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ASSESSMENT OF HUNGARIAN NATURE CONSERVATION CITIZEN SCIENCE PROJECTS IN A MULTIDIMENSIONAL FRAMEWORK

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Title: ASSESSMENT OF HUNGARIAN NATURE CONSERVATION CITIZEN SCIENCE PROJECTS IN A MULTIDIMENSIONAL FRAMEWORK

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1. INTRODUCTION

1.1. Background

Citizen science (CS) has become a transformative approach to research and conservation, enabling volunteers to contribute to data collection, analysis, and dissemination through digital tools that have expanded participation, knowledge and public awareness (Bela et al., 2016; Bonney, 2021). Within biodiversity monitoring, Nature Conservation Citizen Science (NCCS) projects play a vital role by generating long-term datasets essential for detecting trends, guiding strategies, and informing policy, as demonstrated by initiatives like eBird, iNaturalist, and the Christmas Bird Count(McKinley et al., 2017; Fang et al., 2019; Fraisl et al., 2022). In Europe, NCCS combines deep natural history traditions with technological innovation, flourishing especially in Northern and Western regions with strong institutional support, while Central and Eastern Europe lag behind by having fewer documented NCCS projects and less evaluation of them (Duží et al., 2019; Vohland et al., 2021). NCCS has also gained formal recognition in global and European policy frameworks, including the Kunming–Montreal Global Biodiversity Framework, the SDGs, and EU environmental directives, underscoring its policy relevance(Bio Innovation Service, 2018; Convention on Biological Diversity (CBD), 2022; EU, 2000; European Commission. Directorate General for Research and Innovation., 2020). However, persistent concerns about data quality, representativeness, and uneven regional integration highlight the need for rigorous and multidimensional evaluation (Bonney et al., 2014; Robinson et al., 2018; Balázs et al., 2021; Downs et al., 2021).

1.2. Problem Statement and Justification

Evidence-based conservation actions depend on long-term databases and comprehensive information about species distributions to effectively address the challenges posed by global change and biodiversity loss (Johnson et al., 2024). Yet, traditional ecological monitoring methods are often expensive, time-consuming, and geographically limited in scope (Ahmed et al., 2022). Increasingly, evidence shows that NCCS initiatives help overcome the geographic limitations of traditional research by enabling data collection in regions/areas that are otherwise difficult to study, thus filling important gaps and broadening the reach of ecological monitoring, besides benefits related to participants and new scientific knowledge production (Theobald et al., 2015; Pocock et al., 2018; Dimson et al., 2023). However, a persistent challenge in NCCS is ensuring the credibility and reliability of data produced by volunteers (Balázs et al., 2021; Downs et al., 2021). These factors can undermine trust in NCCS data and limit its acceptance for scientific research and policy-making. To address these challenges and build confidence, rigorous evaluation of NCCS projects is crucial. Such an evaluation not only helps identify strengths and weaknesses in data collection and management but also guides improvements in project design, redefines volunteer experience, and adjusts quality assurance procedures. NCCS has made significant contributions to life sciences and nature conservation in Europe (Hecker et al., 2018). However, there is a notable regional disparity: while NCCS projects are well established and widely recognized in Western Europe, they are only now gaining broader recognition in Central and Eastern Europe, both in research and policy contexts (Bio Innovation Service, 2018; Vohland et al., 2021). In Hungary, for example, several longstanding NCCS initiatives exist, such as the Common Bird Monitoring Program and WildWatcher (Vadonleső Group et al., 2018; Szép & Gibbons, 2000), yet systematic research and comprehensive evaluation of these projects remain scarce. Although the evaluation of CS projects is highlighted as a core requirement by the European Citizen Science Association (ECSA) (Robinson et al., 2018), most existing evaluation frameworks focus on single dimensions, such as data quality (Kosmala et al., 2016), learning outcomes (Phillips et al., 2018), or conservation impact (Yang et al., 2019), rather than adopting a multidimensional approach. A comparative, multidimensional framework specific to NCCS is still needed to assess projects simultaneously across science, nature conservation, and participant outcomes (Bonney, 2021; Somerwill & Wehn, 2022)]. Existing guidance calls for field-tailored, standardized, and user-friendly evaluation approaches, but current multidimensional frameworks often omit the nature conservation dimension or, when NCCS-specific, exclude participant outcomes or lack a practical scoring system (Turbé et al., 2020; Schaefer et al., 2021; Price-Jones et al., 2022)This dissertation addresses these gaps by proposing and operationalizing an NCCS-specific three-dimensional framework (science, nature conservation, participants' development) and empirically testing it in Hungary to strengthen systematic NCCS evaluation, enhance project visibility, and support integration into evidence-based conservation and policy; the general framework is adaptable beyond Hungary.

1.3. Research Objectives and Questions

This study aims to strengthen the evidence base for NCCS projects in Hungary by providing a multidimensional assessment of their contributions to science, nature conservation, and participants' development (including knowledge, changes in attitudes and behaviour).

Objective 1. To develop a conceptual framework and evaluation framework for NCCS projects, structured around three core dimensions (science, nature conservation, and participants' development) that are applicable across multiple countries.

- 1.1 What are the key components of a three-dimensional conceptual framework for evaluating NCCS projects?
- 1.2 How can these components be translated/operationalized into a practical, user-friendly three-dimensional evaluation framework for NCCS projects' performance assessment?

Objective 2. To assess the scientific contribution of selected Hungarian NCCS projects.

- 2.1 How do NCCS projects ensure data quality?
- 2.2 Are the outcomes of NCCS projects scientifically robust?

Objective 3. To assess the nature conservation role of selected Hungarian NCCS projects.

- 3.1 How can NCCS projects contribute directly to the monitoring of species?
- 3.2 How are NCCS project outcomes utilized in species management?
- 3.3 How are NCCS project outcomes utilized in policies and conservation actions?

Objective 4. To assess the impact of selected NCCS projects on participants' development.

- 4.1 What motivates citizens to get involved in the selected NCCS projects?
- 4.2 How do NCCS projects influence the knowledge of participants?
- 4.3 How do NCCS projects influence participants' attitudes and behaviours?

2. MATERIALS AND METHODS

2.1. Study design and development

Prior to the empirical application, based on an extensive literature review, a three-dimensional conceptual framework was developed as the foundation for evaluating NCCS projects across three core dimensions: science, nature conservation, and participants' development (Objective 1; Q1.1). Building on the conceptual framework, a three-dimensional evaluation framework was designed as an operational tool (Objective 1; Q1.2) to evaluate selected NCCS projects. Each component of the framework was translated into clear, binary criteria questions, enabling systematic and comparable evaluation. While empirically tested in the Hungarian NCCS context, the framework itself is not country-specific and can be adapted for use in other nations. To define the NCCS projects selected for evaluation, a desktop study was conducted to identify the universe of NCCS initiatives in Hungary, applying predefined inclusion criteria and inviting project coordinators to participate, resulting in eight projects for the qualitative assessment through the three-dimensional evaluation framework. The evaluation drew on qualitative content analysis of interviews conducted among project managers/coordinators of the selected NCCS projects (detailed procedure in section 3.4).To extend the qualitative evaluation, a comparative focus analysis of two NCCS projects was conducted, supplying empirical insight into components of the science and participants' development dimensions. Specifically, the science dimension was examined through a comparative analysis of observation data of two selected NCCS projects, while the participants' development dimension was examined through the comparative analysis of questionnaire surveys conducted among participants of two selected projects. This dual analysis provided a deeper examination of the research questions associated with Objectives 2 and 4 (Q2.1–Q2.2; Q4.1 to Q4.3), complementing the framework-based evaluation. It also strengthened the study by incorporating participants' first-hand perspectives, thereby balancing the earlier framework that primarily reflected project managers' viewpoints with evidence from volunteer experiences and responses. The Amphibian and Reptile Mapping and the WildWatcher were chosen as two NCCS projects for deep-focused analysis. They were selected based on their comparable characteristics, including time scope, data collection protocol, data availability, and flexibility of project managers (detailed procedures are provided in Section 3.5). Overall, the study employed a mixed-methods approach structured into three sequential phases aligned with the components of the three-dimensional conceptual framework (Figure 1):

- Phase 1: qualitative evaluation of eight NCCS projects via semi-structured interviews (Objective 1 to 4)
- Phase 2: comparative analysis of long-term observation databases from two projects to examine data quality practices and scientific robustness, and to evidence monitoring/management relevance (Objective 2; Q2.1–Q2.2
- Phase 3: comparative analysis of participant surveys from two projects to assess motivation, knowledge, and attitudes/behaviours (Objective 4; Q4.1 to Q4.3).

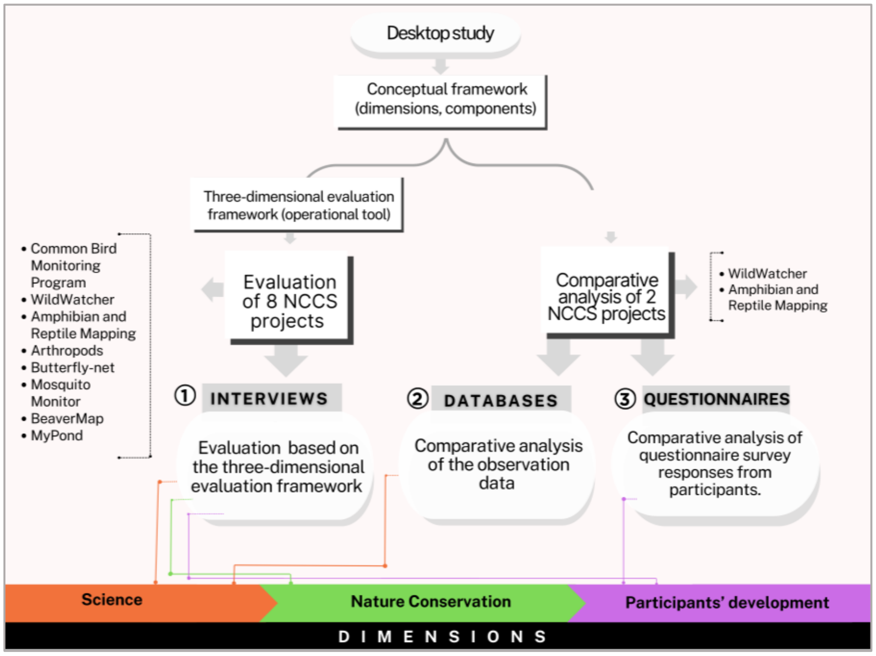

Figure 1: Mixed-methods, three-dimensional evaluation design

2.2. Conceptual three-dimensional framework

A non-country-specific conceptual framework was developed from extensive citizen science literature to evaluate NCCS projects across three dimensions (science, nature conservation, and participants' development), each with three defined components as seen in Figure 2.

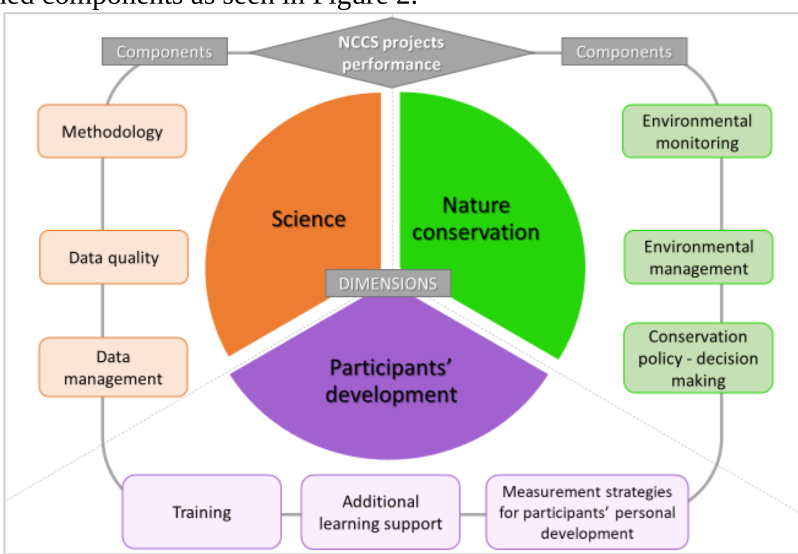

Figure 2. Three-dimensional conceptual framework

The scientific dimension addresses debates on data credibility and impact; the conservation dimension reflects NCCS's core objective of informing management and policy; and the participant development dimension recognizes evidence of knowledge, attitude, and behaviour. To operationalize the framework, research questions were mapped to dimensions and components, aligning instrument design, data collection, and analysis. The following table provides a crosswalk linking Objectives 1–4 and the research questions to specific components within the science, nature conservation, and participants' development dimensions, thereby directing instrument design, data collection, and analysis.

Table 1: Alignment of research questions with conceptual framework components

Dimensions	Research question	Components	Research question
Science	1.1 What are the key components of a three-dimensional conceptual framework for evaluating NCCS projects in a broader country scope? 1.2 How can these components be translated/operationalized into a practical, user-friendly three-dimensional evaluation framework for NCCS projects' performance assessment?	Methodology	2.1 How do NCCS projects ensure data quality?
		Data quality	2.1 How do NCCS projects ensure data quality?
		Data management	2.2 Are the outcomes of NCCS projects scientifically robust?
Nature conservation		Environmental monitoring	3.1 How can NCCS projects contribute directly to the monitoring of species?
		Environmental management	3.2 How are NCCS projects' outcomes utilized in species management?
		Conservation policy – decision making	3.3 How are NCCS project outcomes utilized in policies and conservation actions?
Participants' development		Training	4.2 How do NCCS projects influence the knowledge of participants?
		Additional learning support	4.2 How do NCCS projects influence the knowledge of participants?
		Measurement strategies for participants' personal development	4.1 What motivates citizens to get involved in the selected NCCS projects? 4.3 How do NCCS projects influence participants' attitudes and behaviors?

2.3. Development of the three-dimensional evaluation framework for NCCS projects

To facilitate a clear and comprehensive comparison of project performance across the three key dimensions (science, nature conservation, and participants' development, the conceptual framework was operationalized into an evaluation framework using assessment criteria grounded in each component and widely supported by the literature (see Figure 2 for detailed references). The criteria set, thus, represents a practical extension of the conceptual framework, linking criteria concepts to measurable and actionable assessment items tailored to capture the specific characteristics of each dimension. The differing number of criteria per dimension reflects the unique complexity and scope of each component, ensuring that all significant aspects are adequately covered.

For each criterion, we formulated clear and concise yes/no questions to operationalize the framework effectively. These questions reflect key topics and concerns extensively addressed in the literature and are documented for each criterion in Table 2.

Table 2: Assessment criteria of the three-dimensional evaluation framework for NCCS projects across three key dimensions

Component	Criteria for the assessment	References	Question	No = 0, Yes = 1
Science dimension				
Methodology	Research question	McKinley et al. 2017.	Was a scientific question formulated before starting the project?	
	Methodology for data collection	Kosmala et al. 2016; Stevenson et al. 2021).	When recording an observation, is supporting information (e.g., a photograph, videos) mandatory to upload as part of the data collection methodology?	
	Technology use	Serrano-Sanz et al. 2014; Kosmala et al. 2016; Freitag et al., 2016.	Does the project require the use of technology that supports data collection and data quality? (e.g., smartphones, tablets, sensors)	
Data quality	Data validation	Wiggins et al. 2011; Freitag et al. 2016.; Balázs et al. 2021	Are protocols for data collection tested and validated before starting the project, in order to ensure data quality?	

Component	Criteria for the assessment	References	Question	No = 0, Yes = 1
		Wiggins et al. 2011; 2013; Kosmala et al. 2016; Freitag et al. 2016; McKinley et al. 2017	Do they have an effective strategy for data quality assessment? (e.g., specialized professionals involved, request of more information to participants, site visits)	
	Institutional affiliation	Freitag et al. 2016; Turbé et al. 2019	Is the project formally connected to a larger scientific or conservation organization?	
Data management practices	Long-term databases	McKinley et al. 2017	Does the project have long-term databases?	
	Open data	Murray-Rust 2008; McKinley et al. 2017	Is there any summary of the data collected released for the public? (e.g., summaries in the form of maps, charts, statistics)	
		Wiggins et al. 2013; Freitag et al. 2016	Are data stored in suitable repositories? (e.g., the General Data Protection Regulation [GDPR] considered)	
		Murray-Rust 2008	Are complete or partial databases publicly available for download?	
	Publications	Freitag et al. 2016; Bio Innovation Service 2018; McKinley et al. 2017; Turbé et al. 2019	Have the findings/data been published in peer-reviewed academic journals? (For example, has the collected data been used in scientific publications or cited in academic journals or scientific books?)	
Nature conservation dimension				
Environmental monitoring	Data use in species/ ecosystem monitoring	McKinley et al. 2017	Has the data collected by volunteers through the project been used for species or ecosystem monitoring?	
Environmental management	Data use in species/ ecosystem management	McKinley et al. 2017; Maynard et al. 2020; Kelly et al. 2020.	Has the data collected by volunteers through the project been used for species or ecosystem management?	
Conservation policy-making	Data use in conservation policy making	McKinley et al. 2017; Turbé et al. 2019; Suškevičs et al. 2021	Has the data collected through the project influenced policy decisions at the local, national, regional, or European Union level?	
Participants' development dimension				
Training	Forms of training provided	Turbé et al. 2019; Phillips et al. 2018	Is personal training provided to the participants?	
		Turbé et al. 2019	Is any other form of training/knowledge transfer provided to the participants? (e.g., written guidelines, videos, an informative phone application, or website)	
Additional learning support	Educational events	Serrano-Sanz et al. 2014	Are events to support learning and promote environmental education organized?	
	Communication for gaining knowledge	Brossard et al. 2005	Are there ways to connect with available experts who can answer participant questions and resolve issues? (e.g., via email, social media, app chat)	
Measurement strategies for participants' personal development	Measurement of knowledge gained/reinforced	Maynard et al. 2020; Santori et al. 2021; Brossard et al. 2005; Jordan et al., 2011; Phillips et al. 2018	Is the participant's knowledge assessed? (e.g., species recognition, knowledge about the species ecology, conservation knowledge)	
	Measurement of skills - gained/reinforced	Maynard et al. 2020; Santori et al. 2021; Phillips et al. 2018	Are participants' skills assessed? (e.g., using equipment, data collection protocol)	
	Measurement of attitude/ behavioral change	Somerwill & Wehn, 2022; Maynard et al. 2020; Santori et al. 2021; Brossard et al. 2005; Jordan et al. 2011; Phillips et al. 2018	Are participants' attitudes/behavior assessed?	
	Strategies for reinforcing and increasing knowledge through feedback	Cox et al., 2022; Ceccaroni & Piera, 2017; Tang et al., 2021	Do participants receive feedback that reinforces their knowledge, such as in-person, email, or app-based responses?	

Each project was scored dichotomously within the three dimensions (science, nature conservation, participant development), with 1 = criterion met and 0 = not met. Because dimensions contained different numbers of criteria, raw totals were not directly comparable. To enable fair comparisons, scores were normalized using the Relative Percentage of Maximum: for each dimension, a project's sum of "yes" responses was divided by the total criteria in that dimension and multiplied by 100. This sets the maximum achievable score at 100 and expresses all other scores as a proportion of that maximum, preserving relative differences and allowing interpretable cross-dimension and cross-project comparisons.

2.4. Evaluation of Hungarian NCCS projects based on the three-dimensional framework

The evaluation applied the three-dimensional framework to eight Hungarian NCCS projects to validate coverage and the practicality of binary scoring, generating evidence across science (protocols, validation, data management, open data, publication practices), nature conservation (use in monitoring, management, and policy), and participants' development (training, learning supports, measurement of knowledge, attitudes, behaviours, and feedback mechanisms) (addressing Objective 1,2,3 and 4). Projects were identified via a 2021 desktop survey of platforms and institutional sites; fifteen met inclusion criteria (Hungary origin, biodiversity and nature conservation focus), nine coordinators agreed, one excluded because of foreign origin, and eight distinct projects formed the final sample representing diverse types, geographies, affiliations, and taxa. From April to July 2022, semi-structured coordinator interviews (online and in person) were conducted, recorded, transcribed, and organized thematically around project description, the three framework dimensions, and outcomes/challenges. Qualitative content analysis used *a priori* codes aligned to project characteristics and framework dimensions, with coded excerpts summarized in tables, linked to yes/no criteria for binary scoring, and normalized for cross-project and cross-dimension comparison; excerpts were used to contextualize strengths and limitations and to reflect project development. Ethical procedures followed national and European research integrity codes, with written informed consent covering confidentiality, anonymity, voluntary participation, recording, and no-harm assurances.

2.5. Comparative analysis of observation data of two Hungarian NCCS projects

A focused comparative analysis of two Hungarian NCCS observation databases was conducted to evaluate data quality practices and the scientific robustness of outcomes (addressing Objective 2). Two projects (WildWatcher and the Amphibian and Reptile Mapping Project) were purposively selected for comparable taxonomic scope, protocols, temporal coverage, and data access, yielding structured, time-stamped records with fields for species, observer, coordinates, timing, context, and validation comparisons. Analyses used descriptive statistics and categorical tests (Chi-square/Fisher's exact, with Cramer's V) to compare observation patterns, validation status, interface use over time, and species reporting, providing complementary, data-driven indicators for the science and conservation dimensions. Ethical procedures followed European research integrity standards, with GDPR-compliant anonymization of personal and sensitive geolocation data to protect participant privacy and ensure responsible data stewardship.

2.6. Comparative analysis of participant questionnaires of two Hungarian NCCS projects

A comparative analysis of two questionnaires conducted among participants of two Hungarian NCCS projects was conducted to address Objective 4 by contrasting participant motivations, knowledge, and attitudes/behaviours across the Amphibian and Reptile Mapping and WildWatcher projects, providing complementary evidence for the participants' development dimension supported by coordinator interview insights. Two parallel 31-item questionnaires (English-drafted, Hungarian-translated, manager-validated) were distributed via Google Forms in 2023, covering participation/technology use, knowledge gain, motivation-attitude-behaviour, and demographics, with largely identical items to enable direct comparison and limited project-specific customizations. Responses were cleaned, harmonized, and merged; reverse scoring was applied so higher values consistently indicated greater improvement, and expertise was recoded (Expert/Non-expert). Categorical comparisons used Chi-square or Fisher's exact tests with Cramer's V where significant; non-normal Likert items were compared using Mann–Whitney U tests, with boxplots to visualize medians and

IQRs. Ethical procedures included informed consent and adherence to European research integrity and social research ethics standards, with formal approval obtained for the questionnaire component.

2.7. Challenges and mitigation

Different challenges arose during the research process. The language barrier required careful translation and back-translation of interview and survey materials to preserve meaning. This was addressed through the validation of the questionnaire surveys by project managers and the research supervisor. Second, recruiting participants for the questionnaires required sending personalized email invitations through each NCCS initiative, and multiple reminders were often necessary to achieve a sufficiently representative response rate and encourage participation. These mitigation strategies helped to ensure the integrity and inclusivity of the research process.

2.8. Limitations

Online sampling and coverage. The participant survey was administered online via project mailing lists, relying on self-selection and self-report; this likely underrepresents individuals who are less active online or not on mailing lists and may increase selection bias relative to the wider NCCS population.

Although most items were multiple choice or Likert scale, some open-ended responses allowed descriptive text; these Hungarian texts were translated by a non-native speaker during data cleaning, so nuanced meanings may have been lost or misinterpreted, introducing potential measurement error in the qualitative content used for interpretation.

3. RESULTS AND DISCUSSION

3.1. Results of the three-dimensional evaluation of selected NCCS projects

3.1.1. Overview of evaluated NCCS projects in Hungary

The selected Hungarian NCCS initiatives are diverse in aims, taxa, and data collection protocols, yet converge on collecting species data, and, in MyPond's case, ecosystem-level information, reflecting a broad but coherent monitoring focus. Some long-standing efforts were later framed as citizen science (e.g., WildWatcher evolving from HBMS's Squirrel Watcher; Amphibian and Reptile Mapping after 2012), while newer projects (MyPond, BeaverMap, Mosquito Surveillance) were designed from the start with explicit CS objectives. Most projects are institutionally affiliated (NGOs, conservation authorities, research institutes), with Arthropods notable for starting privately in 2016 and later affiliating. WildWatcher and MyPond span flora and fauna, whereas BeaverMap, Mosquito Surveillance, Butterfly-Net, Arthropods, Amphibian and Reptile Mapping, and the Common Bird Monitoring Program target specific taxa or groups. The longest-running initiative is the Common Bird Monitoring Program (1998, MME BirdLife Hungary), which implements standardized nationwide counts supporting research, conservation management, and annual reporting, and seven of the eight focal projects remain active (Butterfly-Net has concluded), with BeaverMap and MyPond (both 2021) the most recent. Participation models range from skill-dependent structured counts (MMM) to open participation with design choices that ease identification (WildWatcher, Amphibian and Reptile Mapping leveraging expert support and social media), alongside targeted recruitment (MyPond's garden-pond owners; Butterfly-Net's trained students). Across initiatives, both the number of contributors and submitted observations have steadily increased, indicating growing engagement and data flow.Overall performance of NCCS projects

The following results are derived from a comprehensive evaluation of each project, using the multidimensional framework criteria organized into the dimensions of science, nature conservation, and participants' development (see results in Table 3). This assessment highlights how each project performed across dimensions; therefore, according to the key components and criteria per dimension.

Table 3. Performance of NCCS projects per dimension

Dimension	Components	Criteria of the assessment	Question	NCCS Projects							
				Common Bird Monitoring Program	WildWatcher	Amphibian and Reptile Mapping	Arthropods	Butterfly-Net	Mosquito Surveillance	BeaverMap	My Pond
Science	Methodology	Research question	Was a scientific question formulated before starting the project?	1	0	0	0	0	1	1	1
		Methodology for data collection	When recording an observation, is supporting information (e.g., a photograph, videos) mandatory to upload as part of the data collection methodology?	1	0	0	1	1	1	1	1
		Technology use	Does the project require the use of technology that supports data collection and data quality? (e.g., smartphones, tablets, sensors)	1	1	1	1	1	1	1	1
	Data Quality	Data validation	Are protocols for data collection tested and validated before starting the project, in order to ensure data quality?	1	0	0	0	1	0	0	0
			Do they have an effective strategy for data quality assessment? (e.g., specialized professionals involved, request of more information to participants, site visits)	1	1	1	1	1	1	1	1
		Institutional affiliation	Is the project formally connected to a larger scientific or conservation organization?	1	1	1	1	1	1	1	1

Dimension	Components	Criteria of the assessment	Question	NCCS Projects							
				Common Bird Monitoring Program	WildWatcher	Amphibian and Reptile Mapping	Arthropods	Butterfly-Net	Mosquito Surveillance	BeaverMap	My Pond
	Data management practices	Long-term databases	Does the project have long-term databases?	1	1	1	1	0	1	1	1
		Open data	Is there any summary of the data collected released to the public? (e.g., summaries in the form of maps, charts, statistics)	1	1	1	1	0	1	0	1
			Are data stored in suitable repositories? (e.g., the General Data Protection Regulation [GDPR] considered)	1	1	1	1	1	1	1	1
			Are complete or partial databases publicly available for download?	0	0	0	1	0	0	0	0
		Publications	Have the findings/data been published in peer-reviewed academic journals? (For example, has the collected data been used in scientific publications or cited in academic journals or scientific books?)	1	1	1	1	1	1	1	1
Nature Conservation	Environmental monitoring	Data use in species/ ecosystem monitoring	Has the data collected by volunteers through the project been used for species or ecosystem monitoring?	1	1	1	1	1	1	1	1
	Environmental management	Data use in species/ ecosystem management	Has the data collected by volunteers through the project been used for species or ecosystem management?	1	1	1	1	1	0	0	0
	Policy	Data use in conservation policymaking	Has the data collected through the project influenced policy decisions at the local, national, regional, or European Union level?	1	1	1	0	0	0	0	0
Participants' development	Training	Forms of training provided	Is personal training provided to the participants?	0	0	0	0	1	0	0	0
			Is any other form of training/knowledge transfer provided to the participants? (e.g., written guidelines, videos, an informative phone application or a website)	1	1	1	0	1	1	1	1
	Additional learning support	Educational events	Are events to support learning and promote environmental education organized?	1	1	1	0	1	0	1	1
		Communication for gaining knowledge	Are there ways to connect with available experts who can answer participant questions and resolve issues? (e.g., via email, social media, app chat)	1	1	1	0	1	1	1	1
	Measurement strategies for participants	Measurement of knowledge gained/ reinforced	Is the participants' knowledge assessed? (e.g., species recognition, knowledge about the species ecology, conservation knowledge)	0	1	1	0	1	0	0	0
		Measurement of skills -	Are participants' skills assessed? (e.g., using equipment, data collection protocol)	0	0	0	0	1	0	0	0

Dimension	Components	Criteria of the assessment	Question	Common Bird Monitoring Program	WildWatcher	Amphibian and Reptile Mapping	Arthropods	Butterfly-Net	Mosquito Surveillance	BeaverMap	My Pond
		gained/ reinforced									
		Measurement of attitude/ behavioral change	Are participants' attitudes/behavior assessed?	0	1	1	0	0	0	0	0
		Strategies for reinforcing and increasing knowledge through feedback	Do participants receive feedback that reinforces their knowledge, such as in-person, email, or app-based responses?	1	0	1	1	1	1	0	1
				17	**15**	**16**	**12**	**16**	**13**	**12**	**14**

The normalized scores by dimension (maximum 300 points per project) yield distinct profiles: the Common Bird Monitoring Program ranked first (257/300), combining exemplary scientific contribution with robust conservation utility but moderate participant development. Amphibian and Reptile Mapping (256/300) and WildWatcher (241/300) followed, both demonstrating strong translation of CS data into conservation outcomes, with Amphibian and Reptile Mapping notably high in participant development. Butterfly-Net achieved the top participants' development score (100/300) and solid overall performance (237/300), indicating a clear emphasis on engagement and outreach alongside moderate science and conservation delivery (Table 3). Aggregating lower overall scores for Arthropods (171/300), Mosquito Surveillance (166/300), BeaverMap (156/300), and MyPond (180/300) reflect uneven achievements, often comparatively strong in scientific data collection but weaker in conservation integration or participant development (Table 4).

The normalized scores overall by the eight projects per dimension (maximum 800 points each) show that science totalled 660/800, indicating strong attainment; nature conservation reached 533/800, reflecting moderate success in conservation application; and participants' development was lowest at 471/800, signalling the greatest improvement potential (Table 4).

Table 4. Summary of composite normalized score results for evaluated NCCS projects in Hungary

	Science (points)	Nature Conservation (points)	Participants' development (points)	Total
Common Bird Monitoring Program	100	100	57	**257**
WildWatcher	70	100	71	**241**
Amphibian and Reptile Mapping	70	100	86	**256**
Arthropods	90	67	14	**171**
Butterfly-Net	70	67	100	**237**
Mosquito Surveillance	90	33	43	**166**
BeaverMap	80	33	43	**156**
My Pond	90	33	57	**180**
TOTAL	**660**	**533**	**471**	

Scientific contribution of the evaluated NCCS projects

The comparison of scores across the eight Hungarian NCCS projects shows that the science dimension was consistently the strongest. All projects scored above 60 points, with several exceeding 80 points. Notably, the Common Bird Monitoring Program scored 100 points, and Mosquito Surveillance, My Pond, and Arthropods reached 90 points.

Science-related criteria such as the use data validation done by experts, of technology and institutional affiliation were consistently strong across all projects. However, differences emerged in areas like data validation and open data practices. Only a few projects (e.g., Common Bird Monitoring Program, Butterfly-Net, Arthropods) validated data collection protocols before launch, though all employed quality assessment strategies during implementation. While most projects maintained long-term databases, only Arthropods provided publicly downloadable data.

Overall, the selected NCCS projects reflect a shared commitment to scientific rigor and structured collaboration, but open data and dissemination of results is still needed and

Nature conservation role of evaluated NCCS projects

Across eight Hungarian NCCS projects, all contributed meaningfully to conservation, especially in monitoring and managing protected taxa (e.g., Amphibian and Reptile Mapping, WildWatcher, BeaverMap) and tracking invasive species (Mosquito Monitor). The Common Bird Monitoring Program, WildWatcher, and Amphibian and Reptile Mapping achieved the highest scores in the conservation dimension, reflecting sustained contributions to biodiversity monitoring and habitat protection. Collectively, these initiatives supplied long-term datasets on species presence, abundance, and distribution, with open data from Arthropods enabling notable findings, including new national records and detections of invasive species. Beyond monitoring, several projects informed concrete management actions—such as invasive mosquito control, habitat interventions prompted by hedgehog observations, protection of fire salamander habitats, and safeguarding a newly discovered butterfly population—demonstrating practical conservation utility. Established programs also supported policy processes: WildWatcher data entered the national TIR system and EU Habitats Directive reporting, Butterfly-Net contributed records to OpenBioMaps for decision support, Amphibian and Reptile Mapping supplied atlas and EU reporting data, and the Common Bird Monitoring Program underpinned national and EU-level bird monitoring and atlas efforts. Overall, the projects showed strong performance in providing actionable evidence for monitoring, management, and, in several cases, policy, with long-running initiatives exhibiting the broadest influence.

Impact of evaluated NCCS projects on participants' development

Participants' development varied most across the eight projects. Training strategies, for example, Butterfly-Net uniquely combined in-person instruction with field guides, apps, and education events; most others relied on online materials, with the Common Bird Monitoring Program adding bird-sound guides, maps, and diaries, MyPond providing videos and sampling kits (including eDNA tools), and Mosquito Monitor offering trapping tutorials. Projects supported learning through events and expert access (e.g., Mammal/Amphibian-and-Reptile of the Year campaigns, recognition gatherings, expert consultations via email and social media), which fostered community and improved identification before submission. Despite widespread efforts to build knowledge, none of the projects formally measured post-participation changes in knowledge, skills, attitudes, or behaviours at the time of study; coordinators often inferred positive effects from continued engagement and provided feedback via email/apps, though their impact was not formally evaluated.

3.1.2. Discussion of the results of the evaluated NCCS projects

The results of the initial overview of the analysed Hungarian NCCS projects demonstrate strong achievements in both scientific output and contributions to nature conservation. However, our evaluation also reveals substantial opportunities for further improvement in the participants' development dimension outcomes. This pattern closely aligns with the findings of Peter et al. (2021), who, in their assessment of NCCS projects, observed that while these programs are highly effective at generating scientific data and supporting conservation goals, their influence on participants' learning, behavioural change, and wider educational benefits is often inconsistent and not systematically assessed. Their earlier research (Peter et al., 2019) similarly highlighted that, although CS holds significant promise for advancing nature conservation, actual improvements in participants' knowledge, attitudes, or behaviours tend to vary and are frequently under-evaluated.

The outcomes of this research from the science dimension highlight the critical role that high data quality standards play in establishing NCCS projects as valuable contributors to scientific research, a point emphasized by Wiggins et al. (2013). Internationally, projects such as eBird illustrate how rigorous protocols and robust validation processes can lead to significant scientific achievements, including a large number of peer-reviewed publications (Bonney et al., 2014; Sullivan et al., 2014; Kelling, 2018). Within Hungary, the Common Bird

Monitoring Program stands as a leading example, having adopted the UK's Breeding Bird Survey methodology and consistently upholding strict standards for data collection and verification. This dedication has enabled the program to build one of Hungary's most extensive and reliable ornithological databases.

A key factor supporting these high standards is the strong institutional backing observed across the evaluated projects, as institutional support and collaboration with scientific organizations are widely recognized as essential for ensuring data quality and project sustainability in citizen science (Downs et al., 2021b; US Environmental Protection Agency (EPA), 2019). Even projects that initially operated independently, such as Arthropods, have since sought organizational partnerships, highlighting a growing recognition of the importance of institutional support for data quality and project sustainability.

Open data practices further influence the scientific reach and impact of citizen science. As noted by Turbé et al. (2020), projects that make their databases openly available tend to produce more scientific outputs and foster wider data use. In the Hungarian context, only the Arthropods project has fully embraced open access, resulting in a large, widely used database. While other projects are beginning to publish their findings (such as Mosquito Monitor and MyPond) (Garamszegi et al., 2023; Márton et al., 2023), there remains significant potential to improve data accessibility and sharing across the NCCS field and scientific community. Similar trends have been reported in other European countries' assessments; for instance, Von Gönner et al. (2023) found that while data quality assurance is common, open data practices and widespread publication are still developing in Germany, Austria, and Switzerland.

From the nature conservation dimension, our findings confirm that selected Hungarian NCCS projects make valuable contributions to species and ecosystem monitoring, as well as to practical management and conservation actions. All evaluated projects supported monitoring activities, with several also informing habitat protection, invasive species management, and human-wildlife conflict mitigation. Projects with longer operational histories (such as Amphibian and Reptile Mapping, WildWatcher, and the Common Bird Monitoring Program) were particularly strong in this area, reflecting their established roles in environmental management and, to a lesser extent, policy influence. This is consistent with broader research indicating that citizen science data are often most impactful in habitat and population management, rather than direct policy or legislative action, when there are long-term datasets available (Sullivan et al., 2014; Chandler et al., 2017; McKinley et al., 2017; Turbé et al., 2020).

Our results indicate that NCCS projects with the longest temporal scope (such as Amphibian and Reptile Mapping, WildWatcher, and the Common Bird Monitoring Program) achieved the highest scores in the nature conservation dimension, reflecting their substantial roles in environmental management and, to some extent, policy influence. However, at the time of data collection, most projects had not yet seen their data directly used in policy-making or conservation management a pattern that echoes findings from Sullivan et al. (2017), who reported that NCCS data like those from eBird were more frequently applied to habitat management and protection than to formal policy or legislative processes. Since our evaluation, several additional Hungarian projects have begun to demonstrate tangible conservation outcomes, signaling rapid growth in the field (Finger et al., 2023). Notably, the recently one of the last to be launched of all projects, BeaverMap, has already contributed to the management of beaver-created wetlands and the resolution of human-wildlife conflicts, while ongoing data collection continues to identify high-conservation-value habitats and is expected to further refine national beaver distribution maps in the future (Juhász & Biró, 2024). These developments suggest that, with continued emphasis on data sharing, institutional collaboration, and the translation of NCCS data into practical conservation actions, Hungarian NCCS projects are well-positioned to expand their scientific and conservation impact in the years ahead.

Successful NCCS projects not only advance its scientific and conservation objectives but also provide meaningful benefits to its participants' (knowledge, skills gain, attitude and behavior impact), as emphasized in the literature (Kieslinger et al., 2017; Hansen & Bonney, 2022). Our findings illustrate that Butterfly-Net excelled in the participants' development dimension, largely due to its small scale, which made it feasible to offer in-person training and frequent expert interaction. These personalized learning opportunities are widely recognized in the literature as highly effective for enhancing participants' engagement and knowledge (Evans et al., 2005; Phillips et al., 2018). However, such approaches are often impractical for larger projects, which must instead rely on self-guided resources like digital tutorials, printed materials, and mobile applications to support their growing volunteer communities. Bonney et al. (2009) note that these supplementary tools can still foster confidence and skill acquisition among participants, even in the absence of direct training. Despite the recognized importance of participant outcomes, our evaluation, echoing international trends (Leonard et al., 2023), revealed that systematic assessment of changes in knowledge, attitudes, or behaviours remains rare in Hungarian NCCS projects. This gap highlights a missed opportunity, as collecting demographic and outcome data could provide valuable insights into the broader educational and social impacts of NCCS. Strengthening evaluation protocols to better capture participants' development would not only enrich our understanding of project effectiveness but also help tailor future initiatives to maximize benefits for both science and society.

3.2. Results of the comparative analysis of observation data of two Hungarian NCCS projects

3.2.1. Overview of the two selected NCCS projects' observation databases

Amphibian and Reptile Mapping (ARM) amassed 74,415 public-submitted records from 2011–Dec 2024, indicating sustained engagement and broad national coverage; over 60% of entries were amphibians and under 40% reptiles. WildWatcher compiled 17,484 records from 2009–Dec 2024, dominated by mammals (56.6%), with substantial contributions from insects and flowering plants; amphibians and reptiles together formed just over 10% of records (Table 5).

Table 5. Summary of observation records of the two observation databases

			Animals				Plants		
		Class	Mammal	Reptile	Amphibian	Insect	Liliopsida	Magnoliopsida	Total
Project	Amphibian and Reptile Mapping	Count	0	29233	445182	0	0	0	74415
		%	0.0	39.3	60.7	0.0	0.0	0.0	100.0
	WildWatcher	Count	9899	587	1367	3494	633	1504	17484
		%	56.6	3.4	7.8	20.0	3.6	8.6	100.0

3.2.2. Observation distribution across species in two selected NCCS projects

There is a clear contrast in species coverage and observation volume between the two initiatives. Amphibian and Reptile Mapping recorded 34 species with most observations marked as live, and the highest counts for *Pelobates fuscus, Rana dalmatina, Lacerta viridis, Bufo bufo, Pelophylax kl. esculentus, and Emys orbicularis*, each exceeding 5,000 records, with *Pelobates fuscus* approaching 7,000. Most remaining species had fewer than 2,000 observations, indicating a long tail of less-reported taxa. WildWatcher covered 21 species with generally lower observations per species; the most frequently reported were *Erinaceus roumanicus, Sciurus vulgaris, Talpa europaea*, and *Lucanus cervus* (about 1,500–nearly 4,000 records), while *Adonis vernalis, Mantis religiosa, Hyla arborea, and Salamandra salamandra* each had roughly 500–1,500 observations. In both projects, most records referred to live individuals, with relatively few reported as dead or N/A (Figure 3).

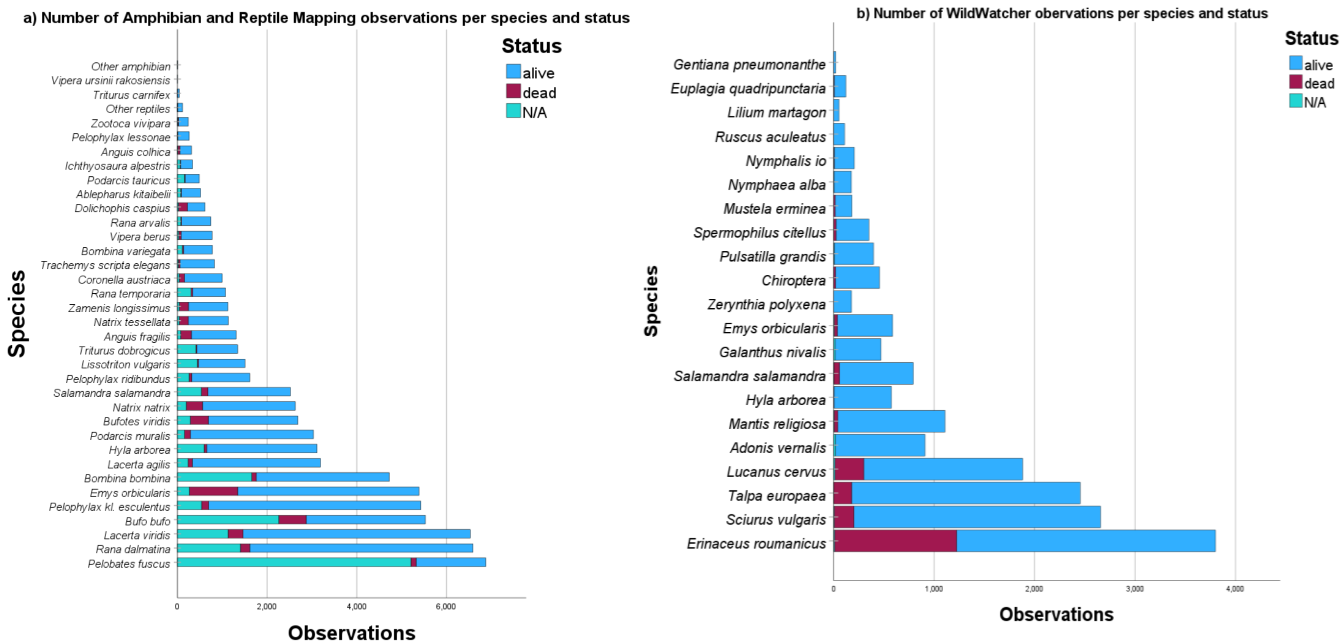

Figure 3. Distribution of species in the Amphibian and Reptile Mapping and WildWatcher project until 2024

In terms of taxonomic classes, the Amphibian and Reptile Mapping project recorded over 45,000 amphibian observations and nearly 30,000 reptile records WildWatcher demonstrated a broader taxonomic distribution, although with lower observation counts in each class. Mammals accounted for the largest share of WildWatcher's records, exceeding 10,000 observations, followed by insects and flowering plants (Magnoliopsida), each with several thousand records (

Figure 4). Amphibians and reptiles were also present in the WildWatcher database, but at much lower levels compared to the Amphibian and Reptile Mapping, focusing on the herpetofauna species.

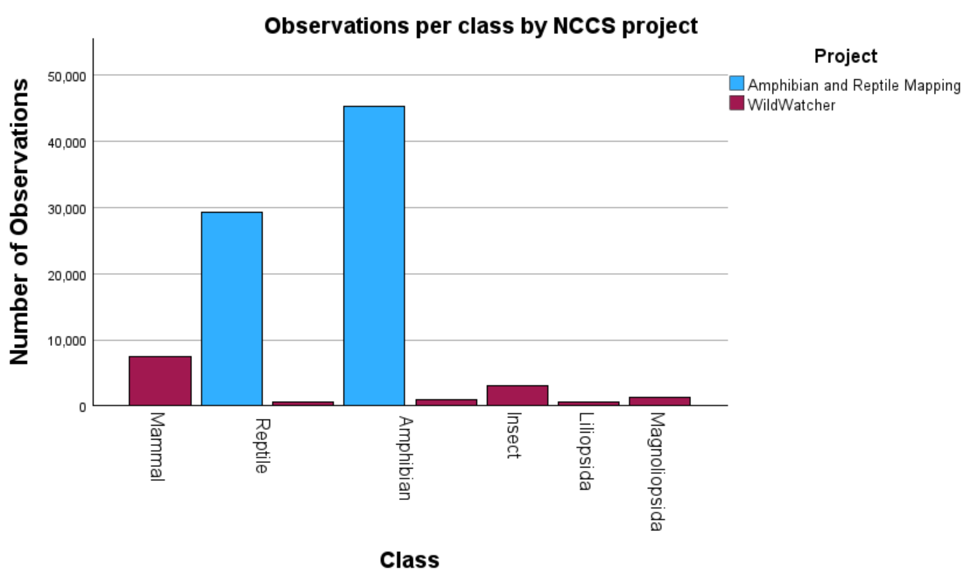

Figure 4. Taxonomic classes observations distribution in the Amphibian and Reptile Mapping and the WildWatcher project

3.2.3. Annual trends in species observations off two selected NCCS projects

Figure 5 illustrates the annual trend of species observations submitted to the Amphibian and Reptile Mapping and WildWatcher projects from 2009 to 2024. Our findings show that the Amphibian and Reptile Mapping project consistently generated a much higher volume of observations per year compared to WildWatcher.

Notably, Amphibian and Reptile Mapping experienced several pronounced peaks, with the most significant spike occurring in 2018, when annual observations exceeded 20,000. Other years, such as 2011 and 2016, also show substantial increases, with observation counts surpassing 10,000 and 7,000, respectively. Between these peaks, the project displayed considerable year-to-year fluctuation but generally maintained higher submission levels than WildWatcher throughout the entire period. In contrast, the WildWatcher project maintained a relatively stable and lower rate of annual observations. Its yearly submissions typically ranged between 1,000 and 3,000, with only minor fluctuations and no dramatic peaks. This pattern suggests a consistent but more modest level of participation and data reporting for WildWatcher compared to the more variable but higher-volume participation seen in Amphibian and Reptile Mapping (Figure 5).

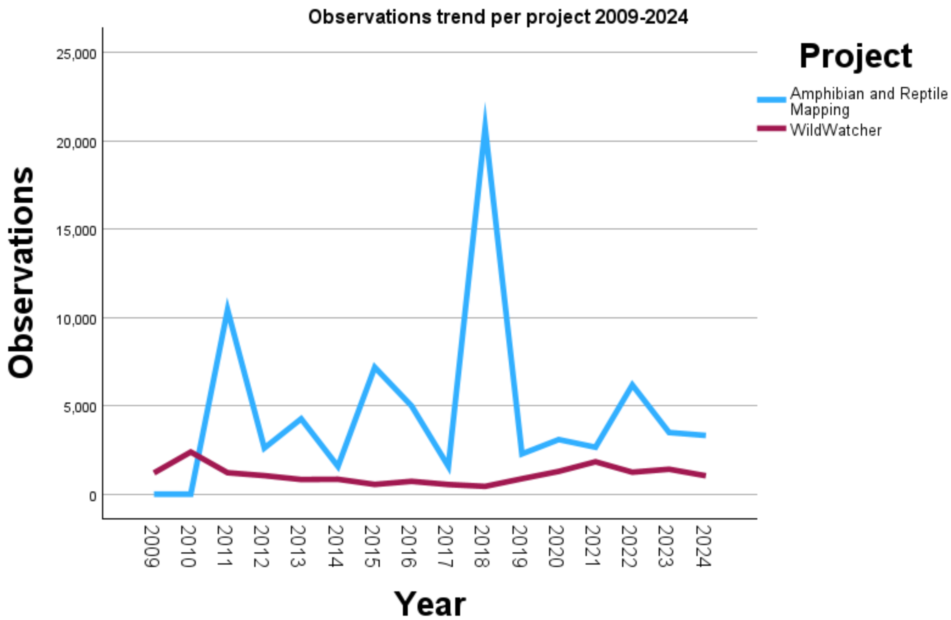

Figure 5. Annual species observations in Amphibian and Reptile Mapping (2011–2024) vs. WildWatcher (2009–2024)

Statistical analysis using the Chi-square test confirmed that the difference in the distribution of annual observation counts between the two projects is statistically significant ($p<.001$). The strength of this difference is moderate, as indicated by Cramer's $V = .318$. This result demonstrates a significant difference in observation volumes between the projects, supporting the descriptive trends observed in Figure 5.

3.2.4. Comparison of data validation status of two selected NCCS projects

Our results revealed that both NCCS initiatives achieved strong data quality assurance, with the vast majority of observations successfully validated. In Amphibian and Reptile Mapping, more than 70,000, representing approximately 95%, were classified as valid. Invalid records accounted for a small minority, and only a minimal number remained unchecked. WildWatcher, with 13,896 total records, showed over 12,000 validated entries, corresponding to about 90%. The proportion of unchecked records was slightly higher in WildWatcher compared to Amphibian and Reptile Mapping, while the number of invalid records remained very low in both projects (Figure 6)

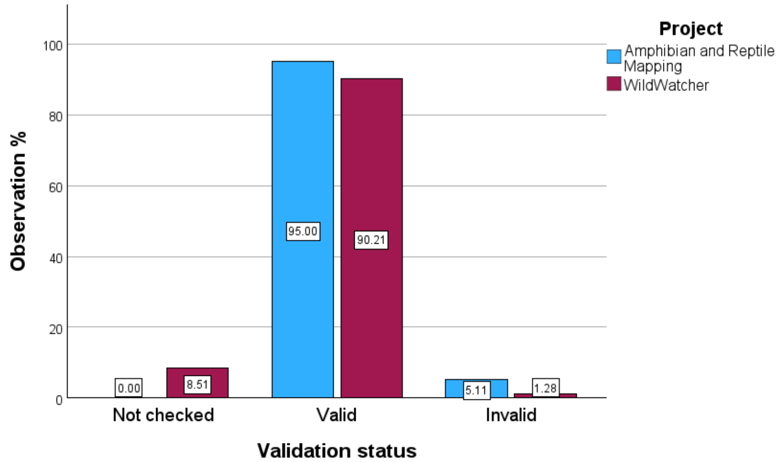

Figure 6. Data validation status in the Amphibian and Reptile Mapping and the WildWatcher project. Note: only observations recorded between 2011 and 2024 were included to ensure that the analysis covers matching time horizons across both projects.

Annual validation patterns differed between projects. Amphibian and Reptile Mapping showed large year-to-year swings but consistently very high validation, peaking at 9,977 validated records in 2011 (95%) and 20,422 in 2018 (98%), with unchecked and invalid records remaining low throughout, indicating strong quality assurance. WildWatcher displayed a steadier trend with peaks of 1,205 validated records in 2011 (99%) and 1,782 in 2021 (97%), but a slightly higher share of unchecked records in recent years; invalid records were rare and showed no clear temporal pattern. A chi-square test confirmed that validation status distributions differed significantly between projects ($p < .001$), with a moderate association (Cramer's V = 0.276), indicating meaningful differences in validation processes (Figure 7).

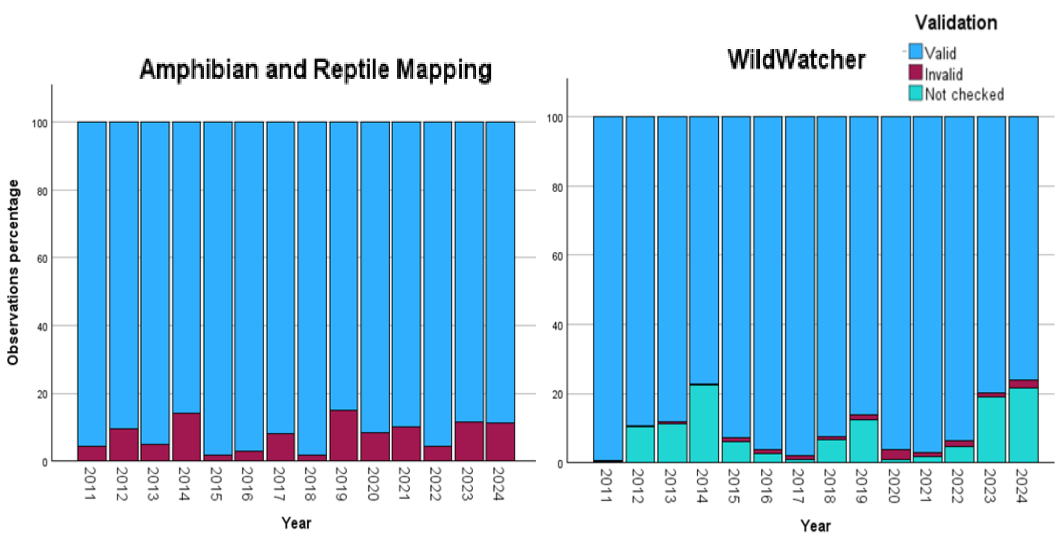

Figure 7. Annual trends in data validation status per NCCS project. Note: only observations recorded between 2011 and 2024 were included to ensure that the analysis covers matching time horizons across both projects.

Statistical analysis confirmed the differences between projects in validation status across years are significant, as indicated by the chi-square test ($p<.001$), consistently. Cramer’s V values ranged from 0.088 to 0.431, indicating that the relationship between year and validation status was generally weak to moderate, but reached moderate to strong levels in certain years (e.g., 2014, 2019, 2023, and 2024). This suggests that, while the overall difference was statistically significant throughout, the practical impact of year-to-year variation in validation outcomes was more pronounced in some periods.

3.2.5. Mobile app usage of two selected NCCS projects

Mobile app usage differed between the two projects: in Amphibian and Reptile Mapping, about 10% of records (~7,500) came via the app versus ~90% (~70,000) through other interfaces, while in WildWatcher, roughly 19% (<3,500) were app-based versus ~81% (~15,000) non-mobile (Figure 8).

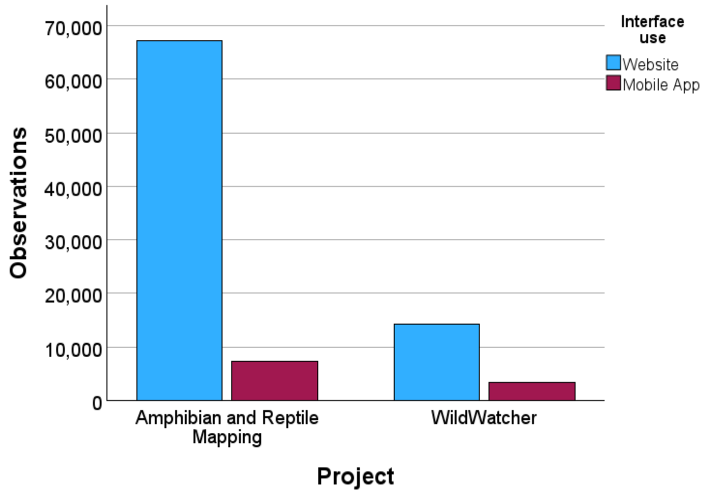

Figure 8. Mobile app usage in the Amphibian and Reptile Mapping and the WildWatcher. Note: only observations recorded between 2011 and 2024 were included to ensure that the analysis covers matching time horizons across both projects.

Fisher's exact test indicated a significant difference in interface use between projects ($p < .001$), and Cramer's V = .150 suggested a weak but meaningful association between project type and preferred submission channel.

3.2.6. Discussion of the results of the comparative analysis of observation data of two Hungarian NCCS projects

Impact of long-term biodiversity databases

Both projects accumulated substantial databases over a decade or more, mirroring the scale and reach of leading platforms like eBird and iNaturalist, which have demonstrated the value of public participation in generating extensive, spatially and temporally rich observation data (Sullivan et al., 2009; Callaghan et al., 2020; Ackland et al., 2024). Similarly, our findings are consistent with experiences in the UK and Germany, where long-term citizen science initiatives like the UK Butterfly Monitoring Scheme have played a vital role in tracking biodiversity trends and informing conservation efforts (Chandler et al., 2017). Across all these cases, expert validation and systematic data management remain essential for ensuring that NCCS data can be translated into credible, policy-relevant outcomes for conservation (Kelling, 2018; Downs et al., 2021b).

The databases have impacted conservation actions. The two analysed NCCS projects have shown strong capacity for sustained public engagement and the generation of high-quality, validated databases. Amphibian and Reptile Mapping, with over 94% of records confirmed as valid, this project's data has directly supported conservation actions. These findings underscore the significant and expanding role of NCCS in biodiversity monitoring and conservation planning, both in Hungary and CCE region. The conservation impacts observed (such as the use of the project's data for habitat protection, species distribution analyses, and the development of mitigation measures) are consistent with outcomes from similar European initiatives, including Austria's Herpetofauna project Red List assessments and conservation policy (Dörler & Heigl, 2019). Furthermore, the integration of rigorously validated, multi-taxa databases with rich metadata into national systems, as exemplified by WildWatcher's contribution to the Hungarian Nature Conservation Information System (TIR), reflects best practices seen in projects like Artportalen in Sweden, which is a national NCCS platform for biodiversity observations. It collects data on plants, animals, and fungi from the public and serves as a primary source of biodiversity information for Swedish authorities and governmental agencies (Sjödin Skarp, 2019). These examples collectively demonstrate that, when supported by expert validation and systematic data management, NCCS can provide high-quality data that are both scientifically valuable and directly relevant for conservation decision-making.

Seasonality and biodiversity observation trends

The pronounced annual peaks in Amphibian and Reptile Mapping (particularly in years such as 2011, 2016, and 2018) reflect not only the impact of targeted campaigns and seasonal events but also the unique biological and ecological characteristics of herpetofauna. Amphibians and reptiles are inherently cryptic, often active only during specific periods that coincide with favourable environmental conditions like optimal temperature and rainfall. These short windows of high detectability naturally concentrate both survey efforts and data submissions, resulting in marked fluctuations in annual observation numbers (Baumgardt et al., 2021).

Unlike more noticeable and easily identifiable species that dominate generalist projects such as WildWatcher or iNaturalist (Callaghan et al., 2022), herpetofauna require specialized knowledge for accurate identification and are less likely to be encountered outside their peak activity periods. This leads to a pattern where professional projects experience bursts of engagement aligned with biological cycles, while generalist projects benefit from a broader display of readily observable species, supporting steadier, year-round participation (Wittmann et al., 2019). Recognizing these differences is essential for interpreting the strengths and limitations of NCCS databases. By adapting project design and data analysis strategies to account for biological factors (such as the seasonality and detectability of target taxa), researchers and conservation practitioners can maximize data quality and reliability. Ultimately, this tailored approach not only improves the scientific value of NCCS data but also increases its credibility and applicability in conservation planning, species management, and policy-making. In this way, thoughtful integration of biological and project design considerations directly supports the effective use of NCCS data for evidence-based nature conservation actions.

3.3. Results of the comparative analysis of the questionnaires for participants of two Hungarian NCCS projects

3.3.1. Overview of respondents' characteristics for the two questionnaires

A total of 291 participants completed the online questionnaires: 185 from Amphibian and Reptile Mapping and 106 from WildWatcher. Most respondents in both projects resided outside Budapest (75.7% and 68.9%, respectively). The majority were middle-aged (31–50 years: 55.7% for Amphibian and Reptile Mapping, 44.3% for WildWatcher), with a substantial proportion over 50 years old. Both projects attracted highly educated participants (over 69% held higher education degrees). About one-third were members of a nature conservation NGO, and a similar proportion worked or studied in nature conservation. A significant gender difference was observed (Chi-square p = .004, Cramer's V = .168), with Amphibian and Reptile Mapping having a higher proportion of male respondents (61.2%) compared to WildWatcher (43.8%) (Table 6).

Table 6. Demographics of participants

Participant Characteristic	Answer Option	Amphibian and Reptile Mapping	WildWatcher	Chi-square / Cramer's V
		%	%	p-value
Total participants		N=185,100%	N=106,100%	
Place of residency	Outside Budapest	75.7	68.9	0.207
	Budapest	24.3	31.1	
Gender	Male	61.2	43.8	0.004* / 0.168
	Female	38.8	56.2	
	Prefer not to say **	1.1	0.9	
Age group	Under 30	13.5	17	0.177
	31-50	55.7	44.3	
	Over 50s**	30.8	38.7	

Participant Characteristic	Answer Option	Amphibian and Reptile Mapping	WildWatcher	Chi-square / Cramer's V
Highest level of education	Primary education **	2.2	7.5	0.393
	Secondary education	28.6	22.6	
	Higher education	69.2	69.8	
Member of a nature conservation NGO	Yes	37.3	32.1	0.37
	No	62.7	67.9	
Workplace/education related to conservation	Yes	30.8	32.1	0.686
	No	69.2	67.9	

Note: *Asterisks indicate p-values that represent statistically significant differences between the two projects (p<.05). **Categories with very few responses were excluded or merged to enable the performance of a Chi-square test.

3.3.2. Participation patterns and technology use

First encounter with the NCC project
Social media was the most common first point of contact for both projects (38.4% for Amphibian and Reptile Mapping; 40.6% for WildWatcher). Traditional media played a minor role and only for WildWatcher: small shares first learned about the project via television/radio or newspapers (2.8% each), whereas none did so for Amphibian and Reptile Mapping; this difference was statistically significant but weak in strength (Chi-square p = .047, Cramer's V = 0.135) (Table 7).

Table 7. Source of first encounter with the NCCS project

Source	Amphibian and Reptile Mapping	WildWatcher	Chi-square /Cramer's V	Fisher's exact Test/Cramer's V
	Yes	Yes	p-value	p-value
Social media	38.4%	40.6%	0.713	
TV, radio	0%	2.8%	-	0.047*/ 0.135
Newspaper	0%	2.8%	-	0.047*/ 0.135
Colleagues	8.1%	15.1%	0.063	
Friends	10.3%	14.2%	0.321	
**A nature conservation organization- WildWatcher option		21.5%		
**MME Birdlife Hungary - Amphibian and Reptile Mapping option	15.3%			
**MME KHVSZ (Amphibian and Reptile Conservation Group)- Amphibian and Reptile Mapping option	26.5%			
**MME website - Amphibian and Reptile Mapping option	17.9%			
**MME KHVSZ website - Amphibian and Reptile Mapping option	15.7%			

Note: A horizontal line (-) indicates that the expected count was less than 5, so Fisher's exact test was used. *p-values marked with an asterisk denote statistically significant differences between the two projects (p<.05). **Options exclusive to each project; therefore, no statistical test was applied.

Observation uploading patterns

Most participants had been involved for 1–5 years (58.9% Amphibian and Reptile Mapping, 52.8% WildWatcher), with no significant difference in involvement duration (Table 8). A significant difference in upload frequency was found (Chi-square p<.001, Cramer's V = 0.286): Amphibian and Reptile Mapping participants more often reported a "variable" upload pattern (51.9% vs. 35.8%), while WildWatcher had more "unknown" responses (19.8% vs. 3.2%) (Table 8).

Interface preferences

Most Amphibian and Reptile Mapping participants preferred the website (63.8%), while WildWatcher users were more likely to use the phone app or both platforms (Chi-square p = .002, Cramer's V = .208). Website usage frequency was similar, but phone app usage differed significantly (Chi-square p<.001, Cramer's V = .273), with 65.9% of Amphibian and Reptile Mapping participants never using the app, compared to 40.6% in WildWatcher (Table 8).

Table 8. Interfaces use patterns

Question	**Options**	**Amphibian and Reptile Mapping**	**WildWatcher**	**Test** **Chi-square / Cramer's V** **p-value**
Q2. Years of involvement	Unknown**	4.9%	4.7%	0.314
	Less than a year	5.9%	12.3%	
	1 to 5 years	58.9%	52.8%	
	6 to 10 years	25.4%	22.6%	
	more than 10 years	4.9%	7.5%	
Q3. Observation upload frequency	Unknown	3.2%	19.8%	<.001*/0.286
	Once	19.5%	19.8%	
	Variable	51.9%	35.8%	
	Yearly	20%	19.8%	
	Several times a year	5.4%	4.7%	
Q4. Changes in Observation upload frequency	Upload more often than before	14.6%	8.5%	0.097
	Upload less often than before	22.2%	28.3%	
	Frequency has not changed	56.2%	50%	
	Other	7%	13.2%	
Q6. Interface preference for uploading observations	Phone app	21.6%	35.8%	0.002*/0.208
	Website	63.8%	42.5%	
	Phone and website equally	14.6%	21.7%	
Q7.1Frequency of website use	Never	5.4%	10.4%	0.336
	Irregular	22.2%	25.5%	
	Yearly	59.5%	53.8%	
	Monthly	13%	10.4%	
Q7.2Frequency of phone app use	Never	65.9%	40.6%	<.001*/0.273
	Irregular	7.6%	16%	
	Yearly	13%	29.2%	
	Monthly	13.5%	14.2%	

*Asterisks indicate p-values showing significant differences between the two projects (p<.05). **The order of response options was adjusted, with "unknown" moved to the first position.

Interface use experience

Participants in both projects generally reported positive experiences with the technology, as reflected by median scores of 4 or higher (agree) on all Q10 items as seen in Figure 9. According to the Mann-Whitney U test results, there were no statistically significant differences between the projects in terms of the clarity and ease of submitting observations via the website or the mobile application, or the perceived effectiveness of receiving responses through the project interfaces (Table 9).

Table 9. Test results interface use experience

Question	Test
	Mann-Whitney U Test
	p-value
Q10. Uploading my observations through the website is understandable and simple.	0.06
Q10.1 Uploading my observations through the phone application is understandable and simple.	0.937
Q10.3 Using the project interfaces, I received answers to my questions during participation	0.664

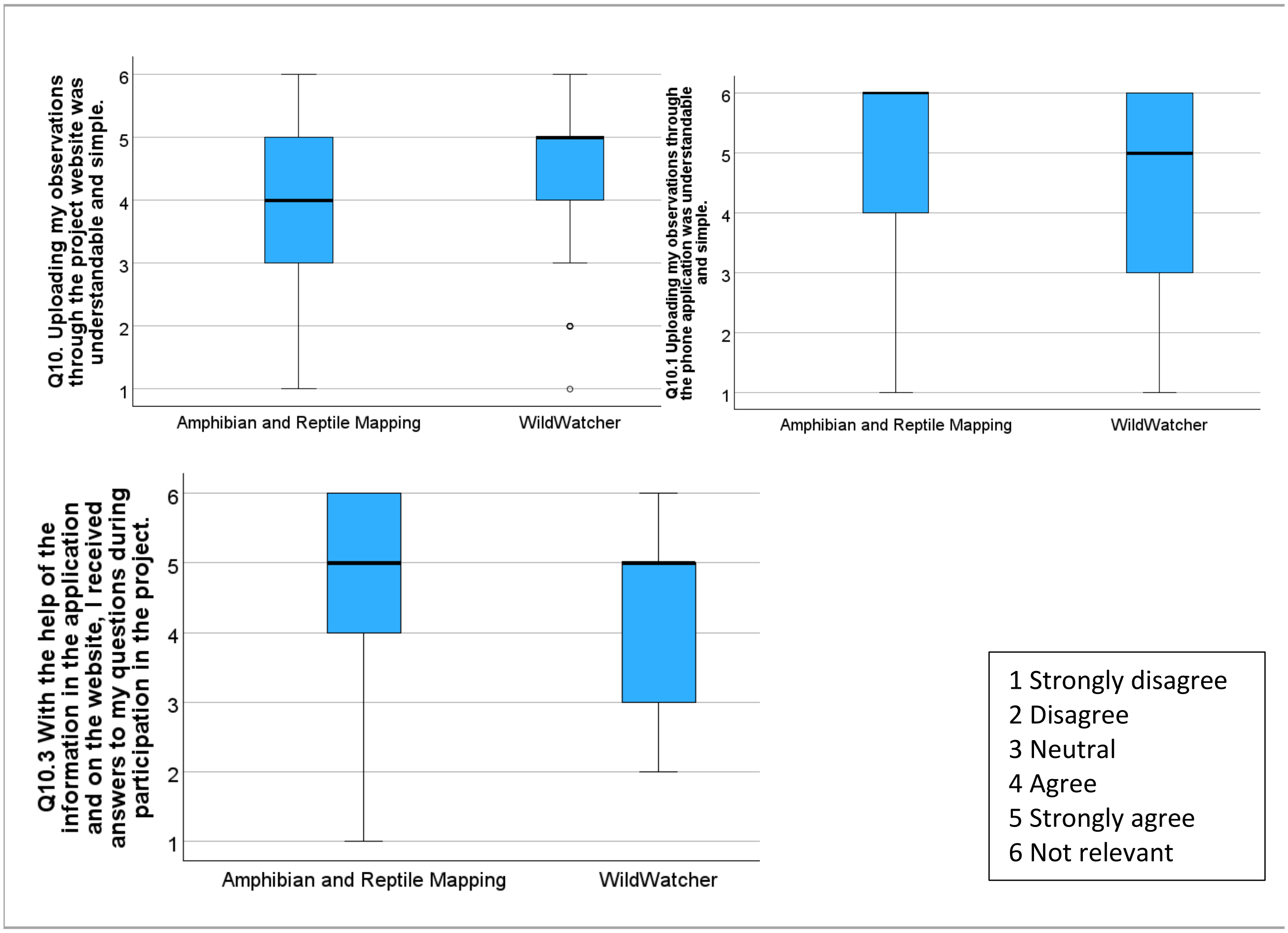

Figure 9. Interface use experience boxplot results

3.3.3. Knowledge gain

Participants' perceptions of knowledge responses for the Amphibian and Reptile Mapping and WildWatcher projects concentrated between medians 3–5 across knowledge items, with significant differences identified for some knowledge-related questions (Q18, Q18.3, Q18.6 and Q16-17):

- Knowledge from the project website (Q18). A significant difference was found between the project (p<.001) (Table 10). Amphibian and Reptile Mapping participants reported stronger agreement about gaining knowledge from the website (median = 4, mostly above neutral), while WildWatcher responses were more mixed (median = 4, but closer to neutral) (Figure 10).
- Knowledge from expert interaction (Q18.3). Participants in Amphibian and Reptile Mapping felt more positively about learning from expert interactions (median = 4) (Figure 10) compared to those in WildWatcher (median = 3), showing a significant difference (p = .028) (Table 10).
- Pre-existing knowledge (Q18.6): Amphibian and Reptile Mapping users were more likely to disagree that their knowledge was already sufficient before joining (median = 2), suggesting they experienced more learning through participation (Figure 10). WildWatcher participants were more neutral (median = 3). These found a statistically significant difference (p = .002) (Table 10).
- Both projects primarily attracted non-expert participants, though WildWatcher included a higher proportion of experts (36.4%) compared to Amphibian and Reptile Mapping (20.7%). This difference was statistically significant but weak (Chi-square p = .002; Cramer's V = .177) (Table 10).

Table 10. Knowledge-related questions test results

Question	**Mann-Whitney U**	**Mann-Whitney U of the median Q18, Q18.1, Q18.3**	**Chi-square/Cramer's V**
	p-value	**p-value**	**p-value**
Q16 & Q17 Level of expertise			0.002*/0.177
Q18. I feel that my knowledge of species has been expanded by using the website	<.001*		
Q18.1 I feel that my knowledge of species has been expanded by using the project phone application.	0.055	0.100	
Q18.3 I feel that my knowledge of species has expanded through interaction with experts from the project.	0.028*		
**Q18.6 I had sufficient knowledge before participating in the project, my knowledge has not changed	0.002*		
Q18.7 Participation in the project made me realize the importance of my observations.	0.463		
Q18.8 I would have been happy to receive personal training before starting my participation in the project.	0.879		
Q18.9 I expanded my knowledge necessary to participate in the project with the help of external information sources (e.g., specialist books, other websites, articles, Facebook groups).	0.360		

Note: *Asterisks indicate p-values showing significant differences between the two projects (p<.05). **Reverse scoring applied

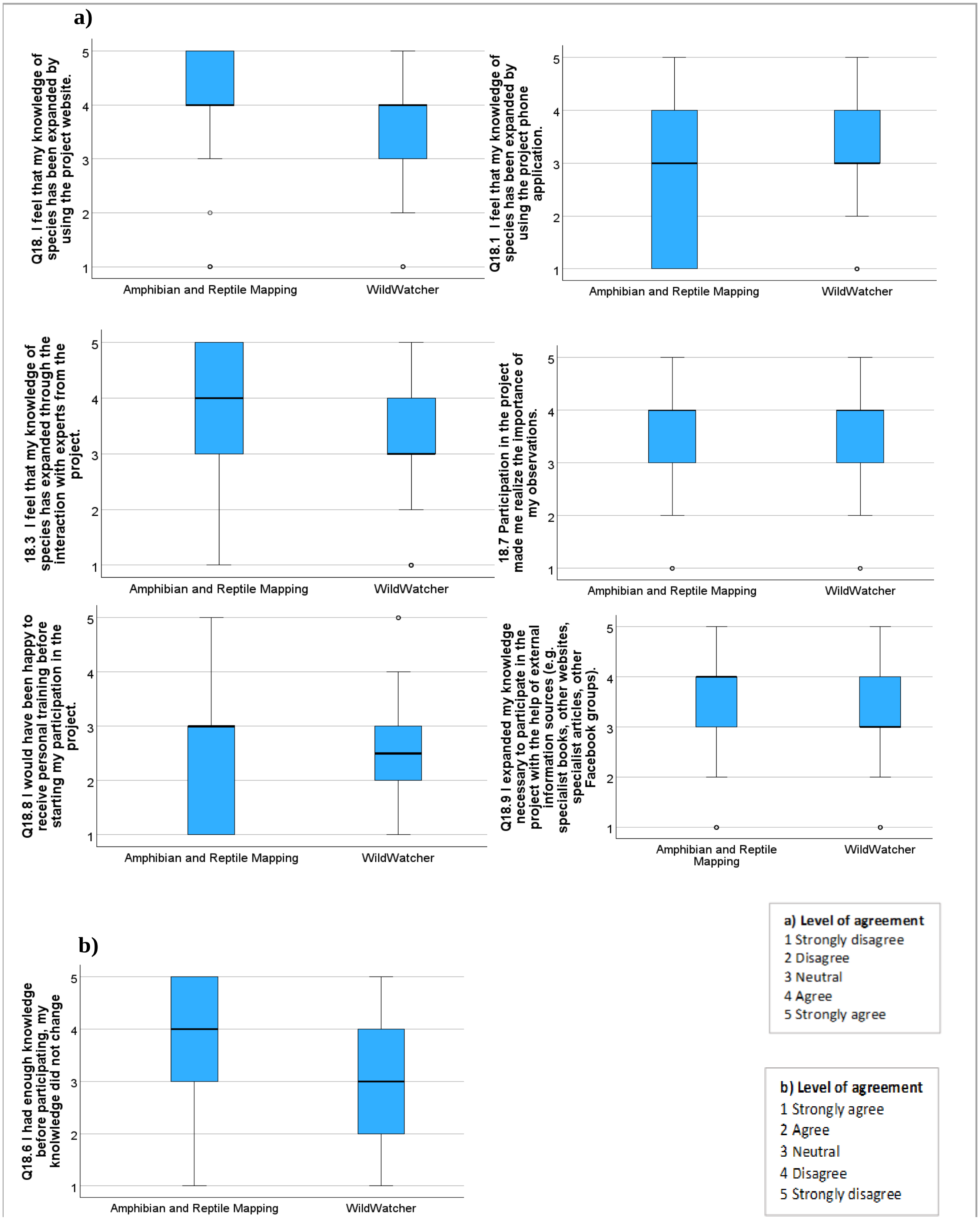

Figure 10.Knowledge-related questions, boxplot results

3.3.4. Attitudes and behaviours

Participants' attitude and behaviour responses in the Amphibian and Reptile Mapping and WildWatcher projects clustered toward positive ratings, with median scores typically at 4 (Agree) and interquartile ranges spanning Neutral to Strongly Agree across items, indicating broadly pro-environmental orientations in both projects (Figure 11).

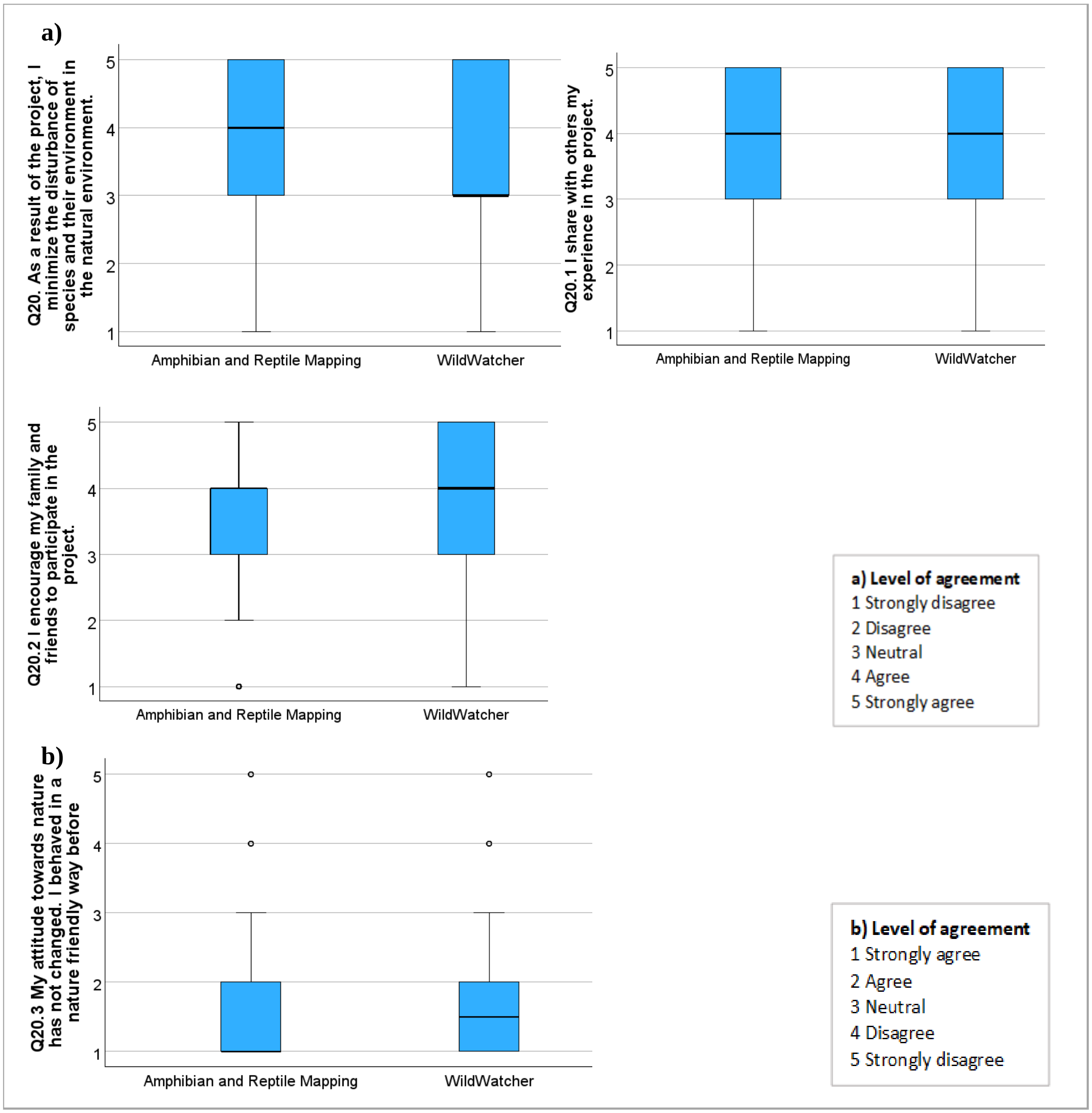

Figure 11. Attitude and behaviour-related questions boxplot results

A single targeted difference emerged; analysis with the Mann-Whitney U test revealed a significant difference between the two projects regarding efforts to minimize disturbance to species and their habitats (Q20; $p = .014$) (Table 11). Amphibian and Reptile Mapping participants reported a higher level of agreement (median = 4). In contrast, WildWatcher participants were more neutral (median = 3) (see Table 11).

For other attitude and behaviour questions (such as sharing experiences, encouraging others to participate, and maintaining environmentally friendly behaviours), no significant differences were found between the projects (all $p > .4$; see Table 11). Both projects typically agreed with these statements.

Table 11. Attitude and behaviour-related questions test results

Question	**Mann-Whitney U**	**Mann-Whitney U of the median Q20, Q20.1, and Q20.2**
	p-value	p-value
Q20. As a result of the project, I minimized the disturbance of species and their environment in the natural environment.	0.014*	0.678
Q20.1 I share with others my experience in the project	0.938	
Q20.2 I encourage my family and friends to participate in the project.	0.755	
**Q20.3 My attitude towards nature has not changed. I have behaved in a nature-friendly way before, the project did not change that.	0.427	

Note:*Asterisks indicate p-values showing significant differences between the two projects (p<.05). **Reverse scoring applied

For Q20.3 ("My attitude towards nature has not changed. I have behaved in a nature-friendly way before, the project did not change that"), the WildWatcher median lies between "strongly agree" (1) and "agree" (2), suggesting most participants already considered themselves to have a nature-friendly behaviour before the project (see b section of Figure 12). However, the Mann-Whitney U test result (p = .427) shows no significant difference between the two groups, indicating both projects attracted similarly predisposed, nature-friendly participants (Table 11).

3.3.5. Motivation

In both the Amphibian and Reptile Mapping and WildWatcher projects, participants' motivation responses clustered at medians of 3–5, indicating moderate to strong endorsement overall, with tighter distributions for website- and expert-related items.

Two motivational differences were detected. Personal interest in the project species was equally high in median terms for both groups (median = 5) as shown in Figure 12, but WildWatcher responses were more consistently at the top end (lower variance: 0.620 vs. 1.024; Mann–Whitney U, p = .001). Research purposes were also a stronger motivator in WildWatcher (Mann–Whitney U, p = .005), with higher central tendency (median = 3, Neutral) and wider spread, whereas Amphibian and Reptile Mapping showed lower motivation for research (median = 2, Disagree) (Figure 12).

Table 12. Motivation-related questions test results

Question	**Mann-Whitney U**
	p-value
Q19. Leisure/family activity	0.295
Q19.1 My responsibility towards nature	0.119
Q19.2 Meet other people with a similar interest.	0.658
Q19.4 Personal interest in the project species	0.001*
Q19.5 Desire to learn	0.539
Q19.6 Research purposes	0.005*

Note:*Asterisks indicate p-values showing significant differences between the two projects (p<.05).

Other motivations did not differ between projects: leisure/family activity (p = .295), responsibility toward nature (p = .119), meeting like-minded people (p = .658), and desire to learn (p = .539) showed similar patterns in both groups, with medians between 3 (Neutral) and 4 (Agree) and interquartile ranges typically spanning Neutral to Agree/Strongly Agree (Figure 12).

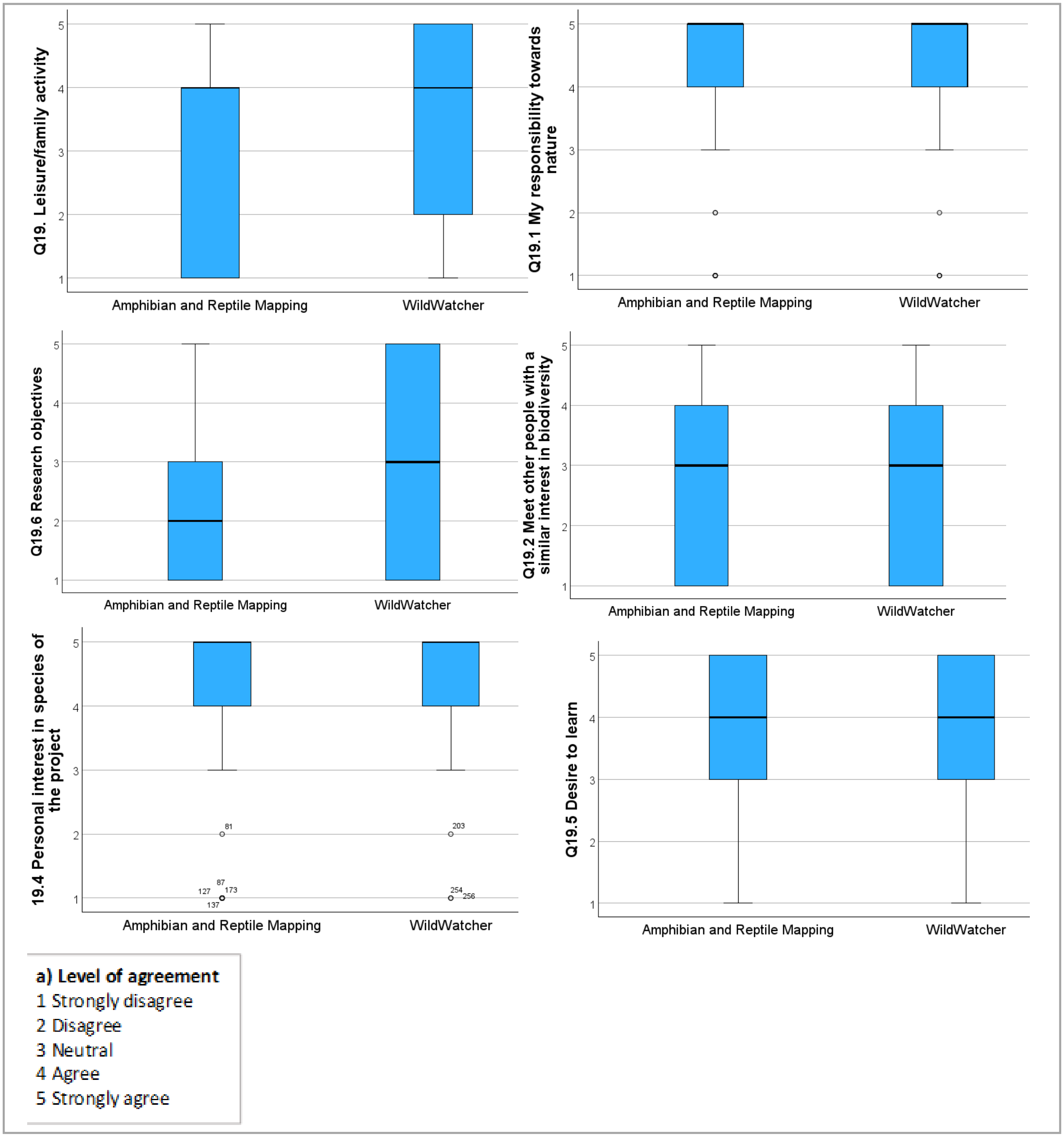

Figure 12. Motivation-related questions boxplot results

In summary, participants in both projects reported moderate to strong motivation across most categories, but WildWatcher participants were more consistently driven by personal interest in the species and showed greater motivation for research purposes.

3.3.6. Discussion of the results of the comparative analysis of the questionnaires for participants of two Hungarian NCCS projects

Demographics of participants

Both NCCS projects attracted predominantly middle-aged, well-educated participants, with about a third having professional links to nature conservation. This demographic pattern is widely reported in NCCS literature, where higher education and middle-to-older age groups are common among volunteers. However, a notable difference (Pateman et al., 2021; West et al., 2021) emerged in gender balance: Amphibian and Reptile Mapping was male-dominated, while WildWatcher saw greater female participation. This may be attributed to the nature of the target taxa and fieldwork requirements; herpetofauna projects often require more challenging fieldwork and have traditionally attracted more male participants, whereas projects featuring easily observable and familiar species tend to appeal to a broader, more gender-diverse audience (Nicholson et al., 2008; Bonney et al., 2016; Reniers et al., 2016; Pateman et al., 2021).

Participation patterns and technology use

Social media proved to be the most effective tool for recruiting participants to both projects, far superior to traditional media channels such as newspapers or television. This is consistent with broader trends in citizen science, where digital platforms now play a central role in outreach and engagement (Oliveira et al., 2021). However, it should be noted that the online nature of the survey may have introduced bias, potentially underrepresenting individuals who are less active online.

When it comes to submitting observations, both projects showed a preference for web-based platforms over mobile apps, though WildWatcher participants were somewhat more likely to use the app. This suggests that while mobile technology is gaining traction, web interfaces remain dominant, especially for tasks requiring more detailed data entry (SPOTTERON, 2019).

Despite positive feedback on technology usability, neither project achieved regular monthly engagement among most users. This pattern is common in NCCS, where a small group of highly active participants contribute most data, while the majority engage sporadically (Lemmens et al., 2021; Etter et al., 2023; Hognogi et al., 2023). Additionally, the strong seasonality of certain taxa (such as amphibians and reptiles) further influences participation rates, with peaks corresponding to periods of increased species activity.

Expertise level and knowledge gain

The two projects differed in the expertise levels of their participants. WildWatcher attracted a broader range of experts, likely due to its diverse set of target species, while Amphibian and Reptile Mapping's narrower taxonomic focus may have limited its appeal to specialists. This finding contrasts with some literature suggesting that specialist projects tend to attract more experienced volunteers, while generalist projects draw more novices (Bonney et al., 2016; Pateman et al., 2021). This discrepancy indicates that contextual factors, such as project design and outreach, can significantly shape the participant pool.

Participants in Amphibian and Reptile Mapping reported greater perceived knowledge gain from the project website, likely due to the in-depth, species-specific information provided. In contrast, WildWatcher's focus on common and easily recognized species may have resulted in less perceived learning, as many participants were already familiar with the taxa. This interpretation is similar to findings of Santori et al. (2021), where participants in specialist citizen science projects, such as TurtleSAT, reported substantial knowledge gains about the target species, with 70% noting increased understanding of turtles. In contrast, participants in broader projects focused on various plant species did not show significant knowledge improvement (Jordan et al., 2011; Crall et al., 2013). Furthermore, direct interaction with experts was rated more positively in Amphibian and Reptile Mapping, where ongoing support and feedback were more readily available, an approach shown to enhance knowledge and motivation in citizen science (Callaghan et al., 2020; Peter et al., 2021).

Attitude, behaviour and motivation

Participants engaged with the Amphibian and Reptile Mapping project exhibited a stronger commitment to minimizing disturbance to wildlife and habitats than those participating in the more generalist WildWatcher initiative. This finding is consistent with the results of Santori et al. (2021), who reported that projects targeting sensitive or less familiar taxa, and which provide explicit guidance on best practices, are more likely to foster a heightened sense of responsibility and conservation-oriented attitudes among volunteers. However, this outcome contrasts with the observations of Lewandowski & Oberhauser (2016), who noted that multi-species citizen science projects, particularly those involving more familiar or less sensitive taxa, often encounter challenges in effecting substantial changes in participant attitudes and behaviours.

Regarding respondents' motivation for participation, WildWatcher participants expressed a greater personal interest in the target species and research objectives, yet both projects demonstrated similar patterns in terms of motivations related to leisure, family involvement, environmental responsibility, and social interaction. These results are in line with previous research indicating that such core motivational factors are prevalent across a wide range of citizen science projects, irrespective of their taxonomic or thematic focus (Rotman et al., 2012; West & Pateman, 2016).

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

Objective 1: To develop a conceptually grounded evaluation framework for NCCS projects, structured around three core dimensions (science, nature conservation, and participants' development) that is applicable across multiple countries.

Research question: 1.1 What are the key components of a three-dimensional conceptual framework for evaluating NCCS projects?

Based on the literature review, a conceptual framework was developed that includes three dimensions (science, nature conservation, and participants' development). It provides a comprehensive basis for evaluating specifically nature conservation citizen science (NCCS) projects, while remaining sufficiently general for application in other countries. Within science, the core components include methodology, data quality, and data management; within nature conservation, the components focus on data use in monitoring, management, and conservation policy/decision-making pathways; and within participants' development, the components cover training, additional learning support strategies, and measurement strategies for participants' personal development.

Research question: 1.2 How can these components be translated/operationalized into a practical, user-friendly three-dimensional evaluation framework for NCCS projects' performance assessment?

Grounded in the three-dimensional conceptual framework, its components were operationalized into a practical, user-friendly three-dimensional evaluation framework by translating each component into several criteria and related binary yes/no questions, as well as applying normalized scoring, enabling clear, comparable assessment across science, nature conservation, and participants' development. When empirically applied to the eight Hungarian NCCS projects, the instrument differentiated performance and qualitative evidence to explain project divergences, demonstrating both validity and interpretability. The tool is simple and easy to use. Managers can use it for self-checks and planning, and external reviewers can use it to target improvements. The questions are general, not specific to the Hungarian context; therefore, they can be applied in other countries as well, where basic project information is available, producing comparable profiles and clear next steps

Objective 2: To assess the scientific contribution of selected Hungarian NCCS projects.

Research question: 2.1 How do NCCS projects ensure data quality?

The results of the evaluation of the data quality component of the science dimension using the evaluation framework, applied across eight Hungarian NCCS projects, showed that all projects implement multiple, layered data quality-assurance strategies: expert validation is a consistent practice of all projects; requests for additional information from contributors when needed; targeted site visits to resolve inconsistencies; and support from institutional expertise. The focused analysis of two long-running NCCS project databases corroborates this in practice: more than 90% of observations were validated in both datasets across years, with only a small recent increase in unchecked records in WildWatcher (2023–2024) relative to Amphibian and Reptile Mapping (Chi square test, $p < .001$), confirming that data validation is performed and embedded throughout the years.

Research question: 2.2 Are the outcomes of NCCS projects scientifically robust?

Based on the evaluation of the science dimension, across eight projects using the evaluation framework, there are scientifically robust outcomes: projects collectively scored 660/800 in the science dimension, reflecting strong methods, validation, and data management. Complementing these results, the comparative analysis of the two NCCS projects shows that the Amphibian and Reptile Mapping provides high, long-term volume and range (74,415 observations, multiple peak years) with balanced coverage of target taxa, while WildWatcher provides a steady annual flow (17,484 observations, 2009–2024) dominated by mammals and complemented by other groups. Together, these longitudinal databases show consistent data production, taxonomic representativeness aligned with project aims, and sufficient volumes for robust inference, confirming the scientific robustness of the selected Hungarian NCCS projects.

Objective 3: To assess the nature conservation role of selected Hungarian NCCS projects.

Research question: 3.1 How can NCCS projects contribute directly to the monitoring of species?

Based on the evaluation of the nature conservation dimension of the eight projects using the evaluation framework, this dimension emerged as the second-strongest across the eight selected projects, totalling 533/800 points. The Common Bird Monitoring Program, Amphibian and Reptile Mapping, and WildWatcher each achieved the maximum 100 points. Consistent with literature emphasizing the value of long-term continuity, projects with longer operational histories (e.g., Amphibian and Reptile Mapping, WildWatcher, Common Bird Monitoring) perform especially well on nature conservation components, reflecting established roles in monitoring of species nationwide; integration into national biodiversity infrastructures such as the Hungarian Nature Conservation Information System (TIR) (e.g., WildWatcher), while projects like the Common Bird Monitoring Program, Arthropods, and Butterfly-Net have identified new populations demonstrating direct contribution on species monitoring in Hungary.

Research question: 3.2 How are NCCS project outcomes utilized in species management?

The evaluation of the species management component (nature conservation dimension) across eight projects using the evaluation framework shows that project outcomes are actively utilized in species management, with validated citizen-generated data triggering concrete interventions across control, mitigation, and habitat protection, mainly in older projects. The Common Bird Monitoring Program led the nature conservation dimension with the highest score (257/300), followed by Amphibian and Reptile Mapping (256/300) and WildWatcher (241/300) as the next best performers. Moreover, (5/8 projects) met the component of environmental management, evidencing direct management uptake by the majority of analysed projects. Open-data adopters (e.g., Arthropods) enabled new species records and invasive detections, while Butterfly-Net observations led to a newly recognized butterfly population and subsequent habitat protection by the Őrség National Park Directorate. Taken together, these findings show that validated NCCS outcomes routinely inform and accelerate species management decisions and actions.

Research question: 3.3 How are NCCS project outcomes utilized in policies and conservation actions?

Based on the evaluation of the policy component (nature conservation dimension) of the eight projects using the evaluation framework, results indicate that collectively, policy uptake remains uneven across the analysed NCCS projects. However, mature initiatives with long-term databases and established institutional linkages have created clear pathways from citizen-generated evidence to conservation policies and official reporting (3/8 projects scored Policy component). WildWatcher data feeds the Hungarian Nature Conservation Information System and supports Article 17 reporting under the EU Habitats Directive, Butterfly-Net records on OpenBioMaps improve access for decision-makers. Amphibian and Reptile Mapping regularly supplies datasets to the European Atlas of Amphibians and Reptiles and EU reporting, and the Common Bird Monitoring Program underpins EU-wide monitoring and Hungary's annual bird atlas.

Objective 4: To assess the impact of selected NCCS projects on participants' development.

Research question: 4.1 What motivates citizens to get involved in the selected NCCS projects?

Based on the results of questionnaire surveys conducted among participants of the two selected projects, participants of Amphibian and Reptile Mapping are highly motivated overall (medians 4–5) by broadly shared motivations of learning, responsibility toward nature, leisure/family activity, and meeting like-minded people. WildWatcher shows stronger, more consistent motivation from personal interest in species (Q19.4; $p = .001$; both medians = 5, but lower variance 0.620 vs. 1.024) and higher motivation for research purposes (Q19.6; $p = .005$; median = 3 vs. 2 in Amphibian and Reptile Mapping).

Research question: 4.2 How do NCCS projects influence the knowledge of participants?

Based on the evaluation of the participants' development dimension across eight projects using the evaluation framework, it was revealed that this dimension lags behind the science and nature conservation dimensions (471/800), largely because most initiatives lack systematic protocols to assess and knowledge. Butterfly-Net stands out as the only project that incorporates structured knowledge-gain measurements into its methodology. Addressing this gap, this study offers the first direct comparison of two select NCCS projects (Amphibian and Reptile Mapping and WildWatcher) through questionnaire surveys conducted among participants, demonstrating that involvement in NCCS fosters knowledge gain in distinct ways (medians above neutral 3–5 across knowledge gain). Specialized NCCS projects focusing on target species, such as Amphibian and Reptile Mapping, yield greater participant knowledge gains than generalist projects like WildWatcher ($p=.014$), which mainly broaden participation but offer smaller learning outcomes.

Research question 4.3: How do NCCS projects influence participants' attitudes and behaviours?

Based on the evaluation of the measurement strategies for participants' personal development component (participants' development dimension) across eight projects using the evaluation framework, none of the eight projects formally evaluate changes in attitudes or behaviours. Nevertheless, coordinator interviews indicate pro-conservation orientations where explicit low-impact norms (codes of conduct, handling guidance, seasonal access rules) are embedded in project practice. Several projects provide feedback to reinforce engagement, attitude, and behavioural change, but the effects of such practices remain unevaluated. Questionnaire surveys conducted among participants of the two selected projects corroborate this pattern. Amphibian and Reptile Mapping participants report stronger agreement with minimizing disturbance than WildWatcher participants ($p = .014$; medians 4 vs. 3), while all other attitude/behaviour items show no significant differences between projects (all $p > .4$) and are generally endorsed (median = 4).

4.2. Recommendations

Policymakers and funders should institutionalize standardized, periodic evaluations of NCCS projects using adaptable frameworks to track scientific rigor, conservation outcomes, and participant development, thereby improving data reliability, enabling adaptive management, and increasing policy uptake. Projects should cultivate strong institutional partnerships with scientific organizations to secure data quality, continuity, and long-term impact. Adopting open-data principles—while applying geoprivacy, role-based access, and clear metadata for sensitive species—can expand reuse, collaboration, and publication outputs. To enhance learning outcomes, participant-focused evaluation protocols should measure knowledge, skills, engagement, attitudes, and behaviours over time, using longitudinal mixed-methods with standardized pre/post instruments and qualitative components. Validated multi-taxa datasets with rich metadata should be integrated into national biodiversity systems (e.g., TIR) to align with standards and support evidence-based conservation and long-term monitoring. Broader, multi-channel survey strategies, including brief targeted instruments, are recommended to reduce online bias and improve representativeness.

Further research is recommended to identify the main factors that drive participants' knowledge gains by repeatedly measuring the same cohort with standardized pre- and post-assessments and interim follow-ups, allowing stronger causal comparisons over time. This work should test how project features (training intensity, expert interaction, frequency of feedback, and task complexity) shape learning, and apply the same approach to track changes in attitudes and behaviors. In parallel, studies should refine how to address open-data practices by protecting sensitive species while maintaining reuse (for example, location sharing) and documenting protection methods in metadata, using role-based access for trusted users or authorities to preserve conservation value, and evaluating effects on volunteer trust, motivation, and knowledge.

5. KEY SCIENTIFIC FINDINGS AND IMPORTANT OUTPUT

1. **A key scientific contribution of this dissertation is the development of a non-country-specific conceptual framework for Nature Conservation Citizen Science (NCCS) projects that uniquely integrates three essential dimensions (science, nature conservation, and participants' development).** This general (non-country-specific) evaluation framework for NCCS projects is structured around three key dimensions, with three components per dimension. The science dimension comprises data quality, validation, and data management; the nature conservation dimension comprises data use in monitoring, management, and policy; and the participants' development dimension comprises training, knowledge gain, and attitude/behaviour change.
2. **Building upon the conceptual framework, a second key contribution is the development of a three-dimensional evaluation framework, specifically designed to assess the performance of NCCS projects.** The framework operationalizes the conceptual framework and its nine components into 18 criteria that are translated into yes/no questions. It can be easily used by project coordinators and can be a base for cross-project comparison along all three dimensions.
3. **The empirical application of the three-dimensional evaluation framework to eight Hungarian NCCS projects showed uneven performance across dimensions.** From the 800 possible maximum points, the projects performed strongly in the science dimension (660 points), moderately in nature conservation (533 points), and weakest in participants' development (471 points).
4. **Based on the comparative analysis of the two selected observation databases, both NCCS initiatives accumulated substantial databases over more than a decade, maintaining consistently high validation rates (>90%) with relatively few unchecked or invalid records.** The analysis also revealed that WildWatcher exhibited a slightly higher proportion of unchecked records in recent years compared to Amphibian and Reptile Mapping, a significant difference (Chi-square test, $p < .001$; Cramér's $V = .276$), most pronounced in 2023–2024.
5. **Based on the results of questionnaire surveys conducted among participants of two selected projects, using a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree), respondents reported moderate-to-high knowledge gains (medians 3–5) alongside broadly pro-conservation attitudes and behaviours (medians ≈ 4) in both projects.** Amphibian and Reptile Mapping showed significantly higher gains of knowledge via the website (Mann-Whitney U test, $p < .001$) and expert interactions (Mann-Whitney U test, $p = .028$) (medians 4), while Wildwatcher showed neutrality (medians 3). Amphibian and Reptile Mapping showed significantly stronger commitment to minimizing disturbance (Mann-Whitney U test, $p = .014$) (median 4) than WildWatcher, with most respondents being neutral (medians 3). Both groups endorsed intrinsic motivations, while WildWatcher was more driven by personal interest in species (Mann-Whitney U test, $p = .001$) and research purposes (Mann-Whitney U test, $p = .005$).

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LIST OF PUBLICATIONS

Journal articles

1. **Q1**: Soria Aguirre, JM, Váczi, O, Biró, M, Juhász, E, Soltész, Z, Barta, B, Márton, Z, Szép, T, Halpern, B, Szentirmai, I, Károlyi, B, Czeglédi, A, Bela, G and Tormáné Kovács, E. (2024). Citizen Science for Nature Conservation in Hungary A Three-Dimensional Approach. Citizen Science: Theory and Practice, 9(1): 30, pp. 1–15. DOI: DOI: 10.5334/cstp.762
2. Soria, J., Tormáné Kovács, E. (2023). "Contribution of Nature Conservation Related Citizen Science Projects to Learning, Attitude and Behavioral Change of Participants". Review on Agriculture and Rural Development 12 (1-2):27-36. https://doi.org/10.14232/rard.2023.1-2.27-36.
3. Soria, J., Tormáné Kovács, E. (2025). How does Nature conservation citizen science affect policy and decision-making? A Review. Review on Agriculture and Rural Development. 13 (1-2):24-33. DOI: 10.14232/rard.2024.1-2.24-33
4. Soria, J., Tormáné Kovács, E., (2025). Ensuring scientific rigor in nature conservation citizen science projects - a review- (Accepted manuscript in Review on Agriculture and Rural Development)

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1. Soria, J.; Bela, G. Tormáné Kovács, E., (2022). Citizen science for nature conservation in Hungary, an overview experiences three dimensions. In: P. Zasadil, V. Ludvíková, A. Báldi, (ed.) 6th European Congress of Conservation Biology Book of abstracts August, Prague, Czech Republic. Book of abstracts. pp. 134"
2. Soria, J.; Tormáné Kovács, E. (2023). Contribution of nature conservation related citizen science projects to learning, attitude and behavioral change of participants. In: Gyalai, Ingrid; Czóbel, Szilárd (ed.) 20th Wellmann International Scientific Conference: Book of abstracts Hódmezővásárhely, Hungary: Szeged University Faculty of Agriculture. pp. 48
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4. Soria, J.; Tormáné Kovács, E. (2024). Strengths and challenges of nature conservation citizen science projects in Hungary. In: Zsolt, L.; Vásárhelyi, Z.(eds.) Book of Abstracts – SEEN (Social Engagement in Ecology Network) conference and workshop, January 18–19, 2024. Tata, Hungary, (2024) 20 p. pp. 17-17. ,
5. Soria, J.; Tormáné Kovács, E (2024). How does Nature conservation citizen science affect policy and decision-making? A Review. In: Gyalai, Ingrid; Czóbel, Szilárd (ed.) 21th Wellmann International Scientific Conference: Book of abstracts Hódmezővásárhely, Hungary: Szeged University Faculty of Agriculture. pp. 81
6. Soria, J.; Halpern, B.; Tormáné Kovács, E. Revealing Participants of Amphibian and Reptile Mapping Citizen Science Project in Hungary. In: Diversity Editorial Office (ed.) The 3rd International Electronic Conference on Diversity: Book of abstracts online conference 15–17 October 2024. pp. 105