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Study of Distribution and Seasonal Variation of Exotic Plant Species in Downstream Tamagawa Riparian Areas Using A Mobile Application and Citizen Science

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ABSTRACT

Exotic plant species are highly fertile in riparian areas and are biologically invasive. In recent years, there has been an increasing need to understand the effect of invasive exotic plant species on the water cycle and biodiversity. It is important for citizens to understand the ecological disturbances caused by invasive exotic plant species, so that they can cooperate and contribute in restoration ecology and conservation biology. However, at present, there are few opportunities for citizens and younger generations to understand the invasive exotic plant species distributed in riparian areas. Since 2017, we have developed and conducted a citizen science program based on information and communication technology (smart phone, mobile application, and operations dashboard for ArcGIS) in the riparian areas of the downstream Tamagawa River and Nogawa River in the Tokyo metropolitan area. Two specific invasive alien species, five alien species under consideration because of ecological disturbance, and three naturalized species were found distributed in the study area, with some annual and seasonal variation. We believe that wide-area and continued citizen science programs can be developed and practiced with the use of mobile applications. The utilization of citizen science data will contribute to the restoration and conservation of aquatic environment and biodiversity.

Key words : *Exotic plant species, Citizen Science, Mobile application, Nogawa River, Riparian area, Tamagawa River*

Introduction

The spread of alien species has been reported to be a major cause of biodiversity loss (Porter and Savignano, 1990; Mills *et al*., 1994; Nakamura, 1994; Ohba, 1996; Wilcove *et al*., 1998; Chapman *et al*., 2003; Davis, 2003; Primack and Kobori, 2008). In recent years, the number of alien species in Japan has reached 2,332, with exotic plant species accounting for majority of them (Ecological Society of Japan, 2002; Shimizu, 2003; Uemura *et al*., 2015). As exotic plant species tend to spread through rivers, they are widely distributed in riparian areas (Yonemori and Kuramoto, 1999; Miyawaki and Washitani, 2004; Muranaka and Washitani, 2006; Hatase *et al*., 2013; Sakio, 2015). However, the overall situation of exotic plant species in riparian areas is not yet fully understood. This is because of limitations of human resource, time, and financial support in national census data as well as limited research. We have developed a new citizen science method to improve citizen science (CS) program.A large amount of highly accurate data using information tools has been generated since 2015 which can supplement the data of

researchers and governments. The definition of "Citizen Science" is accepted globally as "Citizens involved and organized in scientific research processes" (Shirk *et al*., 2012). Citizen science has recently evolved into a new discipline. The Cornell Lab of Ornithology (CLO) at Cornell University in the United States has been a leader since 1980 and has become a hub in citizen science. In recent years, there have been cases in Japan where citizen groups, such as nonprofit organizations (NPOs), conducted surveys in collaboration with governments, companies, and universities (Ogura, 1987; Hanya and Ogura, 1995; Ogura and Kura, 2001; Executive Committee of Water Environment Map, 2004-2019; Ogura, 2004; Ogura *et al*., 2005; Tanno *et al*., 2006; Komatsu *et al*., 2015; Kato *et al*., 2016; Kobori *et al*., 2016; Komatsu *et al*., 2016; Sayama, 2016). In this study, we report the results of a citizen science program targeting exotic plant species using information and communication technology (smartphones, mobile applications, and operations dashboards for ArcGIS) from 2017 to 2019.

Materials and Methods

Study area

The study area is located in Setagaya Ward in the Tokyo Metropolitan area, which has the largest population (approximately 940,000) and the second largest area (approximately 58 km^2) in Tokyo in 2020. As shown in Figure 1, the four sections in the survey area were selected as follows: the right riparian area of downstream Nogawa River (Section A), the left riparian area of downstream Tamagawa River (Section C), and the confluence area of Tamagawa River and Nogawa River (Section D). The Nogawa River is one of the tributaries of the Tamagawa River, which is the largest river in the Tokyo metropolitan area. The participants of this citizen science program gathered at the Tokyo City University Yume Campus, which is a 1-min walk from the Futakotamagawa Station, and about a 10-min walk to the study area.

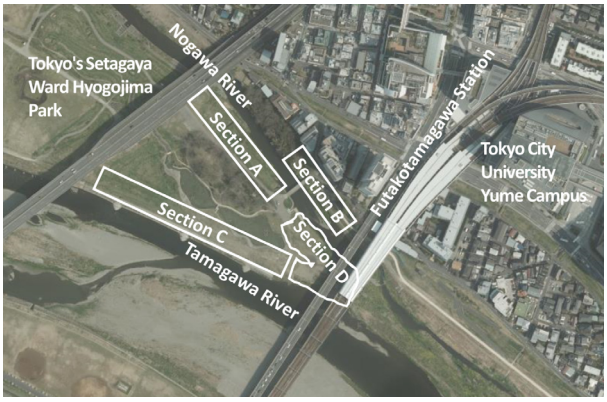

Fig. 1. The description of study areas (Background image map data downloaded from Yahoo! Maps).

In 2021, the annual average air temperature was 16.6 °C with a monthly average of maximum 27.4 °C inAugust and minimum 5.4 °C in January (Japan Meteorological Agency, 2022). In the same year, the annual precipitation was 1895 mm with maximum of 364 mm in the month of August and minimum of 42.5 mm in the month of January (Japan Meteorological Agency, 2022).

Citizen science program

As shown in Table 1, this citizen science (CS) program was developed and conducted with several citizen groups, university researchers, university students, and companies. This citizen science program was planned such that the data collected by the participants using smartphone was processed and the results were visualizedon the map immediately after the survey. The results would contribute to citizen science, environmental education, and regional information, among other advantages. To initiate the citizen science program, we held an organizer meeting with faculty members of the University, Tamagawa Town Association members, regional area management members, general corporation members, NPO members, and graduate and undergraduate students. The citizen science program was hosted by the General Incorporated Association of Biodiversity Academy and the NPO Setagaya Waterside Design Network, and was supported by the Tokyo City University Yume Campus. The citizen science program was carried out in months of May (spring) and October (autumn) from 2017 to 2019.

In this study, exotic plant species which fulfilled the following three conditions were selected for the CS program: 1) the flowers were in bloom, 2) wide distribution of the plant in the survey area, and 3) easy to identify forthe citizens. In spring, red clover (*Trifolium pratense*), rose evening primrose (*Oenothera rosea*), burr cucumber (*Sicyos angulatus*), water speedwell (*Veronica anagallis-aquatica*), ribwort plantain (*Plantago lanceolata*), Brazilian vervain (*Ver-*

bena brasiliensis), and hairy vetch (*Vicia villosa*) were investigated in the CS program. Hairy vetch (*Vicia villosa*) was only investigated in the spring of 2019. In autumn, burr cucumber (*Sicyos angulatus*), Brazilian vervain (*Verbena brasiliensis*), giant ragweed (*Ambrosia trifida*), Devil's beggartick (*Bidens frondosa*), tall flatsedge (*Cyperus eragrostis*), and rose evening primrose (*Oenothera rosea*) were investigated. In Japan, the burr cucumber (*Sicyos angulatus*) and water speedwell (*Veronica anagallis-aquatica*) are designated as specific invasive alien species (Japanese Ministry of the Environment, 2022). In addition, Brazilian vervain (*Verbena brasiliensis*), giant ragweed (*Ambrosia trifida*), tall flatsedge (*Cyperus eragrostis*), devil's beggartick (*Bidens frondosa*), and hairy vetch (*Vicia villosa*) have been designated as alien species under consideration because of ecological disturbances (Japanese Ministry of the Environment, 2022). In the CS program, the participants were asked to download a mobile application of GeoForm (Esri Japan Corporation) dedicated to the citizen science program on their smartphones. In the mobile application, entries were made for the selected species name, and the following data were collected for the exotic plant species community: length (in m), width (in m), average height (in m), and coverage rate (in %). Then, a photograph data of the target plant, the date and time, and the location information were collected using the mobile application Geo Form (Esri Japan Corporation). The participants could immediately visualize the data on the map and shared the information with an operation dashboard for ArcGIS (Esri Japan Corporation) dedicated to the CS program. The General Incorporated Association of Biodiversity Academy and Esri Japan Corporation have developed the mobile application (for smartphones) of the citizen science program in 2016. The General Incorporated Association of Biodiversity Academy has developed the method for investigating alien species by citizen science. The Esri Japan Corporation has collected and visualized citizen science program data using an operations dashboard for ArcGIS (Esri Japan Corporation).

Data quality control

We verified the CS data using the source image data and location information data in the operations dashboard for ArcGIS (Esri Japan Corporation). Outlier data with extremely high or low values were excluded from the dataset. All statistical analyses were performed using IBM SPSS Statistics 19.0, IBM Corporation) for Windows.

Results and Discussion

Development and conduct of citizen science program

Table 2 shows the details of the citizen science programs conducted in spring and autumn from 2017 to 2019. The total number of participants was 375, the total number of citizen science data was 1,304, and the total number of available citizen science data was 1,056 (about 80%). It is probable that pretraining and briefing of citizen science program, color photographic handouts for identifying exotic plant species, participation of experts, and participation of those who have experienced this program more than once contributed to the highpercentage (around 80%) of available citizen science data. In 2017, the age groups of the participants were balanced as follows: teenagers and between 20-–30 years old (42%), between 30–50 years old (36%), and >50 years old (22%). There was almost equal participation of females (53%) and males (47%).The participants belonged to various social groups as follows: students (34%), office workers (21%), housewives (18%), self-employed (8%), administrative staff (3%), and others (16%). There were more participants

Table 1. Organization of the citizen science program.

Participant type	Name of Organization
Citizen group	• General Incorporated Association of Biodiversity Academy • NPO Setagaya Waterside Design Network • Tamagawa Town Association • General Incorporated Association of Futakotamagawa Area Management
Researcher	Tokyo City University, Keio University
Student	Tokyo City University, Keio University
Company	Esri Japan Corporation´0Hakone Ueki Landscape Construction Co. Ltd.
Cooperation	Tokyo City University Yume Campus

from other areas than from Futakotamagawa and Setagaya Ward: 13% were local residents of the place where the citizen science program was conducted, 26% were residents of Setagaya ward, and 61% were residents of other places. In addition, 42% of participants were well aware of this citizen science program and 34% were experienced participants who participated more than once. Therefore, in order to continue this citizen science program, it is necessary to strengthen public relations activities, creating motivation and interests.

Visualization of citizen science data

As shown in Figure 2, the survey data of citizen participants were collected and visualized on a map using an operations dashboard for ArcGIS (Esri Japan Corporation) dedicated to the citizen science program, which was supported by Esri Japan Corporation. The operations dashboard for ArcGIS (Esri Japan Corporation) provides GIS maps and graphic data for the exotic plant species of the CS program with transmission time data, location information data, exotic plant species names, photo data, community length, community width, community average height, and community coverage rate. Giant ragweed (*Ambrosia trifida*) and hairy vetch (*Vicia villosa*), which are designated as alien species under considerationbecause of ecological disturbance (Japanese Ministry of the Environment, 2022), and rose evening primrose (*Oenothera rosea*) and ribwort plantains (*Plantago lanceolata*) were observed in the Nogawa River sections (Sections A and B, both of which are close to a natural type of riparian with a lot of soil) in the spring of 2019 (Figure 2). In addition, Brazilian vervain (*Verbena brasiliensis*), which is designated as an alien species under consideration because of ecological disturbance (Japanese Ministry of the Environment, 2022), accounted for approximately 80% of the survey area exotic plant species community coverage rate in the Tamagawa River section (Section C, which is close to an artificial concrete type of riparian) in the spring of 2019 (Figure 2). There was a large difference in the distribution rate, exotic plant species, and riparian environment between the Nogawa River sections (Sections A and B) and the Tamagawa River section (Section C) (Figure 2). The Brazilian vervain (*Verbena brasiliensis*) in the Tamagawa River section showed a peculiarity of preferring places where the river is susceptible to flooding and inundation during heavy rainfall, and where it is generally difficult for plants to grow. In addition, even though the confluence section (Section D) of the downstream Tamagawa River and Nogawa River is close to a natural riparian with a large amount of soil, most exotic plant species were observed in Section D, which is geographically susceptible to the influence of the Tamagawa River and Nogawa River (Figure 2).

Annual and seasonal variation of exotic plant species

In the spring of 2017, 2018, and 2019, a water speedwell (*Veronica anagallis-aquatica*), which is designated as a specific invasive alien species, was widely observed in the Nogawa River sections (Sections A and B) and the confluence section (Section D) of the downstream Tamagawa River and downstream Nogawa River (Figure 3). In the autumn of 2017 and 2018, burr cucumber (*Sicyos angulatus*), which is also designated as a specific invasive alien species, was predominantly distributed in the Nogawa River sections (Sections A and B). In contrast, the water speedwell (*Veronica anagallis-aquatica*) community area tended to decrease in the spring of 2019 compared to that in the spring of 2017 and 2018 (Figure 3).

The Brazilian vervain (*Verbena brasiliensis*), designated as an alien species under consideration be-

Table 2. Details of the citizen science program.

Period	Number of participants	Number of survey data	Number and percentage of available data	Number of programs	Data management
Spring of 2017	40	278	245 (88%)	2 times	Removed outliers
Fall of 2017	50	126	120 (95%)	1 time	Removed outliers
Spring of 2018	110	485	330 (68%)	1 time	Removed outliers
Fall of 2018	76	243	221 (91%)	1 time	Image data verification
Spring of 2019	99	172	140 (81%)	1 time	Image data verification
Total	375	1,304	1,056 (81%)	6 times	

Fig. 2. Exotic plant species distribution in downstream Tamagawa River and Nogawa River riparian areas determined using an information and communication technology (smartphone, mobile application, operations dashboard for ArcGIS supported by Esri Japan Corporation).

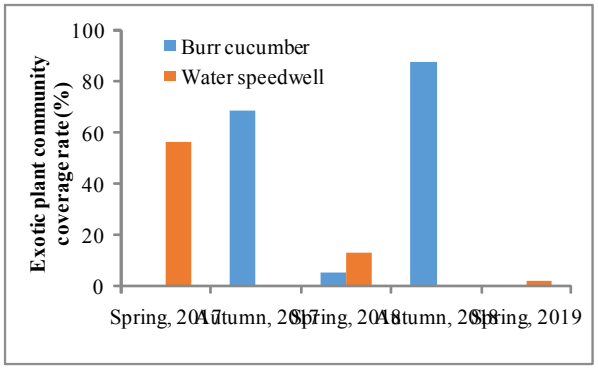

Fig. 3. Annual and seasonal variation of specific invasive alien species in the survey area.

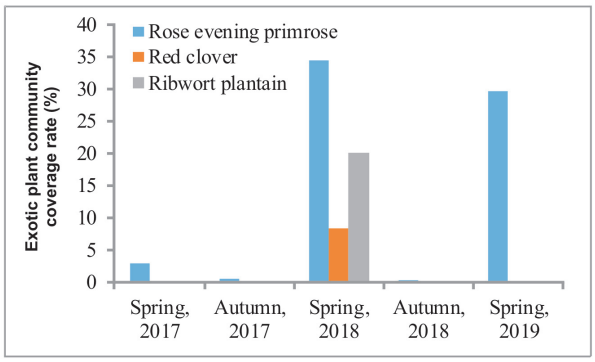

Fig. 5. Annual and seasonal variation of naturalized species in all survey areas.

cause of ecological disturbance, was widely distributed in the left riparian section (Section C) of the Tamagawa River in spring and autumn (Figure 2 and 4). However, the Brazilian vervain (*Verbena brasiliensis*) community coverage rate decreased annually (Figure 4). In addition, hairy vetch (*Vicia villosa*) showed the highestcommunity coverage rate for analien species under considerationdue to ecological disturbance in all survey sections, even though it was surveyed only in the spring of 2019 (Figure 2 and 4).

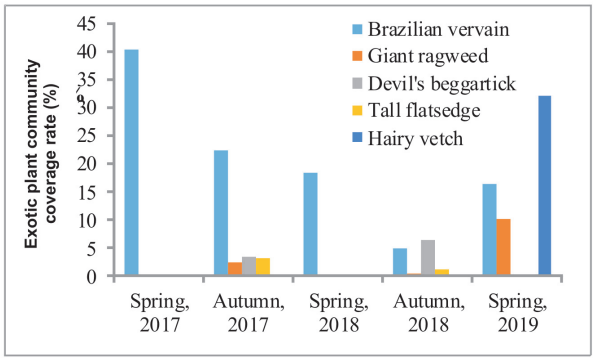

Fig. 4. Annual and seasonal variation of alien species under consideration because ofecological disturbance in the survey area. Hairy vetch was investigated only in the spring of 2019.

As shown in Figure 5, the rose evening primrose (*Oenothera rosea*) community coverage rate was abundantly distributed, mainly in spring, and there was a small annual change between the spring of 2018 and 2019. In addition, the community coverage rate of rose evening primrose (*Oenothera rosea*) increased significantly in spring of 2018 and 2019 compared with that in spring of 2017 (Figure 5).

Conclusion

In this citizen science program, the participants followed seven steps described as follows: 1) finding issues and setting themes; 2) gathering information such as past research; 3) discussing research plans

and survey methods; 4) monitoring surveys; 5) summarizing data; 6) analyzing data; and 7) presenting and sharing results. This CS program made it possible to share the purpose and results with citizen participants. By introducing information and communication technology, it was possible to visualize the distribution of exotic plant species in the survey section. The main conclusions are as follows:

(1) We have developed and improved a citizen science program, a mobile application of GeoForm, and an operations dashboard for ArcGIS.
   - To successfully conduct this citizen science program,it made use of a mobile application, color photographs to identify exotic plant species, briefing session, on-site rehearsals, placement of leaders and supporters in each section, and participation of experienced people.
   - In this citizen science program, a briefing session, result presentation, and discussion were held at the Tokyo City University Yume Campus, which is a 1-min walk from the Futakotamagawa Station. In addition, the survey area is about a10-min walk from Futakotamagawa Station. Consequently, this study is supporting that easy access is an important factor for the establishment of a citizen science program.
   - The mobile application of GeoForm was developed and improved such that even elementary school students can make use of it.
   - The operations dashboard for ArcGIS was able to aggregate citizen science data and provide graphs and map data on the distribution of exotic plant species in real time.

(2) The annual and seasonal fluctuations from 2017 to 2019 could be analyzed under the data quality control that we excluded outlier data and verified the all data using the source image data and location information data. Consequently, this study is supporting that the data quality control is also an important factor in the establishment of citizen science programs.

(3) It is expected that the widearea covered and continued citizen science data collected in this study will contribute to the restoration and conservation of the aquatic environment and biodiversity in the study area.

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