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Possibility of applying unmanned aerial vehicle (UAV) and mapping software for the monitoring of waterbirds and their habitats

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Abstract

Background: Conventional bird observation methods are line survey or point count method by bare eyes or through binoculars or telescopes. But in this study, the possibility of monitoring waterbirds using drones beyond the conventional research methods was explored. It also describes the direction of producing and accumulating images of waterbird habitats as a method to efficiently determine changes in waterbird habitats.

Results: From the study, it was concluded that waterbird monitoring using drones was a new monitoring technique which could be applied to the field and 26 kinds of waterbirds were observed. In the case of a drone with a single lens, it was difficult to identify objects because the size of the subject was too small at a certain altitude. In this case, zoom lens can be an alternative. It has also been verified that image analysis software can be used to accumulate images of waterbird habitats.

Conclusions: If various kinds of advanced drones and cameras are used, it would be possible to monitor larger areas including the areas that are difficult for human access and to observe more waterbirds and wider habitats.

Keywords: UAV, Drone, Water bird, Monitoring, Habitat, Image, Mapping software

Background

This study explored the possibility to apply drones as a method to monitor waterbirds and their habitats in the Upo wetland in Korea. As wetland is ecologically located at the border between the terrestrial ecosystem and aquatic ecosystem, it is considered to be a habitat with high biodiversity and important ecological functions (Bernard and Tuttle 1998). The Upo wetland, the subject area of this study, was registered as a wetland in 1998 by the Ramsar Convention, and it has been managed as wetland preservation area by the Ministry of Environment of Korea since 1999. Additionally, as it has fewer damages out of development than any other wetland, it provides stable habitat and shelter to a variety of waterbirds including winter visitors. Birds in the Upo wetland were mainly surveyed by Kang and Hahm (1997) and Kim (2001). In particular, Kim (2001) surveyed and reported 133 species of birds. However, as those studies were performed through classical observation methods such as line survey or point count method by bare eyes or with binoculars and telescopes (Bibby et al. 2000), they are different from this study which uses drones. From the perspective of the results, they are fundamentally different from this study as they include general bird species as well as waterbirds.

Recently, applications of drones to wild animal monitoring have been rapidly increasing worldwide (Christie et al. 2016; Ivosevic et al. 2015; 2017; Jones et al. 2006; Koh and Wich 2012; Linchant et al. 2015). In particular, monitoring studies targeting birds that are physically difficult to access or susceptible to human interference have been constantly made using drones (Hodgson et al. 2016; Sarda-Palomera et al. 2012).

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Fig. 1 Survey sites in the Upo wetland

As described above, surveys on birds in the Upo wetland have been made many times for the time being but interest in environmental changes of habitats affecting bird communities was not very high. Accordingly, in this study, it was tried to discuss storing and accumulating data on environments of habitats or resting place of waterbirds as well as monitoring waterbirds using drones.

In this study, a few commonly used rotary drone models were selected to monitor waterbird community and habitat. In this study, appropriate shooting criteria were proposed according to targets by changing camera and flight method depending on the subject of observation (waterbird community or habitat) and the monitoring possibility of waterbird using drones was reviewed. Additionally, it was tried to describe how to make and store various images such as orthomosaic images using image analysis software in order to quickly and accurately determine changes in habitats.

Table 1 Main specifications of drones (cameras) used in this study

		Phantom 2 Vision +	Inspire 1	Phantom 4	Zenmuse Z3 (camera)
Weight		1242 g	2395 g	1380 g	–
flight time		About 25 min	About 18 min	About 28 min	–
Operating distance (from remote controller)		0.4–0.8 km	3.5–5 km	3.5–5 km	–
Max flight speed		15 m/s (not recommended)	22 m/s (ATTI mode, no wind)	20 m/s (S-mode)	–
Max flight altitude		About 762 m	4500 m	6000 m	–
Camera spec.	Sensor	1/2.3″	1/2.3″ CMOS	1/2.3″ CMOS	1/2.3″ CMOS
	Lens	20 mm (guessed) f/2.8	20 mm (35 mm format equivalent) f/2.8 focus at ∞ 9 Elements in 9 groups Anti-distortion	FOV 94° 20 mm (35 mm format equivalent) f/2.8 focus at ∞	×3.5 optical zoom, 22–77 mm equivalent F2.8 (Wide–F5.2 (Tele)
	FOV	110°/85°	94°	94°	92° (Wide)–35° (Tele)
	ISO range	100–400 (photo)	100–3200 (video) 100–1600 (photo)	100–3200 (video) 100–1600 (photo)	100–3200 (video) 100–1600 (photo)
	Image size (photo resolution)	4384 × 3288	4000 × 3000	4000 × 3000	4:3 L: 12 M, 4000 × 3000 16:9 L: 9 M, 4000 × 2250
	Effective pixels	14 M	12.4 M	12.4 M	12.4 M
	Video recording (video resolution)	HD: 1080 × 720 30p	UHD (4K): 4096 × 2160 24/25p, 3840×2160 24/25/30p FHD: 1920 × 1080 24/25/30/48/50/60p HD: 1280 × 720 24/25/30/48/50/60p	UHD: 4096 × 2160 (4K) 24/25p, 3840 × 2160 (4K) 24/25/30p, 2704 × 1520 (2.7K) 24/25/30p FHD: 1920 × 1080 24/25/30/48/50/60/120p HD: 1280 × 720 24/25/30/48/50/60p	UHD: 4K (4096 × 2160) 24/25p, 4K (3840 × 2160) 24/25/30p 2.7K (2704 × 1520) 24/25/30p FHD: 1920 × 1080 24/25/30/48/50/60p
	Note	This camera is dedicated to this model	This camera is dedicated to this model	This camera is dedicated to this model	This camera can be mounted on and detached from Inspire 1

Methods

Survey area and time

The survey area was the Upo wetland located in Changnyeong-gun, Kyungsangnam-do province in Korea. The area with abundant waterbird population was selected as a subject area (Fig. 1), and photos were taken 38 times in total from May 2015 to December 2016 including four seasons to identify diverse migratory birds and resident birds.

Survey method

To observe the waterbird communities and their habitats in the Upo wetland and to identify suitable drones and cameras, photos were taken using drones such as Phantom 2 Vision+, Inspire 1, and Phantom 4 (DJI, China) and cameras such as Zenmuse ×3 and Zenmuse Z3 (DJI, China). Detailed specifications of drones and cameras used for the survey are shown in Table 1. Waterbird observation results were also recorded in video form at various altitudes through manual flight of the aforementioned drones, and habitat status observation results were collected in the form of photographs through automatic flight according to the flight path setting (Fig. 2).

Analysis method

Videos of the waterbirds taken in the field were identified and classified by a bird expert on the monitor. Based on the identification and classification results, list of waterbird species was created. The aerial photos of the waterbird habitat taken in the field were edited using photogrammetry software such as Pix4Dmapper Pro (Pix4D, Switzerland) and PhotoScan Professional (Agisoft, Russia). As the aforementioned two programs can be set to capture images by superimposing the images themselves using GPS coordinates, a single image can be produced and orthomosaic images can be produced through geometric correction by automatic air trigonometry (Siebert and Teizer 2014; Lee and Choi 2015). Habitat data are stored and managed in the form of images through these techniques.

Results and discussion

Identification of waterbird community through manual flight of drones and exploration of possibilities

As the result of surveys on waterbird communities in the Upo wetland using a camera mounted on drones, a total of 26 species of waterbirds including *Cygnus Cygnus,* a natural monument and grade II endangered wildlife were identified (Table 2). In case of Phantom 2 Vision+, Inspire 1, and Phantom 4 (DJI, China) equipped with 20-mm single-lens camera, it was difficult to identify species of waterbirds as waterbird subjects for photography were too small in the photos when they were taken at the altitude where waterbirds are not disturbed from the drones' flight (at least 30 m in altitude). When the altitude of the drone is less than 25 m, most of waterbirds were found to be disturbed or interfered with by flying drones and they flew into the air or moved quickly over the surface. In particular, *Anser fabalis*, a typical winter bird, showed a tendency to react more sensitively than other species. There was a situation that they might collide with a drone when they soared up to the sky. However, Zenmuse Z3 (DJI, China) that can be mounted on the Inspire 1 has built-in ×3.5 optical zoom function and it was possible to enlarge the size of the subject for species identification. In addition, it was possible to enlarge the subject up to

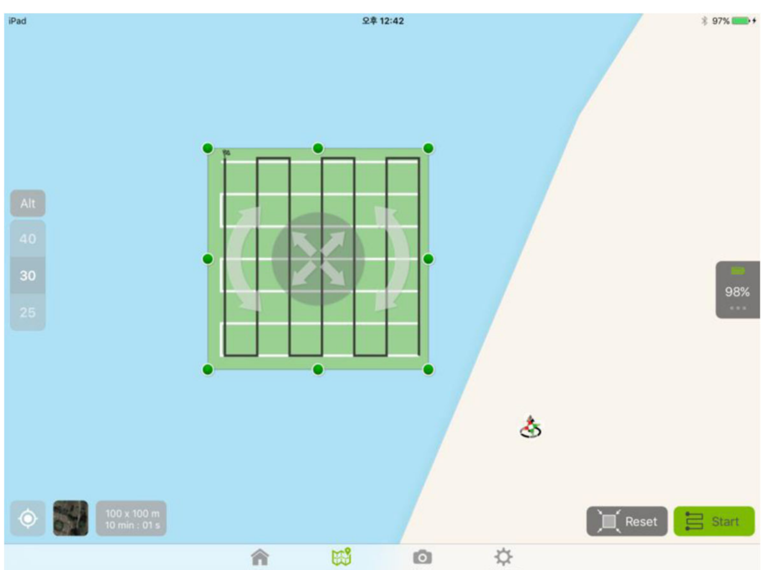

Fig. 2 An example of automatic flight route selection

Table 2 List of water birds identified by drones in the Upo wetland

No.	Scientific name	S1	S2	Maximum number of individuals
1	*Tachybaptus ruficollis*	2	1	2
2	*Podiceps cristatus*		2	2
3	*Cygnus cygnus*	220	50	220
4	*Anser fabalis*	1500	30	1500
5	*Anas crecca*	100	30	100
6	*Anas platyrhynchos*	500	150	500
7	*Anas acuta*	6	12	12
8	*Anas poecilorhyncha*	300	120	300
9	*Anas clypeata*	40	2	40
10	*Fulica atra*	1500	40	1500
11	*Gallinula chloropus*		7	7
12	*Egretta garzetta*	8		8
13	*Ardea cinerea*	20	5	20
14	*Ardea alba*	35	15	35
15	*Egretta intermedia*	3	12	12
16	*Himantopus himantopus*	2		2
17	*Corvus macrorhynchos*	2		2
18	*Phalacrocoracidae spp.*	10		10
19	*Threskiornithidae spp.*	11		11
20	*Geese spp.*		40	40
21	*Ducks spp.*	2000	300	2000
22	*Small size ducks spp.*	10	30	30
23	*Scolopacidae spp.*	5		5
24	*Charadriidae spp.*	5		5
25	*Laridae spp.*	1		1
26	*Motacillidae spp.*		2	2
No. of species		22	18	26
No. of individuals		6280	585	4042

7 times using digital zoom (×2) on the screen. Accordingly, it was found that Zenmuse Z3 camera could shoot at a level allowing accurate identification even when it took photos at the altitude that would not give any stress to waterbirds (Fig. 3).

Although in this study various kinds of drones and cameras were used for shooting, subjects that could not be identified because it was taken too small were excluded from the study. Furthermore, there were some times when photos were not taken due to weather conditions and occurrence of avian influenza (AI). It seems that species diversity is lower than previous studies because of aforementioned reasons. Additionally, as camera lens of Phantom 2 Vision+ is made to provide a wider angle of view, it made distortion of the edge of the screen unlike Phantom 4 or Inspire 1.

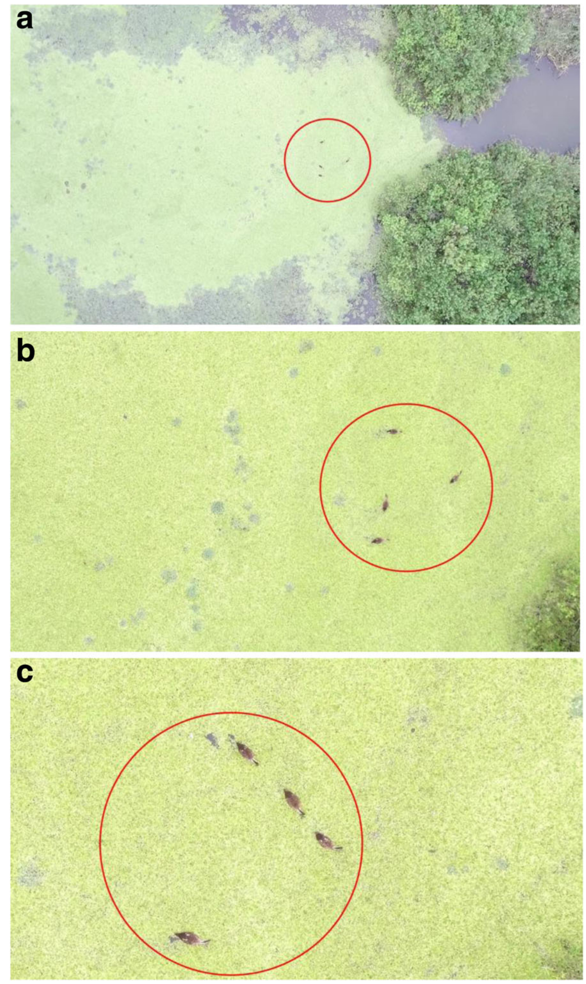

Fig. 3 Images of *Anas poecilorhyncha* photographed with a Zenmuse Z3 camera on Inspire 1. **a**. Resolution 1920 × 1080 (60p), shooting altitude 40 m, camera angle 90°, lens zoom: none (It is difficult to identify species). **b**. Resolution 1920 × 1080 (60p), shooting height 40 m, camera angle 90°, lens zoom ×3.5 (optical) (It is possible to identify species). **c**. Resolution 1920 × 1080 (60p), shooting height 40 m, camera angle 90°, lens zoom ×3.5 (optical), ×2 (digital) = ×7 (It is easy to identify species)

Acquisition and accumulation of images of habitats through automatic flight of drones

We have collected photos of subject site through automatic flight in order to accumulate image data of waterbird habitat, and photos were taken in every survey with waterbird community monitoring to easily identify seasonal changes. At the same time, we tried to identify the most appropriate shooting options by varying the conditions of shooting options. For example, on August 17, 2016, 163 photos were collected using Inspire 1 (Zenmuse ×3 camera) at the altitude of 40 m through double grid mission. Details of photo-taking options are shown in Fig. 4. From the collected 163 images, a high-resolution orthomosaic image was produced through

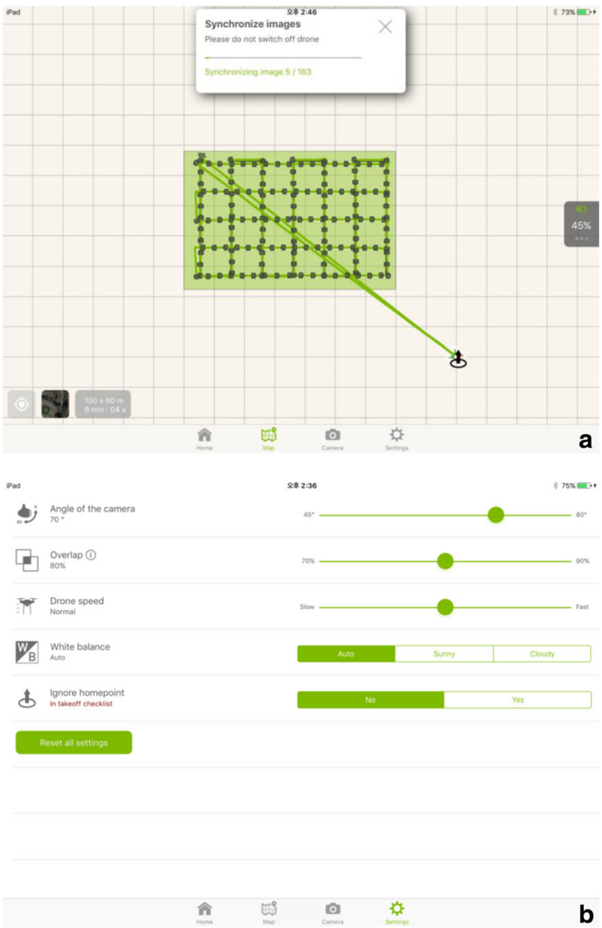

Fig. 4 Example of automatic flight path (**a**) and photo shooting conditions (**b**) to collect images of waterbird habitat

image analysis software such as PhotoScan Professional (Agisoft, Russia) or Pix4D mapper Pro (Pix4D, Switzerland) (Fig. 5). Photographs stored and managed as such can be used more efficiently to identify waterbird habitat environmental factors. It is considered that they may be useful for long-term ecological monitoring to observe changes according to space and time.

Additionally, it was found that image files generated by image analysis software are superimposed on a relatively accurate location of Google Earth through the GPS coordinate system (Fig. 6), and that the resolution is higher than the surrounding images captured by the satellite. In addition, it is difficult to quickly respond to various environmental changes such as habitat destruction as satellite images are large in size and cannot be updated in real time because of relatively longer shooting interval. On the other hand, the results of aerial photographs using drones can be great help in monitoring small-scale areas as they can be collected and processed quickly when needed.

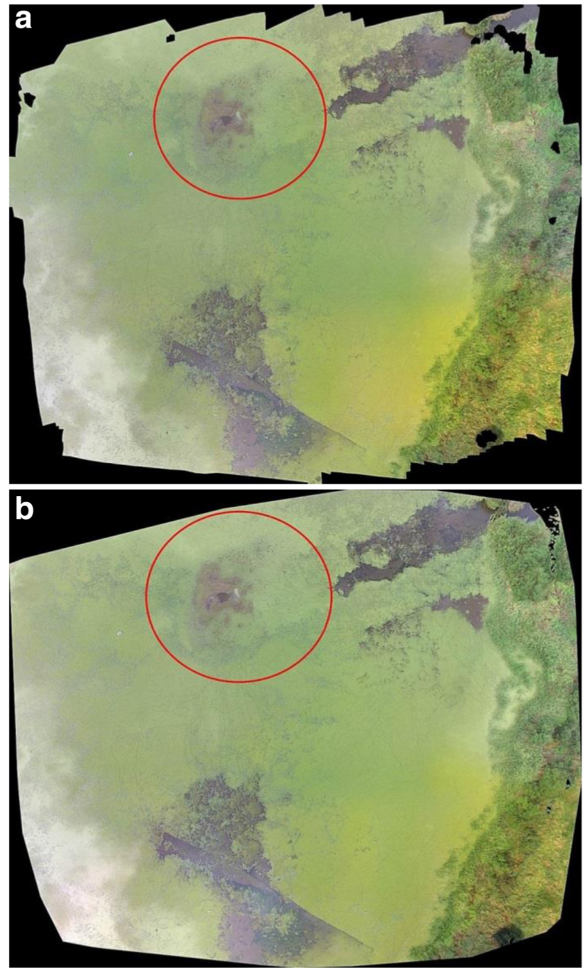

Fig. 5 Orthomosaic image of high-resolution waterbird habitat using image analysis software (The *red circle* shows that various waterbirds stay in groups). **a**. It was produced as orthomosaic image by PhotoScan Professional (Agisoft, Russia) after acquiring 163 photos through automatic flight of Inspire 1 (Zenmuse ×3 camera) on August 17, 2016. **b**. It was produced as orthomosaic image by Pix4D mapper Pro (Pix4D, Switzerland) after acquiring 163 photos through automatic flight of Inspire 1 (Zenmuse ×3 camera) on August 17, 2016

Conclusions

Conventional bird observation methods are line survey or point count method by bare eyes or through binoculars or telescopes. But in this study, the possibility of monitoring waterbirds using drones beyond the conventional research methods was described. Additionally, not only observation of waterbirds but also method to accumulate images of waterbird habitat was searched for. As a result of this study, it was confirmed that waterbird monitoring using drones can be applied to the field as a new monitoring technique, and in total, 26 species of waterbirds were observed. This study applied rotary wing drones only. But if fixed wing drones are used considering conditions of the survey site, a long-term

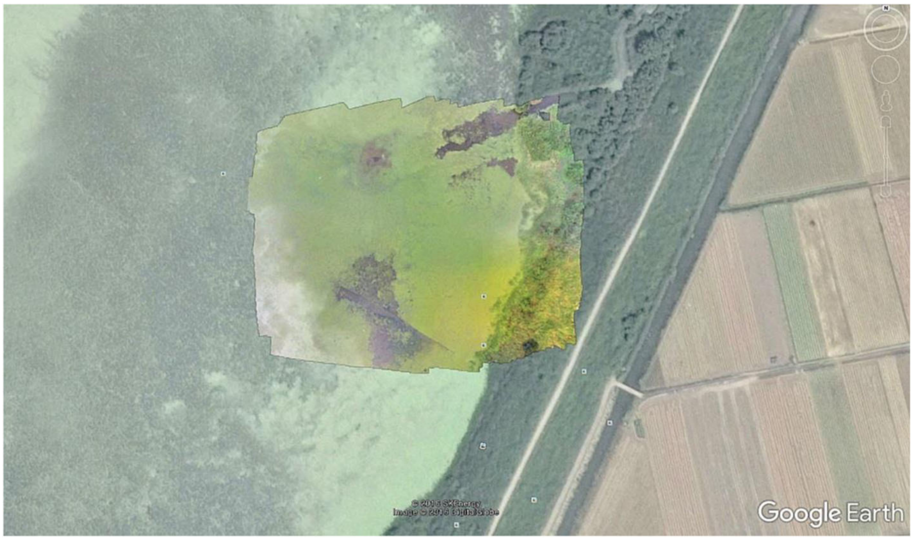

Fig. 6 Google Earth linked file (kmz) (Google Earth Capture) of waterbird habitat extracted from image analysis program PhotoScan Professional (Agisoft, Russia)

monitoring can be made under the condition that it less interferes with waterbirds by reducing the noise and vibration. In the case of a drone with a single lens, it was difficult to identify the subject because the size of the subject was too small. In such a case, a zoom in-out lens may be an alternative.

Additionally, it was confirmed that images of waterbird habitat could be accumulated through commercially used image analysis software such as Pix4D mapper Pro (Pix4D, Switzerland) and PhotoScan professional (Agisoft, Russia). Such data can be used to help quick and easy identification of the status of waterbird habitat by seasonal or environmental changes due to specific causes.

Furthermore, if advanced drones and cameras are used, it is possible to survey larger areas and to monitor even the most inaccessible areas. Consequently, more species, individuals and habitat can be observed. Besides, it is necessary to explore the possibilities of the method to survey waterbird quantitatively using drones.

Abbreviations
GPS: Global positioning system

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Not applicable

Authors' contributions
In this study, Y-GH mainly collected images with UAV and analyzed the image data using various software, and was a major contributor in writing the manuscript. SHY mainly contributed to identifying the waterbirds on the images taken by drones and made the list of species. OK mainly designed this work and revised the paper totally. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

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