related outcomes, and motivation-related outcomes. In the following, we provide details about the self-related, ecology-related, and motivation-related outcomes each before we turn to the crucial role of attitudes toward engagement in citizen science as inputs (Shirk et al. 2012) for these outcomes (see also Toomey and Domroese 2013).

In the citizen science literature, psychological ownership and pride are important self-related concepts. Psychological ownership is the subjective feeling of owning or possessing an object or entity (Pierce et al. 2001, 2003). That can be a concrete object, such as a camera trap that is often used in wildlife research. It can also be an abstract entity, such as the citizen science project one is involved in. Therefore, psychological ownership is a state that represents a close, affective relationship between an object or entity (e.g., a citizen science project) and an individual (e.g., a citizen scientist, Pierce et al. 2001, 2003, Van Dyne and Pierce 2004, Peck and Shu 2009). Research on ownership has also demonstrated that individuals feel ownership for concrete objects, such as mugs and pens (Peck and Shu 2009), and also for abstract objects, such as the organization they work for (Van Dyne and Pierce 2004). These effects can be transferred to the citizen science context because citizens may similarly experience ownership for the citizen science project they participate in (e.g., the Neighborhood Nestwatch Program, Evans et al. 2005; see also Greving et al. 2020).

Pride—as another self-related concept—is a positive, self-conscious emotion that is strongly related to the self (Lewis 2016). It represents a positive evaluation of one's own behavior in the sense that, when people are proud of their behavior, they like a lot what they have done. This is also referred to as *authentic pride* (Tracy and Robins 2007, Lewis 2016; for another form of pride, see Lewis 2016). Research has shown that pride elicited proenvironmental behavioral intentions (Schneider et al. 2017) and was related to engagement in proenvironmental behavior (Onwezen et al. 2014, Bissing-Olson et al. 2016). It may seem natural that citizens feel proud of their participation in a citizen science project, because they engage in them voluntarily (e.g., Cohn 2008, Newman et al. 2012, Cappa et al. 2016; see also Festinger 1957).

Because citizen science projects often focus on ecological issues, such as wildlife, ecology-related concepts are relevant for engaging citizens (e.g., Phillips et al. 2018, Peter et al. 2021), such as attitudes toward and enthusiasm about wildlife (see also Manfredo 2008, Jacobs 2009, 2012). We conceptualize attitudes in the present article in a psychological sense. That is, people have a positive attitude toward something when they evaluate it positively (e.g., Bohner and Dickel 2011, Albarracin and Shavitt 2018). This positive evaluation can refer to an object, a person, an abstract idea, a behavior, or nearly anything that can be evaluated positively. These attitude objects or entities are also referred to as *subject matter*. Therefore, people can also evaluate wildlife positively and have a positive attitude toward it (Manfredo 2008, Jacobs 2009). Moreover, attitudes toward wildlife develop in childhood and youth in the same way from experiences as other attitudes (e.g., Kidd and Kidd 1996) and persist and apply to several wildlife categories (e.g., Kansky et al. 2014). It has also been found that positive attitudes toward wildlife developed during environmental education programs, notably also persisted after the programs, and motivated further engagement behavior (e.g., Dettmann-Easler and Pease 1999).

Besides attitudes, enthusiasm about wildlife (Manfredo 2008, Jacobs 2012) is a highly positive and activating emotion. Being enthusiastic about wildlife means that people are excited about and experience strong positive emotions about wildlife (Watson et al. 1988, Phillips et al. 2019). It is, therefore, different from pure interest, which is a more mildly positive emotion. Enthusiasm has proven to be an important emotion that is worthwhile studying in general (Keltner et al. 2016). Because enthusiasm has turned out to be relevant in the wildlife conservation context as well (Manfredo 2008, Jacobs 2009, 2012, Phillips et al. 2019; for other emotions, such as compassion, see Greving and Kimmerle 2021, Straka et al. 2021), we have examined this concept in the study presented in the present article as an additional ecology-related variable.

Motivation is strongly related to behavior in many situations (e.g., Pelletier et al. 1995, 1997). Therefore, it is important to consider people's motivation concerning engagement in citizen science (e.g., Hobbs and White 2012, Domroese and Johnson 2017, Phillips et al. 2019, Molinario et al. 2020), which may also raise awareness for conservation in general (Toomey and Domroese 2013, Phillips et al. 2018, 2019). In particular, citizens may engage in citizen science projects for different underlying reasons. Following self-determination theory (Deci and Ryan 1985, 2000, Ryan and Deci 2000a, 2000b), when citizens are internally motivated, they engage in a citizen science project for the fun and joy of doing so. This means that internal motivation concerns the behavior itself that provide citizens with the reasons to perform it. In contrast, when citizens are externally motivated, they engage in a citizen science project because of obligations, norms, or other external rewards, such as making friends. Therefore, external motivation is concerned with any other external entity that is not the behavior itself and where the performed behavior is only a means to attain it. Such internal and external motivations have been shown to be valuable predictors of learning and engaging in or maintaining certain behavior (e.g., Pelletier et al. 1995, 1997), which is why they are relevant for the citizen science context. Besides these self-related, ecology-related, and motivation-related concepts, attitudes toward engagement in citizen science projects are also discussed in the literature—so far, however, merely as an implicit outcome of citizen science projects (e.g., Brossard et al. 2005, Bonney et al. 2009, Jordan et al. 2011, Crall et al. 2012).

In the present article, we do not solely investigate attitudes toward citizen science—which is, in a psychological sense, a positive evaluation of citizen science itself—but in particular *attitudes toward engagement in citizen science*, which more broadly captures attitudes toward a specific behavior, that is, *participating* in citizen science projects. Therefore, attitudes toward engagement in citizen science can be defined in terms of citizens' positive evaluation of their contribution in citizen science and of its utility for research and applications (e.g., Sickler et al. 2014, Lewandowski et al. 2017). Such attitudes may be embedded in a more complex constellation of different variables that contribute to attitude formation (Crain et al. 2014, Sickler et al. 2014, Lewandowski et al. 2017). Therefore, we used the theory of planned behavior (Ajzen 1991, Fishbein and Ajzen 2010) as the underlying conceptualization. Notably, this theory is primarily used to understand behavioral intentions. Still, besides intentions, it also captures attitudes toward that behavior and several other beliefs that we all deemed important for participating in citizen science projects. Consequently, we explicitly acknowledge the behavioral intention aspect in this theory. To address this aspect, we therefore do not solely refer to attitudes toward citizen science but use the phrase *attitudes toward engagement* in citizen science.

In general, the theory of planned behavior (Ajzen 1991, Fishbein and Ajzen 2010) assumes that people have certain beliefs about whether they can perform a certain behavior, whether this behavior is useful for them and whether it fits to the norms that surround them. Following these beliefs, people have a certain attitude toward that behavior. Finally, on the basis of these considerations, they have certain intentions to perform the behavior. However, because we were mostly interested in the general attitudes toward engaging in citizen science and not so much how intentions toward that behavior precisely developed, we followed a research approach from the context of science education. Using this approach, Abd-El-Khalick and colleagues (2015) developed and refined the theory of planned behavior and developed a measurement approach in which they assessed attitudes toward engagement in science (i.e., the Behaviors, Related Attitudes, and Intentions toward Science survey; Summers and Abd-El-Khalick 2018, 2019). Even though this approach was based on the theory of planned behavior, it treated the underlying dimensions as being on the same level and did not order them in a hierarchical sense. As we were similarly interested in attitudes, we followed this approach (Abd-El-Khalick et al. 2015, Summers and Abd-El-Khalick 2018, 2019), because it provided a comprehensive, elaborated conceptualization and feasible assessment of attitudes toward engagement in citizen science.

Therefore, we conceptualized positive attitudes toward engagement in citizen science as having five underlying dimensions: three dimensions concern the beliefs, one dimension the attitudes, and one dimension the intentions. In order to have a positive attitude toward engagement in citizen science, individuals need to have a strong *behavioral belief* that citizen science helps them in various ways in their own life, such as when making decisions about their own health or protecting the environment. They need to have a strong *control belief* that they are able to perform citizen science activities, such as that performing citizen science tasks is easy for them or that they can also deal with difficult situations. They need to have a strong *normative belief* that other individuals in their close surroundings are also involved in citizen science, such as their family, relatives, and friends. Besides these beliefs, the individuals need to have positive *attitudes* toward citizen science, that is, they need to evaluate it positively. Finally, they need to have strong *intentions* to engage in citizen science in the future and to learn more in further citizen science projects.

However, the role of attitudes toward engagement in citizen science is unclear. In research and frameworks in the citizen science context, attitudes have been mostly regarded as an outcome that develops during citizen science participation (e.g., Brossard et al. 2005, Bonney et al. 2009, Jordan et al. 2011, Crall et al. 2012, Shirk et al. 2012, Sickler et al. 2014, Phillips et al. 2018, Aristeidou and Herodotou 2020). Following the citizen-science–conservation behavior feedback model (Toomey and Domroese 2013) and the framework for public participation in scientific research (Shirk et al. 2012), we suggest that attitudes toward engagement in citizen science may be a highly relevant but rarely studied prerequisite and input of other learning outcomes (see also Haywood et al. 2016). Such attitudes toward engagement in citizen science may then further motivate participation and conservation attitudes, self-related internal factors, and motivation. Therefore, a positive attitude toward engagement in citizen science may be essential even to start participating in a citizen science project (Shirk et al. 2012, Toomey and Domroese 2013), because citizens who have applied for and are about to participate in a citizen science project should have a clear idea about how they evaluate citizen science projects in general and that project in particular. Consequently, they may already have developed a certain attitude toward engaging in the project. Therefore, positive attitudes toward engagement in citizen science may be an essential prerequisite and input for citizen science participation and further learning outcomes and, notably, may have strong predictive value for other outcomes of the citizen science participation (Shirk et al. 2012).

In contrast, although the participants may be, for example, highly enthusiastic about wildlife when they start participating in a citizen science project on wildlife, this emotion may not have as much predictive value over a longer period of time as attitudes toward engagement in citizen science. This argument may also be true for ownership, pride, motivation, and attitudes toward wildlife. Moreover, some outcomes may also need some time to develop. For example, experiencing a sense of psychological ownership or feeling proud about one's participation entails that citizens have had some experience participating in the project. Therefore, it may take some time to develop feelings of ownership and pride (for exceptions in laboratory contexts, see Peck and Shu 2009, Greving et al. 2020). These concepts may not be the strongest predictors for participating in citizen science at the start of a citizen science project. Therefore, we propose that attitudes toward engagement in citizen science may be a better predictor and input (Shirk et al. 2012, Toomey and Domroese 2013). When citizens have a positive attitude toward engagement in citizen science, they may get more involved in the project, which, as a consequence, may increase their self-related, ecology-related, and motivation-related experiences.

In the present article, we therefore investigated the influence of attitudes toward engagement in citizen science at the beginning of the citizen science project on self-related (i.e., psychological ownership and pride), ecology-related (i.e., attitudes toward and enthusiasm about wildlife), and motivation-related outcomes (i.e., internal and external motivation) 2 months later at the end of the citizen science project. Following our considerations above, we stated the following hypotheses: First, attitudes toward engagement in citizen science projects have positive influences on psychological ownership (hypothesis 1a) and pride (hypothesis 1b). Second, attitudes toward engagement in citizen science projects have positive influences on attitudes toward wildlife (hypothesis 2a) and enthusiasm about wildlife (hypothesis 2b). Finally, attitudes toward engagement in citizen science projects have positive influences on internal motivation (hypothesis 3a) and external motivation (hypothesis 3b).

To test our hypotheses, we conducted four 2-month-long field studies in a citizen science project on urban wildlife ecology in a German metropolitan city and analyzed the two-wave questionnaire data by means of cross-lagged panel analyses (Kenny 1975, Kenny and Harackiewicz 1979). These analyses were well suited to answer our research question because they allowed for testing cause–effect relationships with such questionnaire data that have two measurement points and a time lag in between. Notably, although the study design for using cross-lagged panel analyses is the same as for an analysis of pre- and postsurvey data, the goal is different. Pre- and posttest analyses aim to test changes of one variable over time and, therefore, only one variable is investigated at a time. In contrast, cross-lagged panel analyses aim to test for influences of one variable onto another variable and, therefore, at least two variables are involved. Moreover, and importantly, not their change over time, but their relation to the other variable over time is the focus of the analysis.

In more detail, the rationale behind the simplest form of cross-lagged panel analyses (Kenny 1975, Kenny and Harackiewicz 1979) is that there are two variables, *A* and *B*, that have been both measured twice over time such that there is *A*1, *B*1, *A*2, and *B*2. If variable *A* has an influence over time on variable *B*, then there should be a relation between *A*1 and *B*2 (a so-called cross-lagged path), but not between *B*1 and *A*2 (the second, reversed cross-lagged path), given that both variables are highly autocorrelated over time (i.e., high correlations between *A*1 and *A*2 and between *B*1 and *B*2). These analyses are useful in cases when experimental manipulations are not feasible, but influences of one variable on another still need to be tested (for more details and critical discussions, see Kenny 1975, Hamaker et al. 2015, Kenny and Harackiewicz 1979). Therefore, we used cross-lagged panel analyses to test our hypotheses.

Methodological approach for answering the research question

We tested the hypotheses in four field studies of a local citizen science project in a German metropolitan city that were conducted in April–May of 2019, October–November of 2019, April–May of 2020, and October–November of 2020. The project was called "Wildlife Researchers," and its aim was to assess the occurrence of wildlife in the city. It offered an Internet platform to the participating citizens that was used to gather, analyze, and discuss the data that the participants collected offline with so-called camera traps. These are cameras that are triggered automatically by movements or body heat and take photographs of passing wildlife. The participants' tasks were to install such a camera trap in their private garden, upload the camera trap photographs onto the platform, assess and identify the wildlife species in the photographs, analyze the data in several steps, and discuss their results with other citizens and scientists on the platform. Therefore, apart from taking the photographs with the camera traps, all of the other activities in the "Wildlife Researchers" project were performed online.

Dropout analysis and participants. We recruited citizens from the general public as participants for the "Wildlife Researchers" project by means of public relation campaigns. Across all four field studies, 702 participants filled out the questionnaire at time 1 (T1), from which 383 also filled out the questionnaire at time 2 (T2; see the procedure below). This means that 319 participants dropped out over time, which is a dropout rate of 45.4%. This dropout referred only to the questionnaires and not to the participation in the citizen science project. Compared with the participants who only completed the first questionnaire, those who filled out both questionnaires did not differ from them in their gender ($\chi^2(2) = 0.55$, $p = .759$) or their education ($t(700) = -0.72$, $p = .475$) but were a bit older ($t(700) = -2.12$, $p = .032$). Concerning our measures of interest, the participants who completed both questionnaires tended to be a bit more enthusiastic about wildlife than the participants who only filled out the first questionnaire ($t(700) = -1.89$, $p = .059$). For all other measures, there were no differences between these two groups of participants (all *t*s < 1.1, all *p*s > .270). In the analyses, we therefore included 383 participants (213 female, 169 male, 1 nonbinary, mean age = 53.16, standard deviation = 12.13, range: 19–83).

Procedure. The participants filled out an online questionnaire at the beginning of each field study (T1) and approximately 2 months later at the end of each field study (T2). Apart from demographic data that we gathered only at T1, the questionnaires were identical. They assessed attitudes toward engagement in citizen science, ownership, pride, attitudes toward wildlife, enthusiasm about wildlife, and motivation to engage in citizen science. Besides these measures, we also assessed other measures not reported in the present article (i.e., epistemological beliefs, attitudes toward engagement in science, scientific reasoning skills, and topic-specific knowledge; see also Bruckermann et al. 2021, 2023). An institutional ethics committee approved both questionnaires.

Measures. Detailed information about each measure is presented in table 1. In all four field studies, we assessed attitudes toward engagement in citizen science with five underlying dimensions (Abd-El-Khalick et al. 2015, Summers and Abd-El-Khalick 2018, 2019). With three items each, we measured behavioral beliefs, control beliefs, normative beliefs, attitudes toward citizen science, and intentions to engage in citizen science. Ownership (Pierce et al. 2001, Peck and Shu 2009) and pride (Lewis and Sullivan 2005, Lewis 2016) were each assessed with three items. The participants' attitudes toward wildlife were measured with 12 self-developed items based on general attitude approaches (see Bohner and Dickel 2011, Albarracin and Shavitt 2018), and the participants' enthusiasm about wildlife was assessed with one item. Finally, we measured the participants' internal and external motivation with four items each on the basis of self-determination theory (Deci and Ryan 1985, 2000, Ryan and Deci 2000a, 2000b).

Data analysis. We tested our hypotheses by means of cross-lagged panel analyses. These analyses allowed us to test cause–effect relationships over time between our variables of interest (Kenny 1975, Kenny and Harackiewicz 1979). Following our research question and hypotheses, we specified three linear path models. Model 1 represented

Table 1. Measures used in the field studies.

Variable	N^a	Example item	Cronbach's (alpha) αT_1	Cronbach's (alpha) αT_2	References
Attitudes toward engagement in citizen science					Summers and Abd-El-Khalick 2018
Behavioral beliefs	3	"Citizen science projects help me understand the world around me."	.82	.83	Summers and Abd-El-Khalick 2018
Control beliefs	3	"Participating in citizen science projects is easy for me."	.83	.83	Summers and Abd-El-Khalick 2018
Normative beliefs	3	"People in my direct surroundings engage in citizen science projects."	.79	.83	Summers and Abd-El-Khalick 2018
Attitudes toward citizen science	3	"I consider citizen science projects a good cause."	.82	.87	Summers and Abd-El-Khalick 2018
Intentions to engage in citizen science	3	"I want to engage in future citizen science projects."	.93	.95	Summers and Abd-El-Khalick 2018
Ownership	3	"The "Wildlife Researchers" project feels like it is mine."	.78	.84	Pierce et al. 2001, Peck and Shu 2009
Pride	3	"When I think about my participation in the 'Wildlife Researchers' project, I am proud of myself."	.75	.82	Lewis and Sullivan 2005, Lewis 2016
Attitudes toward wildlife	12	"Wildlife are fascinating animals."	.75	.78	Ad hoc
Enthusiasm about wildlife	1	"When I think about wildlife, I am enthusiastic."	–	–	Ad hoc
Internal motivation	4	"I participate in the 'Wildlife Researchers' project, because it is fun for me to do so."	.79	.86	Pelletier et al. 1995, 1997
External motivation	4	"I participate in the 'Wildlife Researchers' project, because I want to get to know new people."	.71	.72	Pelletier et al. 1995, 1997

Note: The references for each of the dependent variables are in regards to the attitudes toward engagement in citizen science with its five underlying dimensions behavioral beliefs, control beliefs, normative beliefs, attitudes toward citizen science, and intentions to engage in citizen science, ownership, pride, attitudes toward wildlife, enthusiasm about wildlife, and internal and external motivation. [a]On a rating scale on a five-point scale, where 1 represents *does not apply at all* and 5 represents *completely applies*.

the interrelations between attitudes toward engagement in citizen science and ownership and pride (hypotheses 1a and 1b). In this model, attitudes toward engagement in citizen science at T1 and T2 were latent variables. Latent means that attitudes toward engagement in citizen science were not assessed directly by asking the respondents about them, but were statistically inferred from related constructs that were directly measured. Therefore, attitudes toward engagement in citizen science were latent variables that consisted of its five underlying dimensions (i.e., behavioral beliefs, control beliefs, normative beliefs, attitudes, intentions). These underlying dimensions were all manifest variables. Manifest means that these underlying dimensions were assessed directly by asking the respondents about them by means of several items or a scale. As we measured the five underlying dimensions at T1 and T2 each, we added the correlations between each of the five dimensions of attitudes toward engagement in citizen science at T1 and its corresponding dimension at T2 to the model. Ownership at T1 and T2, as well as pride at T1 and T2, were manifest variables. In the present article, we added the correlations between pride and ownership at T1 and T2 each to the model. Regarding the paths in the model, we added the autocorrelative paths between the two measurement points of each variable to the model (i.e., ownership at T1 to ownership at T2, pride at T1 to pride at T2, attitudes toward engagement in citizen science at T1 to attitudes toward engagement in citizen science at T2), assuming that these paths all represented high autocorrelations. Finally, we added the expected cross-lagged paths (i.e., attitudes toward engagement in citizen science at T1 to ownership at T2, attitudes toward engagement in citizen science at T1 to pride at T2) and the reversed cross-lagged paths (i.e., ownership at T1 to attitudes toward engagement in citizen science at T2, pride at T1 to attitudes toward engagement in citizen science at T2; see also table 2) to the model.

Model 2 represented the interrelations between attitudes toward engagement in citizen science, and attitudes toward and enthusiasm about wildlife (hypotheses 2a and 2b). Again, attitudes toward engagement in citizen science were assessed as latent variables in the same way and with the same added correlations as in model 1. Attitudes toward wildlife at T1 and T2 as well as enthusiasm about wildlife at T1 and T2 were manifest variables. We added the correlations between attitudes toward and enthusiasm about wildlife at T1 and T2 each to the model. Finally, we again added the autocorrelative paths, the expected cross-lagged paths, and the reversed cross-lagged paths to the model.

Model 3 represented the interrelations between attitudes toward engagement in citizen science, and internal and

Table 2. Model test effects.

Model	Type of path	Path	β	B	SE	95% CI_B	p
Model 1	Autocorrelative	Ownership at T_1–ownership at T_2	0.51	0.55	0.04	[0.471, 0.629]	<.001
		Pride at T_1–pride at T_2	0.44	0.45	0.04	[0.371, 0.529]	<.001
		Attitudes toward engagement in citizen science at T_1–attitudes toward engagement in citizen science at T_2	0.70	0.81	0.06	[0.692, 0.928]	<.001
	Expected cross-lagged	Attitudes toward engagement in citizen science at T_1–ownership at T_2	0.17	0.27	0.08	[0.113, 0.427]	<.001
	Reversed cross-lagged	Ownership at T_1–attitudes toward engagement in citizen science at T_2	0.05	0.04	0.03	[–0.019, 0.099]	.213
	Expected cross-lagged	Attitudes toward engagement in citizen science at T_1–pride at T_2	0.12	0.22	0.09	[0.043, 0.397]	.011
	Reversed cross-lagged	Pride at T_1–attitudes toward engagement in citizen science at T_2	0.01	0.01	0.03	[–0.049, 0.069]	.733
Model 2	Autocorrelative	Attitudes toward wildlife at T_1–attitudes toward wildlife at T_2	0.62	0.63	0.04	[0.551, 0.709]	<.001
		Enthusiasm about wildlife at T_1–enthusiasm about wildlife at T_2	0.51	0.54	0.04	[0.461, 0.619]	<.001
		Attitudes toward engagement in citizen science at T_1–attitudes toward engagement in citizen science at T_2	0.71	0.82	0.06	[0.702, 0.938]	<.001
	Expected cross-lagged	Attitudes toward engagement in citizen science at T_1–attitudes toward wildlife at T_2	0.07	0.06	0.04	[–0.019, 0.139]	.082
	Reversed cross-lagged	Attitudes toward wildlife at T_1–attitudes toward engagement in citizen science at T_2	–0.02	–0.02	0.07	[–0.158, 0.118]	.735
	Expected cross-lagged	Attitudes toward engagement in citizen science at T_1–enthusiasm about wildlife at T_2	0.13	0.20	0.07	[0.062, 0.338]	.005
	Reversed cross-lagged	Enthusiasm about wildlife at T_1–attitudes toward engagement in citizen science at T_2	0.04	0.03	0.04	[–0.049, 0.109]	.378
Model 3	Autocorrelative	Internal motivation at T_1–internal motivation at T_2	0.39	0.49	0.06	[0.372, 0.608]	<.001
		External motivation at T_1–external motivation at T_2	0.56	0.53	0.04	[0.451, 0.609]	<.001
		Attitudes toward engagement in citizen science at T_1–attitudes toward engagement in citizen science at T_2	0.65	0.75	0.06	[0.632, 0.868]	<.001
	Expected cross-lagged	Attitudes toward engagement in citizen science at T_1–internal motivation at T_2	0.18	0.23	0.07	[0.092, 0.368]	<.001
	Reversed cross-lagged	Internal motivation at T_1–attitudes toward engagement in citizen science at T_2	0.06	0.07	0.05	[–0.028, 0.168]	.181
	Expected cross-lagged	Attitudes toward engagement in citizen science at T_1–external motivation at T_2	0.17	0.24	0.06	[0.122, 0.358]	<.001
	Reversed cross-lagged	External motivation at T_1–attitudes toward engagement in citizen science at T_2	0.09	0.07	0.03	[0.011, 0.129]	.024

Note: Model 1 fit, χ^2/df = 3.46, p <.001, NFI = .92, TLI = .93, CFI = .94, RMSEA = .08.
Model 2 fit, χ^2/df = 4.01, p < .001, NFI = .92, TLI = .91, CFI = .94, RMSEA = .09.
Model 3 fit, χ^2/df = 2.94, p < .001, NFI = .94, TLI = .95, CFI = .96, RMSEA = .07.
Abbreviations: CFI, comparative fit index; CI_B, confidence interval for B; NFI, normed fit index; RMSEA, root mean square error of approximation; SE, standard error; TLI, Tucker Lewis index.

external motivation (hypotheses 3a and 3b), following the same principles as models 1 and 2.

Besides testing the paths within each model, we also checked how well each of the three models fit to our data. For this purpose, we applied commonly used fit indices (e.g., Mulaik et al. 1989, Iacobucci 2010, Cangur and Ercan 2015) that were χ^2/df, the normed fit index, the Tucker Lewis index, the comparative fit index, and the root mean square error of approximation. We conducted all analyses with SPSS Amos v22.0 (Arbuckle 2013).

Table 3. Test effects for the paths between attitudes toward engagement in citizen science and its five underlying dimensions.

Model	Measurement time	Underlying dimension	β	*B*	SE	95% CI_B	*p*
Model 1	T1	Behavioral beliefs	0.81	1.31	0.08	[1.153, 1.467]	<.001
		Control beliefs	0.79	1.16	0.07	[1.022, 1.298]	<.001
		Normative beliefs	0.57	1.03	0.09	[0.853, 1.207]	<.001
		Attitudes	0.79	1	–	–	–
		Intentions	0.81	1.41	0.08	[1.253, 1.567]	<.001
	T2	Behavioral beliefs	0.82	1.18	0.06	[1.062, 1.298]	<.001
		Control beliefs	0.76	1.03	0.06	[0.912, 1.148]	<.001
		Normative beliefs	0.61	1.03	0.08	[0.873, 1.187]	<.001
		Attitudes	0.83	1	–	–	–
		Intentions	0.84	1.37	0.07	[1.232, 1.508]	<.001
Model 2	T1	Behavioral beliefs	0.81	1.32	0.08	[1.163, 1.477]	<.001
		Control beliefs	0.79	1.18	0.07	[1.042, 1.318]	<.001
		Normative beliefs	0.57	1.03	0.09	[0.853, 1.207]	<.001
		Attitudes	0.78	1	–	–	–
		Intentions	0.81	1.42	0.08	[1.263, 1.577]	<.001
	T2	Behavioral beliefs	0.82	1.17	0.06	[1.052, 1.288]	<.001
		Control beliefs	0.77	1.03	0.06	[0.912, 1.148]	<.001
		Normative beliefs	0.61	1.03	0.08	[0.873, 1.187]	<.001
		Attitudes	0.83	1	–	–	–
		Intentions	0.84	1.37	0.07	[1.232, 1.508]	<.001
Model 3	T1	Behavioral beliefs	0.81	1.31	0.07	[1.172, 1.448]	<.001
		Control beliefs	0.78	1.15	0.07	[1.012, 1.288]	<.001
		Normative beliefs	0.56	1.01	0.09	[0.833, 1.187]	<.001
		Attitudes	0.79	1	–	–	–
		Intentions	0.81	1.42	0.08	[1.263, 1.577]	<.001
	T2	Behavioral beliefs	0.82	1.17	0.06	[1.052, 1.288]	<.001
		Control beliefs	0.76	1.02	0.06	[0.902, 1.138]	<.001
		Normative beliefs	0.60	1.01	0.08	[0.853, 1.167]	<.001
		Attitudes	0.83	1	–	–	–
		Intentions	0.85	1.38	0.07	[1.242, 1.518	<.001

Note: To conduct a path analysis with a latent variable consisting of several manifest variables in SPSS Amos (Arbuckle 2013), one of the paths between the latent variable and its manifest variables must be set to 1, and we chose the path to attitudes to be 1. Therefore, we cannot provide standard errors (SEs), confidence intervals (CIs), or *p*-values for these paths.

Research findings

In table 2, we present the model fits and test statistics of the autocorrelative and cross-lagged paths for all three path models. In table 3, we present all test statistics for the paths between attitudes toward engagement in citizen science (latent variable) and its five underlying dimensions (manifest variables) for all three path models. Model 1 fit well to the data and all variables were highly autocorrelated (all *p*s < .001). The results revealed that attitudes toward engagement in citizen science at T1 had a positive influence over time on ownership at T_2 and pride at T2 (see table 2 and figure 1), supporting hypotheses 1a and 1b.

Model 2 fit to the data and all variables were highly autocorrelated (all *p*s < .001). The results showed that attitudes toward engagement in citizen science at T1 had a positive influence over time on attitudes toward wildlife at T2 and enthusiasm about wildlife at T2 (see table 2 and figure 2), supporting hypotheses 2a and 2b.

Finally, model 3 fit well to the data and all variables were highly autocorrelated (all *p*s < .001). The results revealed that attitudes toward engagement in citizen science at T1 had a positive influence over time on internal and external motivation at T2 (see table 2 and figure 3), supporting hypotheses 3a and 3b.

Discussion of the findings

This research set out to investigate the influence of attitudes toward engagement in citizen science at the beginning of a citizen science project on self-related (i.e., psychological ownership and pride), ecology-related (i.e., attitudes toward

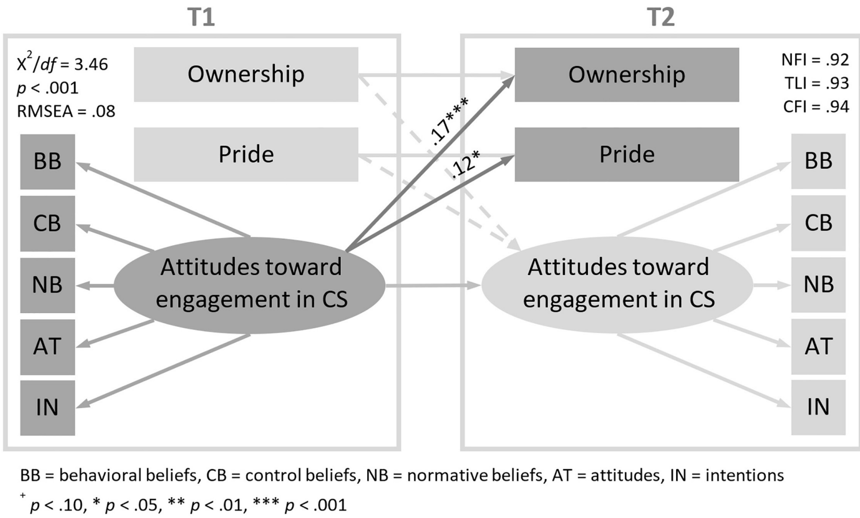


Figure 1. Path model with attitudes toward engagement in citizen science, psychological ownership, and pride across T_1 and T_2. The solid lines represent significant paths, and the dashed lines represent nonsignificant paths. For coefficients of all paths, see tables 2 and 3.

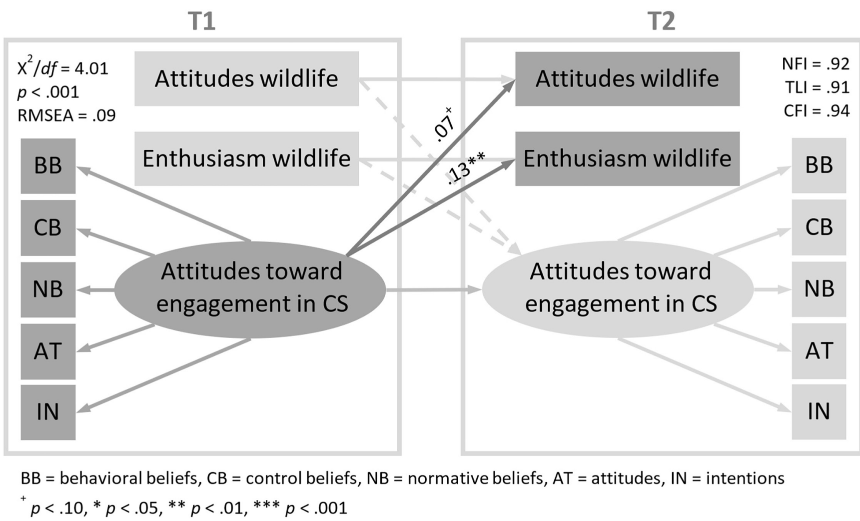


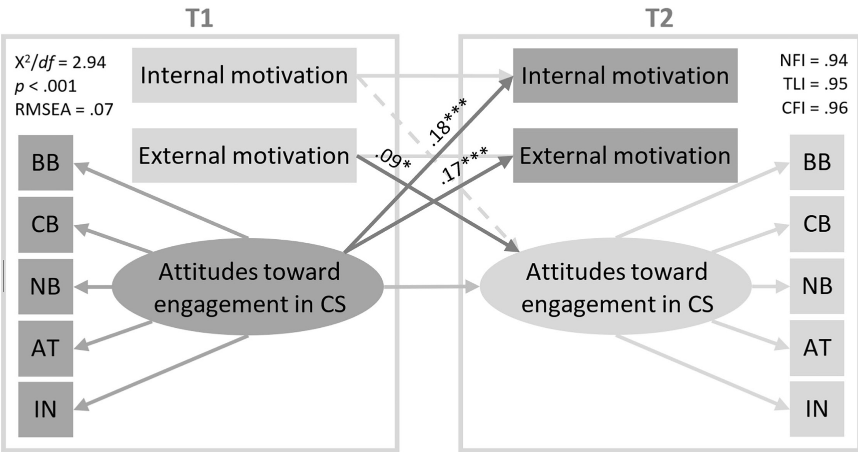
Figure 2. Path model with attitudes toward engagement in citizen science, attitudes toward wildlife, and enthusiasm about wildlife across T_1 and T_2. The solid lines represent significant paths, and the dashed lines represent nonsignificant paths. For coefficients of all paths, see tables 2 and 3.

and enthusiasm about wildlife), and motivation-related outcomes (i.e., internal and external motivation) 2 months later at the end of the citizen science project. We examined these influences in four field studies of a citizen science project on urban wildlife ecology in a German metropolitan city. Our findings consistently indicated that attitudes toward engagement in citizen science had positive influences on ownership and pride, attitudes toward and enthusiasm about wildlife, and internal and external motivation over time. Therefore, it was shown that attitudes toward engagement in citizen science played a crucial role for self-related, ecology-related, and motivation-related outcomes that could be further relevant for citizens' awareness of wildlife and ecological conservation.

The results of this research extend previous research by presenting three consistent findings that may shed new light on the mixed results in citizen science research to date that have mostly been short-term investigations (e.g., Trumbull et al. 2000, Brossard et al. 2005, Jordan et al. 2011, Crall et al. 2012). Therefore, the use of comprehensive and established measures in cross-lagged panel studies may be a first step toward understanding the role of attitudes toward engagement in citizen science for citizen science projects (see also Phillips et al. 2018).

Our results also revealed that attitudes toward engagement in citizen science are an important prerequisite and input (Shirk et al. 2012, Toomey and Domroese 2013) rather than an outcome of participation in citizen science projects. This finding is different from research that has perceived attitudes toward citizen science mostly as a learning outcome of citizen science projects (e.g., Brossard et al. 2005, Bonney et al. 2009, Jordan et al. 2011, Crall et al. 2012, Shirk et al. 2012, Phillips et al. 2018). However, it fits the citizen-science–conservation behavior feedback model (Toomey and Domroese 2013) and the framework for public participation in scientific research (Shirk et al. 2012), because it shows that those concepts relevant for participating in citizen science projects may be part of a behavior feedback loop in which a starting point of engaging in citizen science projects could possibly be attitudes toward engagement in citizen science (see also Haywood et al. 2016).

Following this reasoning (Shirk et al. 2012, Toomey and Domroese 2013), we can discuss how attitudes toward engagement in citizen science could have increased the self-related, ecology-related, and motivation-related outcomes. However, these thoughts are only speculations as we do not have any data on how the outcomes exactly increased. We assume that when the participants started the field studies with a positive attitude toward engaging in the project (i.e., "inputs," Shirk et al. 2012; "attitudes toward participating in citizen science," Toomey and Domroese 2013), they could have engaged more intensively in the activities of the project (i.e., "activities," Shirk et al. 2012; "participation in citizen science," Toomey and Domroese 2013). This would be in line with previous research suggesting that more positive attitudes



BB = behavioral beliefs, CB = control beliefs, NB = normative beliefs, AT = attitudes, IN = intentions
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Figure 3. Path model with attitudes toward engagement in citizen science, and internal and external motivation to participate in citizen science across T_1 and T_2. The solid lines represent significant paths, and the dashed lines represent nonsignificant paths. For coefficients of all paths, see tables 2 and 3.

toward engagement in citizen science are related to stronger engagement in citizen science projects (e.g., Eveleigh et al. 2014). The participants could also have engaged in more conservation activities outside the platform (i.e., "outputs," Shirk et al. 2012; "perception of citizen science as conservation behavior," Toomey and Domroese 2013). Such activities could have led the participants to experience the project as "theirs," to have more reasons to be proud of themselves, to like wildlife better, and to be more motivated to engage in citizen science (i.e., "outcomes," Shirk et al. 2012; "attitudes toward conservation" and "internal factors," Toomey and Domroese 2013). Following these outcomes, the participants could then have been more willing to participate in more conservation efforts (i.e., "impacts," Shirk et al. 2012; "intentions to engage in conservation behavior," Toomey and Domroese 2013). This reasoning corresponds to previous findings that engaging in several citizen science project activities increased psychological ownership and thereby also increased intentions to further engage in citizen science (Kieslinger et al. 2018, Greving et al. 2020; see also Haywood et al. 2016). These assumptions about what could have happened between the two measurement points need to be tested in further studies.

Finally, the findings of this research may be an important contribution to research on biological and ecological conservation. Although some research has perceived ecological concerns and interest as important prerequisites for participation in citizen science projects (e.g., Shirk et al. 2012, Phillips et al. 2018, 2019), our results indicated that attitudes toward engagement in citizen science may also be relevant prerequisites. This is good news for ecology and conservation efforts: If citizens have just positive attitudes toward engaging in a citizen science project, they will develop more psychological ownership, more pride, more positive ecological attitudes and enthusiasm, and more motivation. These qualities can have meaningful consequences for future ecology and conservation efforts and citizen science projects provide a starting point for these efforts (see also Shirk et al. 2012, Toomey and Domroese 2013). Therefore, citizen science participation may play a key role in engaging especially those citizens who may not have been initially interested in ecological and conservation efforts.

Implications

Our findings have theoretical and practical implications. In theoretical terms, our results showed that assessing citizens' attitudes toward engagement in citizen science with a comprehensive, behavior-related measure (Abd-El-Khalick et al. 2015, Summers and Abd-El-Khalick 2018, 2019; see also Ajzen 1991, Fishbein and Ajzen 2010) yielded clear findings. Although there are few models that take several factors relevant for attitudes into account (e.g., Toomey and Domroese 2013), research in the context of citizen science that incorporates attitudes (e.g., Sickler et al. 2014, Lewandowski et al. 2017) would probably benefit from conceptualizing attitudes in a more comprehensive way (see also Phillips et al. 2018, Bruckermann et al. 2021), with a clear reference to behavior. The refinement of the theory of planned behavior in the science education context may be one promising example, but other attitude models could also be relevant for citizen science (for overviews, see Bohner and Dickel 2011, Albarracin and Shavitt 2018). Regardless of the specific model, theoretically grounded conceptualizations of attitudes in the citizen science context may help citizen science researchers specify clear effects and relationships between attitudes and other outcomes (e.g., Haywood et al. 2016).

In practical terms, our findings are relevant for citizen science practitioners who conduct and organize citizen science projects. In previous research, for example, the participants' involvement in several typical citizen science activities increased their perceived ownership (Greving et al. 2020). In the present article, we could demonstrate that initial positive attitudes toward engagement in citizen science were important for the development of psychological ownership, and also pride, positive evaluations of wildlife, and motivation. Therefore, it is not these outcomes but citizens' positive attitudes toward engagement in citizen science at the start of a citizen science project (Shirk et al. 2012, Toomey and Domroese 2013) that influence the self-related, ecology-related, and motivation-related outcomes at the end of a citizen science project. Nonetheless, increasing these outcomes at the end of a citizen science project could carry over into engagement in related, subsequent conservation projects.

For new, unrelated projects, in contrast, it may again take some time to develop, for example, a certain degree of psychological ownership, pride, or motivation.

Strengths, limitations, and future research. We have presented four field studies of an existing citizen science project with a sample that was representative of typical citizen science participants with a sound sample size. All studies considered 2-month periods and used cross-lagged panel analyses, which allowed us to test cause–effect relationships (Kenny 1975, Kenny and Harackiewicz 1979). We also used established measures and applied established theories as underlying theoretical frameworks. Besides these strengths, we also need to discuss some limitations.

With about 45%, the field studies had a relatively high dropout rate during the collection of the questionnaire data. Although the dropped-out participants did not substantially differ from those who completed both questionnaires, we could not use nearly half of the questionnaire data, which is suboptimal. The reason for the high dropout could be that the citizen science project intentionally did not offer the participants any monetary incentive for filling out the questionnaires, because the initiators were seeking voluntary participation in the project. citizen science projects that are scientifically evaluated would probably benefit from incentives in the future. Such incentives should certainly not be used as a motivation for participating in the citizen science project but should only be clearly offered for completing the questionnaires.

In order to have enough statistical power, we analyzed different field studies together. Probably, these studies were slightly different from each other—for instance, because of the seasons in which they were conducted (i.e., spring or autumn). On the other hand, the times and seasons when the field studies were conducted were relatively fixed, because they were dependent on the urban wildlife habits. Moreover, except for some slight adjustments, we kept the procedure and the measures in the field studies completely the same to be able to analyze them together. Nonetheless, future research could strive to keep field studies even more similar to each other and to minimize possible confounding factors. Alternatively, researchers could aim to increase the number of participants in each field study so that they would have a more significant number of participants for testing the path models. In our studies, we could not increase the number of participants, because we were restricted by the number of camera traps that were available.

Although we found clear effects over time, we do not exactly know what the participants did or experienced between the two measurement points. In particular, we do not know whether they engaged in more activities on the platform, motivated by their positive attitudes toward engagement in citizen science, and as a consequence experienced more pride, ownership, wildlife enthusiasm, and motivation. Future research could therefore assess the participants' activities over time within the project and use them as a junction between the two measurement points in the path models. Such models could provide relevant information and relations between questionnaire variables and other activities.

Conclusions

All in all, this research has presented evidence that positive attitudes toward engagement in citizen science have clear effects over time on self-related (i.e., psychological ownership and pride), ecology-related (i.e., attitudes toward and enthusiasm about wildlife), and motivation-related (i.e., internal and external motivation) outcomes. These outcomes may all be relevant for awareness of and further participation in ecological conservation efforts. Therefore, initial positive attitudes toward engagement in citizen science may be an important means to increase citizens' awareness and ultimately willingness to engage in ecological efforts and the conservation of wildlife.

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