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RESEARCH

Monitoring, collecting, and validating data of inland wetland survey based on citizen science methodology

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Background: In this study, citizen scientists gathered survey data by monitoring inland wetlands, recognized as carbon sinks, and verified the accuracy of the data for incorporation into ecosystem management policies.
Results: In October 2022, citizen scientists conducted surveys on three taxonomical groups (plants, mammals, terrestrial insects) in three wetland protection areas. After capturing photographs with location information, these images were uploaded to a national ecological information bank (EcoBank) managed in Korea. The information collected by citizen scientists underwent cross-validation through two expert methods, involving ecology field experts. First, experts conducted a survey of invasive alien plants in the designated areas and compared their findings with those of citizen scientists. The choice of survey locations by citizen scientists was influenced by their proximity to their residences. Second, an expert scrutinized the accuracy of species names collected and uploaded to EcoBank by citizen scientists, presenting their findings. The classification accuracy for species names was 98.8% for vegetation ($n = 83$), 21.6% for terrestrial insects ($n = 21$), and 66.7% for mammals ($n = 8$). These results indicate that citizen scientists may lack detailed classification ability at the species level.
Conclusions: Moving forward, it will be imperative to offer diverse forms of education to strengthen the capabilities of the citizen scientists, including sharing wetland survey results to enhance expertise in species identification, creating and distributing educational materials, and providing on-site education through professional surveyors.

Keywords: citizen science, conservation, ecosystem monitoring, wetland protection areas, wetland survey

Introduction

Aligned with the 4th General Plan for Wetlands Conservation, there is a growing trend of citizen participation in wetlands research with individuals contributing to expert-level surveys. This active participation frequently involves wetland surveys, intending to strengthen conservation and management capabilities for wetland protection areas, while also promoting awareness of conservation initiatives. By integrating citizen science methodology into ecological monitoring across all wetland protection areas, challenges such as budget constraints and staff shortages can be addressed. This approach complements the method of short-term monitoring by a limited number of professionals, providing a means to acquire abundant monitoring data.

Citizens participating in surveys across wetland protection areas are typically residents residing in these regions. These residents have developed an enhanced awareness of local ecosystem conservation through their involvement in the processes of exploration, designation, and conservation of protected areas. Consequently, they have developed a fundamental sense of empathy for ecological surveys and management efforts directed towards the conservation of their local environment. Residents are well-positioned to conduct ecological surveys due to their in-depth knowledge of local ecological resources. Compared to experts from other regions, they also benefit from better geographical accessibility and more frequent access to the area. Citizen scientists often survey multiple locations, including hotspots, multiple times to supplement the results of single surveys conducted by experts focusing on ecological hotspots. Moreover, several residents, including semi-professionals or individuals working in related industries, are capable of conducting ecological surveys. This group, which includes natural environmental interpreters, contributes significantly as a complementary force. Given the variance in survey abilities between professionals and citizen scientist groups, as well as among individual citizen scientists, there is a need to enhance the capabilities of citizen science groups through mutual support and collaboration with professional surveyors.

To enhance the accuracy and reliability of survey results, citizen scientists and professionals should play complementary roles. For instance, citizen scientists can use smart devices to collect data from multiple locations at different times, capturing photographs of species with location information. They can then register the photographs alongside the species' name on an information platform. Experts can review the photographs and openly approve or edit the uploaded information, including the species name. Additionally, providing education to enhance skills, with experts educating citizen scientists in ecological survey methods, can elevate the quality of biological surveys and nurture the growth of additional experts in the long run. Competency-based education can help bridge the gaps within citizen scientist groups by addressing issues like identifying invasive alien species that require removal or management and addressing gaps in knowledge regarding management techniques. This, in turn, enhances the overall quality of survey data.

Policy trends

Concerning citizen participation in the field of ecology, the National General Environmental Plan (2020–2040), the highest-level environmental plan in Korea, indicates an increase in national involvement (Ministry of Environment 2020). This is based on big data and citizen science, to enhance the ecological capacity of the land and achieve ecological welfare. Specifically addressing wetlands, the 3rd General Plan for Wetlands Conservation (2018–2022) launched a citizen participation project (Ministry of Environment 2018). The goal was to rectify the lack of guidelines for citizen surveys and enhance the utilization of survey results. However, limitations in this project were recognized, leading to the development of the 4th General Plan (2023–2027) to improve methods in citizen surveys and systematize the utilization and return of results (Ministry of Environment 2023). Simultaneously, the 4th National Biodiversity Strategy (2019–2023) emphasized the need for the systematic implementation of ecological monitoring at relevant institutions, such as the Ministry of Environment (Related Authorities 2018). This strategy includes the preparation of citizen participation guidelines to enhance the effectiveness of biodiversity policies. The upcoming strategy must further progress in fostering and monitoring citizen scientists. To realize the objectives of the aforementioned plans, including the General Plan for Wetlands Conservation, citizen science research on wetland ecosystems should incrementally focus on developing manpower, enhancing competencies through collaboration with professional wetland surveyors, reinvesting research outcomes in the local community, and diversifying methods to broaden participation among the population.

Research trends

Based on global research trends, numerous case studies have emphasized the crucial role of citizen participation in ecological monitoring and management, especially in addressing ecological challenges like invasive alien plant species. In Korea, a focus on national institutions has leveraged citizen science research methodology for surveying ecosystems, including protected areas, with efforts to integrate results into policies. A notable instance is the integration of citizen participation approaches with projects targeting ecological disturbance eradication. Studies underscore the need for citizen participation, utilizing local cooperative networks and management, to overcome the limitations of projects aimed at eradicating invasive alien species. This involves selecting target areas based on the monitoring of invasive alien species. In this context, Park and Lee (2018) analyzed data from a 2009 project in Gangwon-do, highlighting the necessity for efficient plans and policies for managing invasive alien plants. These plans include the construction of a monitoring and management system for invasive alien plants and the promotion of civilian participation. Kim and Koo (2021) reviewed the state of invasive alien plant designation and management and proposed external cooperation and publicity. Their recommendations include initiating a project to prevent the spread of invasive alien species, constructing a local cooperative network, and reinforcing citizen education.

In addition to the domestic and international studies mentioned earlier, numerous reports worldwide detail methodologies involving citizens in ecological monitoring and management, featuring case studies applying this methodology. Petersen et al. (2021) underscored the significance of data collection incorporating citizen science research methodology in biodiversity studies. They provided a summary of a case study demonstrating species frequency data collection using citizen participation to enhance the spatial precision of ecological surveys by ecosystem type and taxonomic group. The authors noted that data collected by citizen scientists is actively contributing to biodiversity research, including studies on species distribution, abundance, habitat use, and phenology.

In Europe and the US, research outcomes highlight spatial information, such as invasive alien species monitoring and maps, employing public or citizen participation as tools for managing protected areas. Notably, ecological management and policies are often combined with citizen science research methodology in studies focused on non-native species. In the US, citizen scientists utilized GPS and mobile devices for data collection on invasive species in urban forests and green spaces, and this data played a crucial role in shaping the management strategies for these areas (Hawthorne et al. 2015). Johnson et al. (2020) showcased data collection on invasive species using web and mobile application-based interfaces, visualizing the spatial distribution of these species. In Portugal, Gil et al. (2016) created the volunteered geographic information-Priolo Atlas through citizen participation, mapping the distribution of the endangered Azores bullfinch via a bird survey on São Miguel Island (the autonomous region of the Azores).

Citizen scientists are increasingly utilizing mobile application-based monitoring and data collection platforms to reduce human error in their tasks. Schade et al. (2019) presented a case study in the EU where citizens employed a mobile application to collect data on the time of detection, location, and species abundance of non-native species. These data were subsequently used in EU policies to manage non-native species. Bonnet et al. (2020) described a case study where citizen scientists used the plant data collection platform Plant Net in conjunction with automatic plant identification tools. They collected data on habitat locations for various plant species in wetland protection areas, supplying this information to workers involved in the management of these areas.

To enhance the utility of citizen-collected data for analysis and policymaking, alongside the ecological data collected through citizen participation, validation guidelines have been developed, incorporating research on quality control. Johnson et al. (2020) reported that citizen-collected observational data for invasive species, including maps showing the spatial distribution of species, could significantly contribute to the analysis and policy-based data production essential for controlling alien species. The Joint Research Center of the European Community provided validation guidelines, emphasizing the importance of validating citizen science data. They proposed processes for improving the reliability and accuracy of citizen-collected data for use in ecology-related policies, including (a) peer and expert validation, (b) automated quality assessment using algorithms and tools, and (c) model-based quality assessment employing statistical models (Adriaens et al. 2021).

Materials and Methods

Research design

The specific survey content and methods are determined based on the goals of the citizen science activity. For instance, in monitoring and collecting data on plants, when a citizen scientist discovers an invasive alien plant, taking a photograph with location information using their smartphone and uploading it to a digital platform allows experts to review and/or edit the species name to ensure that only accurate data are recorded (Stage 3). Depending on the goals of the citizen science research activity, after identifying the beneficiary, data validated by an expert are processed into a usable form by the beneficiary. For example, if citizen scientists are monitoring the distribution of invasive alien plants, the data could be transformed into detailed distribution maps for use in invasive alien plants' control by the Ministry of Environment or local governments, or it could be made into educational materials for students, including residents and other citizen scientists. This way, the products of citizen science research are reinvested toward citizen scientists and their communities.

Research procedure

In this study, we applied the four pre-stages from the above model of citizen science research for wetland protection areas (Fig. 1). In the planning stage (Stage 1), the goal of the citizen science research was to ascertain the habitats of invasive alien plants throughout the wetland protection areas and to construct data-based materials, such as distribution maps, for use in projects to eradicate invasive alien plants by the Ministry of Environment and local government. The study area was a wetland protection areas under three metropolitan/basic local autonomous entities, including Gwangju, where an ongoing project to improve

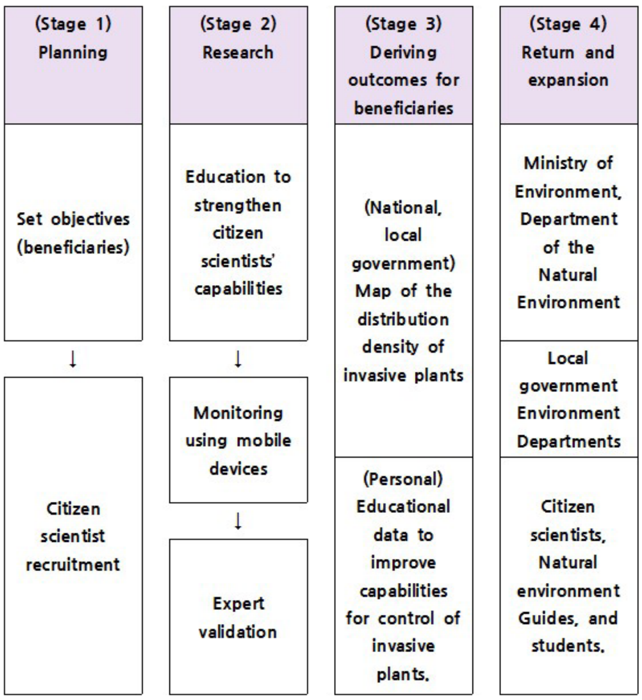

Fig. 1 A model of citizen science research in protected wetland areas (an example of invasive plant monitoring).

residents' capabilities is underway. Citizen scientists were recruited from among the residents of these areas. In the active research stage (Stage 2) (Fig. 2), the recruited citizen scientists participated in training tailored to the characteristics and needs of the group, including teaching competencies for surveying invasive alien species. Subsequently, the citizen scientists visited the wetland protection areas in their residential area during everyday activities, took photographs with location information on their smartphones when they discovered an invasive alien plant and registered the photographs on EcoBank, a national ecological information portal. In the registration process, the citizen scientists indicated the name and extent (colonies, population, individuals) of the invasive alien plant they photographed. Experts then checked the photographs, names, and distribution information, correcting any errors before the information was revealed to the public. The information collected on EcoBank includes the registrant (citizen scientist), the registration date, the taxonomic group, the species, the distribution density, the latitude and longitude, and the validator (expert). After one month of the citizen science research activity in October 2022, the monitoring data on EcoBank were used to create maps of the density of each invasive alien plant species (Stage 3). These maps were then provided to the Ministry of Environment and local governments for use in control policies, such as the selection of areas to prioritize the eradication of invasive alien plants. The results of using the plant distribution map were obtained from the recipients to review its utility (Stage 4).

Study area

The study area consisted of the wetland protection areas of Jangnok in Gwangju, Ungok Wetlands in Gochang, Jeollabuk-do, and Madong-ho Lake. Since 2021, there has been an ongoing project in this area to improve the capabilities of residents. Jangnok Wetlands, which was designated as a protected area on December 8th, 2020, is an urban river wetland with high biodiversity that is relatively unchanged. Ungok Wetlands in Gochang, Jeollabuk-do, which was designated a protected area on March 14th, 2011, is characterized by its high biodiversity and is a habitat for endangered wild plants and animals. Madong-ho Lake in Goseong, Gyeongsangnam-do, which was designated a protected area on February 3rd, 2022, is characterized by rich biodiversity, including a high concentration of legally protected species, such as black-faced spoonbill.

Education to improve survey capabilities among citizen scientist

This education consisted of a program that reflected the prior educational needs of all the citizen scientists. Since this was the first stage at the start of the citizen science research project, in the basic education lectures, the citizen scientists were instructed on the value of wetlands conservation, the means of contributing to citizen science research, and the objectives and content of this study. Following this, they practiced methods for surveying plants and terrestrial insects on-site in the wetland protection areas. The lecturers were experts in ecological surveys and research who worked, either currently or previously, at a national public institution.

During the educational course, a research activities manual (explanation of methods) was prepared and distributed to the citizen scientists for use during the on-site lectures. The content included survey procedures and methods that the citizen scientists could use whenever performing surveys during the research period, as well as safety precautions to be followed during activities. This content was visualized, so that it could be understood easily and intuitively, and photographs of invasive alien species specified by the Ministry of Environment were also included (Fig. 3).

In the manual (National Institute of Ecology [NIE] 2022), survey target taxonomy were clarified with example pictures such as invasive alien species designated from The Ministry of Environment in Republic of Korea. The material was guiding the research process for citizen scientists how to find, to take pictures and to upload the target species near wetlands on EcoBank, the information platform. As the experts group were supposed to validate and refine the data that citizen scientists' collected, the guidebook was focused on how to take clear pictures for citizen scientists with their own cell phones and to obtain certain shoots of photo containing morphological features for accurate classification.

To reduce differences in knowledge of invasive alien plants among the citizen scientists and to help the group accurately identify invasive alien plants during field prac-

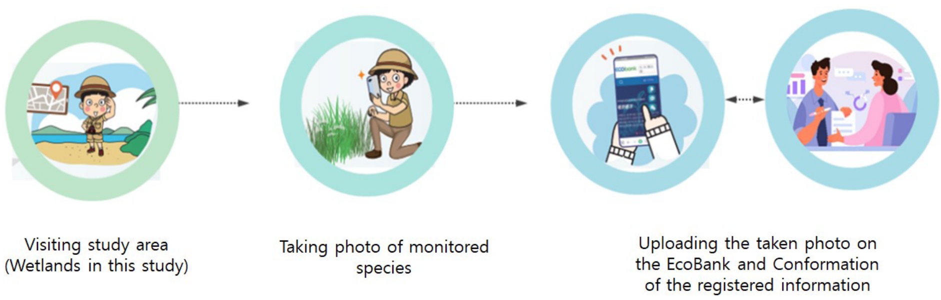

Fig. 2 Process of citizen science applied in this study.

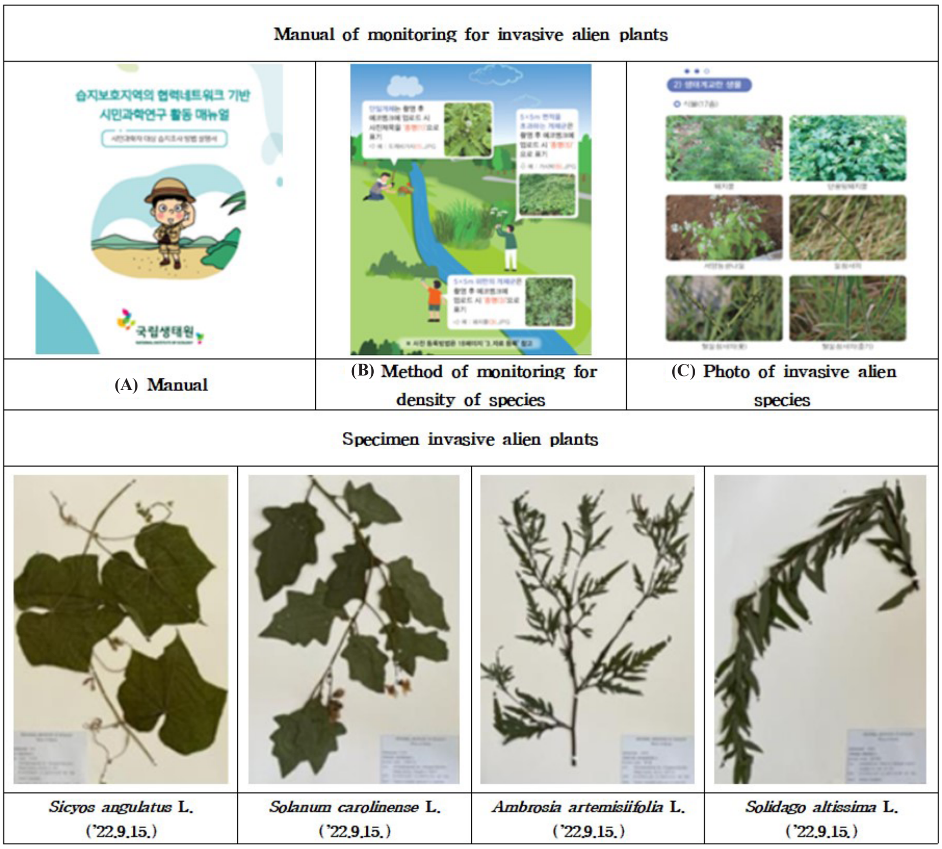

Fig. 3 Education material for monitoring invasive alien plants (manualand plants' specimen).

tice and survey activities, samples of four invasive alien plant species from the survey (*Sicyos angulatus*, *Ambrosia artemisiifolia*, *Solanum carolinense*, and *Solidago altissima*) were prepared and used during the indoor lectures.

Results

Monitoring fields and methods

To boost the spatiotemporal precision of wetland surveys conducted by experts throughout wetland protection areas, the citizen scientists conducted surveys on three taxonomic groups, including vegetation, terrestrial insects, and mammal footprints. The citizen scientists used smartphones to take photographs of biological species and registered those on EcoBank, an international platform for aggregating ecological data. Benthic invertebrates, amphibians, reptiles, and fish were excluded from the survey because they require separate equipment and introduce safety hazards such as slipping or snake bites.

Collection, storage, and sharing of monitoring data

The invasive alien plant data obtained from citizen scientists was stored and shared with the public on EcoBank. EcoBank is an international ecological data hub run by the NIE. The NIE uploads national ecosystem survey results (natural environment surveys, ecological zoning maps, and more) and biological/ecological data from related institutions, increasing the accessibility of ecological information for researchers and the general public (reference).

On this platform, monitoring data are registered by participants in the role of enactor and the specific target, such as an inland wetland survey. Only the data that have been verified by an expert are made available for use. After the citizen scientists took photographs of invasive alien plants across the wetland protection areas, they registered the photographs on EcoBank and generated database (DB) files. The DB properties comprised the name of the citizen scientist, the taxonomic group and species name of the photographed object, the date of registration, the coordinate (longitude/altitude), and the name of the expert who reviewed the accuracy (validator) (Table 1).

Validation method

To investigate the characteristics of expert surveys and citizen science surveys, on February 2nd, 2022, four wetland surveyors surveyed four species of invasive alien plants across the entirety of the Jangnok wetland protection areas in Gwangju. The survey method was identical to the citizen science method, with the surveyors taking photographs when they detected an invasive alien plant and uploading the photographs to EcoBank. Since the experts only collected data after identifying the species name and determining whether it was one of the target species, their

Table 1 Attributes recorded in the database on EcoBank (example)

Content (species name + density)	Taxonomic group	Species name	Date of registration	Registrant	Validator	Date of validation	State	Latitude	Longitude
Solidago altissima 5	Plant	*Solidago altissima*	Oct 27th 2022	A.B.C.	D.E.F.	Oct 27th 2022	Approved	35.11556	126.7814
Solanum carolinense 3	Plant	*Solanum carolinense*	Oct 27th 2022	A.B.C.	D.E.F.	Oct 27th 2022	Approved	35.14306	126.7689
Solanum carolinense 1	Plant	*Solanum carolinense*	Oct 27th 2022	A.B.C.	D.E.F.	Oct 27th 2022	Approved	35.14389	126.7689
Solidago altissima 5	Plant	*Solidago altissima*	Oct 27th 2022	A.B.C.	D.E.F.	Oct 27th 2022	Approved	35.14444	126.7675
Solidago altissima 1	Plant	*Solidago altissima*	Oct 27th 2022	A.B.C.	D.E.F.	Oct 27th 2022	Approved	35.14833	126.7608

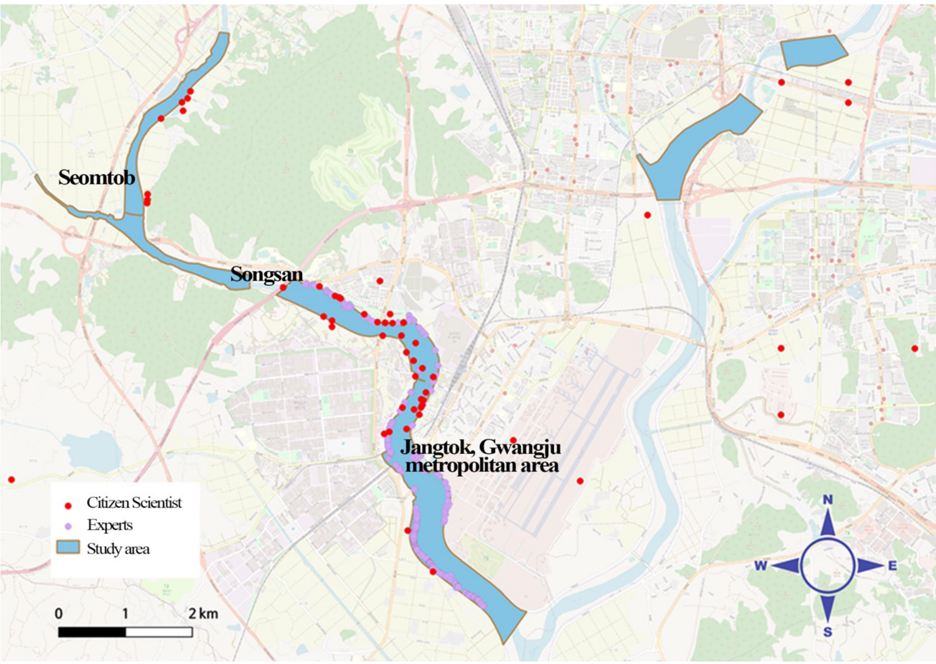

Fig. 4 Result of distribution of invasive alien plants (4 species) monitored by citizen scientist and experts.

collected data were not reviewed on EcoBank. The citizen scientists and experts surveyed the four invasive alien species in the wetland protection areas around October, close to the end of the plant life cycle, when plant growth (stem height, rhizome propagation) and proliferation stop, and plants begin to flower and bear fruit. The reason for choosing this period was the fact that the proliferation of invasive alien plants within the wetland protection areas slowed during this survey period, minimizing the possibility of changes in the distribution and thereby enabling accurate comparisons of the survey scope and locations between citizen scientists and experts. The figure shows the comparison of the expert survey and the results of the citizen scientists' survey for the month of October 2022. The expert survey region was along the two borders (left and right sides, surveyed by groups of two experts) on either side of the Jangnok Wetlands protected area. The citizen scientists' survey region was mostly concentrated in the upstream part of the Hwangryong River, in the area between Dosan Station (Gwangju Metro Line 1) and Eodeung-daero (Fig. 4). This was because citizen scientists had to travel by footpaths while surveying the expansive wetland areas, and also because there was a dense cluster of residential complexes around the upstream area.

The number of survey locations for the citizen scientists was relatively high at the borders of the wetland protected areas between Eudeung-daegyo and Gwangju Metro Line 1, in the upstream part of the Hwangryong River. This is because there are residential areas in the upstream region, as well as parks, such as Seonun Park, between this area and the wetland protection areas, making this part of the survey region more accessible. Around Gwangju Metro Line 1 and the downstream area, the left and right sides of the Yongdu Confluence Ecological Park, which are the borders of the wetland protection areas, there are agricultural facilities, such as greenhouses, and mountains on the right side. Thus, the citizen scientists started their research activities upstream and, rather than continuing to survey the entire length downstream, where Hwangryong Riverside Park is located, they usually finished their survey activities close to where they started. In the upstream area, where the citizen scientists' survey points were concentrated, the citizen scientists were able to obtain data from a more diverse range of locations compared to the experts, who surveyed along the borders of the wetland protection areas. This suggests that it would be possible to obtain even richer survey results by combining the data from the citizen scientists with the data from the experts. Based on the comparison, mentioned earlier, between the expert and the citizen scientist survey, in future studies, to obtain data from multiple locations, which is one of the advantages of citizen science research, it will be important to share the survey results with the citizen scientists and to work together to find less surveyed areas and discuss safe survey routes and methods, such as identifying survey routes that give access to neglected areas, to encourage a more evenly distributed survey across the whole wetland protection areas.

Expert validation and accuracy analysis

Species identification

In this study, we reviewed errors in the citizen scientists' survey results for each taxonomic group by enlisting experts holding a doctorate and currently working in the field. This is because the citizen scientists who participated in this study included amateur learners with an interest in biology, including individuals with semi-professional opinions about species classification. As such, the data surveyed and uploaded to EcoBank by the citizen scientists would inevitably show errors compared to the expert survey, and we also anticipated differences in accuracy between individual citizen scientists, depending on their capabilities. The rate and level of errors in the data provided by the citizen scientists constitute important information to develop strategies to improve survey accuracy in the future.

As described in Section 4, the surveyed taxonomic groups consisted of plants, including four species of invasive alien plants, terrestrial insects, and mammals. Among the wetland organisms data registered by the citizen scientists, the most common were terrestrial insects (107 cases), followed by plants (86 cases), and then by mammals (16 cases; Table 2). This indicates that it was easier to identify plants and terrestrial insects in comparison to mammal footprints. Among the data registered by citizen scientists, experts rejected data that were insufficient for species identification by photograph alone, or where there was an error in the selection of taxonomic group (e.g., benthic invertebrates or plants being mistakenly registered as terrestrial insects). Additionally, the experts corrected errors and approved data where identification was possible. Table 3 shows the error rate between the initial species name added by the citizen scientist and the final, accurate species name after correction by experts. Among taxonomic groups, the citizen scientists showed the highest accuracy for species identification of plants (83 cases, 98.8%); for terrestrial insects and mammals, the number of correctly identified species as a ratio to the total number of approved cases was 21.6% and 66.7%, respectively. Given that there were only nine species of plants and four species of mammal footprints surveyed, this shows that taxonomic groups with a smaller number of target species are surveyed more accurately. In particular, the reason for the high accuracy rate for plants could be due to the training provided to the citizen scientists for identifying the four invasive alien species through specimens, manuals, and field practice before the survey. For terrestrial insects, a wide range of species (41 species) was detected on a total of 97 occasions, but the citizen scientists only accurately identified the species name in 21.6% of cases. There were also 10 cases where the citizen scientists only recognized that the target was a land insect, but could not guess the name. Regarding the taxonomic levels, the citizen scientists were able to recognize 20 genera, 26 families, and 37 orders, indicating that, for citizen scientists to accurately identify insects at the species level, in-depth education, through various media, about insect morphology and classification methods is necessary (Table 4).

As citizen scientists who participated in this research were not the experts who majored in biology or ecology

Table 3 Species identification accuracy rate for each taxonomic group

Accuracy rate	Vegetation	Land insects	Mammals
Correct (case [%])	83 (98.8)	21 (21.6)	8 (66.7)
Incorrec (case [%])	1 (1.2)	76 (78.4)	4 (33.3)
Total (case [%])	84 (100)	97 (100)	12 (100)

Table 2 Data registration results from citizen science research activities according to surveyed taxonomic group

Category	Vegetation	Land insects	Mammals
Number of species	Nine species (*Sicyos angulatus, Ambrosia artemisiifolia, Solanum carolinense, Solidago altissima, Lespedeza bicolor, Metaplexis japonica, Euryale ferox, Nymphoides indica, Symplocos paniculata*)	41 species (*Coccinella atomaria*, etc.)	Four species (*Lutra lutra, Hydropotes inermis, Prionailurus bengalensis, Sus scrofa*)
Approved cases (approval rate [%])	84 (97.7)	97 (75.0)	12 (90.7)
Registered cases	86	107	16

Table 4 Number of accurate cases for land insects according to taxonomic level

	Species	Genus	Family	Order	Taxon
Number of cases	21	20	26	37	10

and were in their initial step to citizen science research, classification accuracy broadly relied on the quantity of species in each taxa (based on the nationallistof species of Korea in 2023, registry was shown as 20,710 species for insects, 4,641 species for vascular plants, and 125 species for mammals). In this study, target species of insect were not constraint while plants and mammals were set as invasive alien plants and footprint or excrement of mammals. Decisively, lower accuracy of citizen scientists' classification for insects mainly comes from lack of knowledge and technique that professional scientists have to tell apart morphology and scientific name for the species.

To improve the expertise of citizen scientists, in the future, it will be critical to provide training using various approaches, including sharing the results of wetland insect surveys, making and distributing educational materials, and providing field training through professional surveyors.

Discussion

Citizen scientists' survey capabilities and data accuracy

Our findings indicated that citizen scientists demonstrated a better ability to accurately identify species names when there were fewer target species (invasive alien plants: when the target species were present; mammals: when the target species were absent), and when they had received more education about the target species using various media. Although citizen scientists with semi-professional capabilities might be able to conduct accurate surveys, most citizen scientists, who are in the early stages of learning, find accurate recognition of species more complicated when there are a larger number of target species, for instance, the identification of terrestrial insects in this survey.

In the future, to improve the accuracy of citizen scientist surveys, we should first consider the method of setting a limited number of target species, depending on the abilities of the citizen scientist group, and then gradually expand the number of target species over time. One option is to allow citizen scientists with semi-professional ability to survey various species, while citizen scientists who are still learning could be given a smaller set of target species, along with sufficient theoretical and practical training before starting the survey, and then expanding the number of target species based on their survey accuracy. Second, citizen scientists will need to improve their capabilities concerning recognizing taxonomic groups where they have had relatively little opportunity to learn about accurate species names and life cycles. Through linkage with taxonomic groups, like plants, that they have commonly encountered in real life and learned the names of, citizen scientists should be provided opportunities to learn, through various media, about the ecological characteristics of terrestrial insects and mammals that intake related plants as food sources or habitats. Third, there should be mutual communication between the citizen scientists and the experts who make the final species identification based on the survey results. The experts who participate in species identification check the data uploaded to EcoBank by the citizen scientists, identify differences in the capabilities of citizen scientists during the process of rejecting/correcting/approving the data, and learn about the types of misidentification. Given their expertise, these professionals are well-suited to educate citizen scientists about potential survey errors for each taxonomic group. They can also engage in discussions with citizen scientists to highlight common errors to be mindful of during surveys and collaborate on strategies to enhance classification accuracy.

Measures to improve accuracy by strengthening citizen scientists' capabilities

The goal of training to enhance the capabilities of citizen scientists extends beyond the collection of accurate data for the wetland surveys and the study sponsor. It should also cater to the individual interests and learning requirements of citizen scientists regarding wetland ecosystems and organisms, ultimately enhancing their self-efficacy. It is crucial to boost the self-efficacy of citizen scientists by enabling them to expand their knowledge of species and their abilities to collect accurate data resulting in an increased rate of approval by experts and agreement with experts in species classification. This can be achieved by demonstrating how their surveyed data contributes to solving problems in the local environment and ecosystems. To obtain accurate survey data, this training should include not only knowledge about ecological characteristics, such as life cycles of wetland organisms and species classification but also techniques for uploading photographs to EcoBank (e.g., how to take photographs that capture sufficient species information to enable expert identification). Training to enhance the capabilities of citizen scientists should cover all stages of the survey, including improving knowledge about species and training survey methods before starting the survey. Additionally, consistent communication with experts during the survey (e.g., feedback on survey results through rejection or approval of species identification on EcoBank) and sharing of research results and practical outcomes after the survey are crucial aspects to be incorporated (Fig. 5).

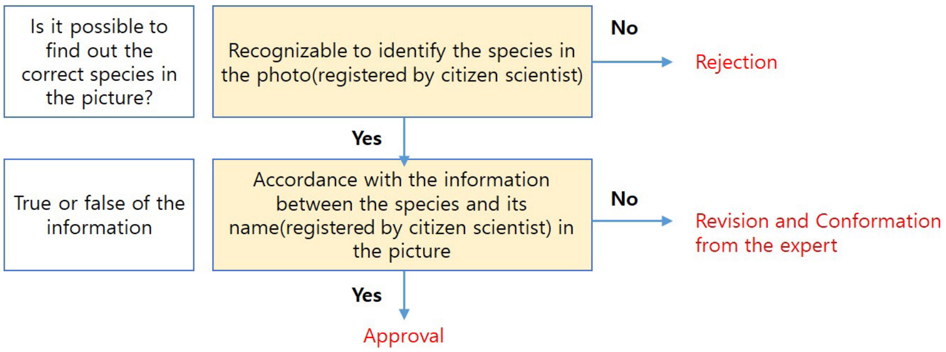

Fig. 5 The process of expert's identification of species.

Conclusions

Citizen science research using the cooperative network of wetland protection areas has the advantage that it allows the yearly collection of precise survey data from inland wetlands, which are currently surveyed by the Ministry of Environment every five years. Ecological surveys using citizen science research methodologies enable the collection of data from various times and locations, due to citizens living nearby who have good access to the survey region. However, for the meaningful analysis and utilization of this survey data, a substantial amount of accurate data needs to be collected. In this study, we proposed the need for the appropriate division of labor (outside the citizen scientist group) to maximize the strengths of citizen scientists and survey experts (citizen scientists take photographs of species at various times and locations and upload these to an integrated information platform, where experts perform species identification based on the uploaded data), and for adequate training to enhance the capabilities of the citizen scientists during each stage of the survey. In the case of amateur individuals participating in citizen science research activities, training before the survey should incorporate knowledge of species and survey methods to enhance their ability to accurately identify species through feedback from experts. These experts would correct the data uploaded to EcoBank, during the survey, and, after the survey, to improve expertise by examining invasive alien plant distribution maps or educational material on the species based on the data collected from the wetland protection areas by citizen scientists. Wetland surveyors could also help train new surveyors in the long term by participating in training and citizen science research activities and improving citizen scientists' ecological surveying capabilities. In this study, the accuracy of species identification based on taxonomic groups, by citizen scientists in the first year of research showed considerable variation, ranging from 21.6% to 98.8%. However, when the same citizen scientists are trained through participation in research activities in the long run and undergo repeated learning, they can be anticipated to generate high-quality data with enhanced accuracy. By contributing these data toward the formation of national regional ecological policies, citizen scientists can contribute to improving their self-efficacy.

Abbreviations
Not applicable.

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Authors' contributions
IY designed the study, carried out the fieldwork, and wrote the manuscript. KC conducted the field survey, performed the analysis. YC and SH assisted with data collection. PK assisted with data collection and revised the manuscript.

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Availability of data and materials
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Competing interests
The authors declare that they have no competing interests.

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