

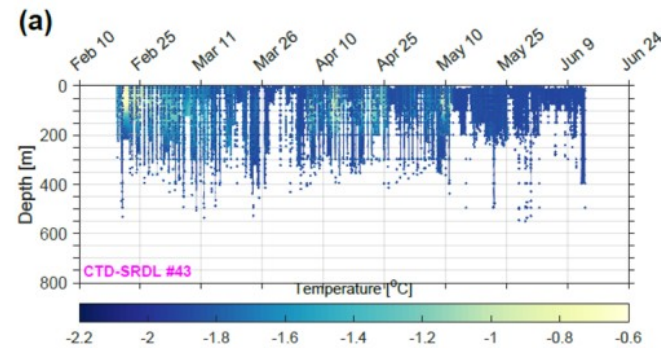
Wintering Waterbird Movements and HPAI Risk in Korea: Implications for Avian Health and Surveillance

Won Young Lee

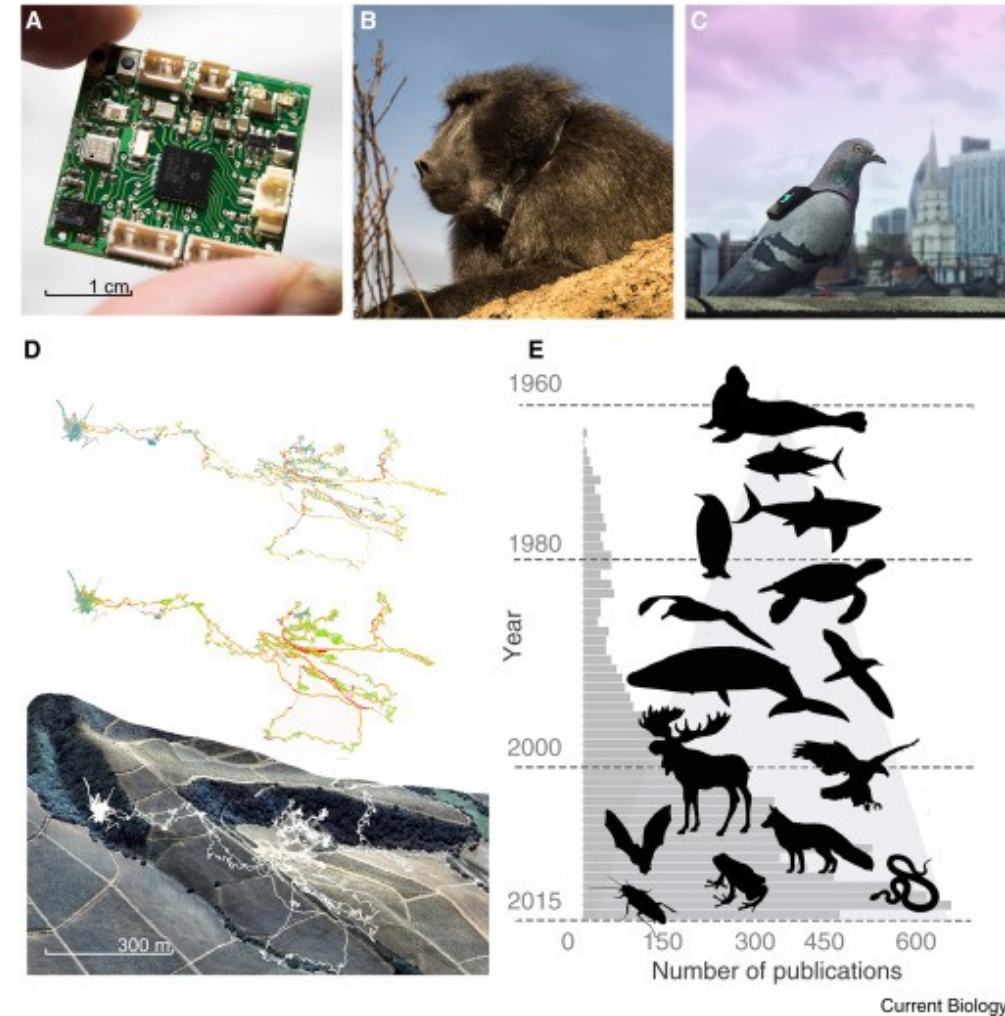
Division of Glacier and Earth Sciences, Korea Polar Research Institute



Research background: Bio-logging for behavioral study

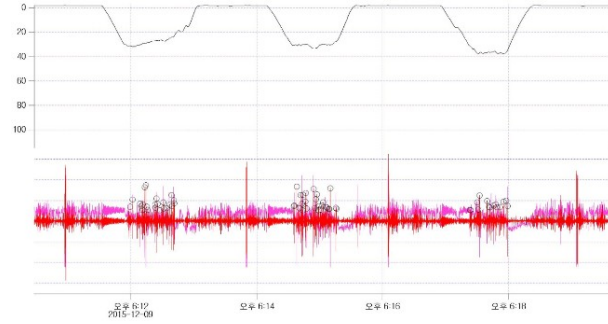


Yoon and Lee 2021 Ocean and Polar Re-

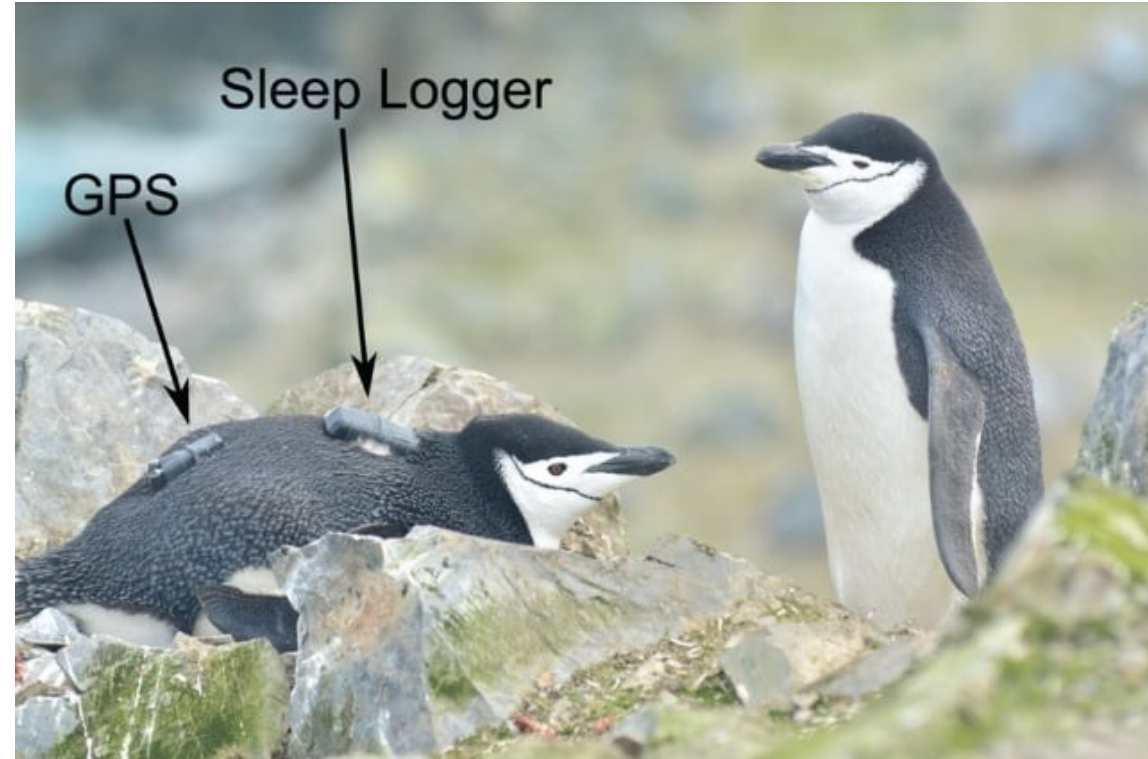
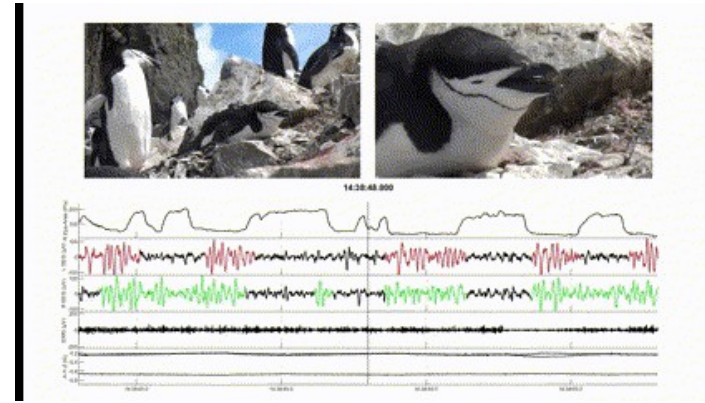


Fehlmann and King 2016 Current Biology

Research background: Bio-logging in Antarctica

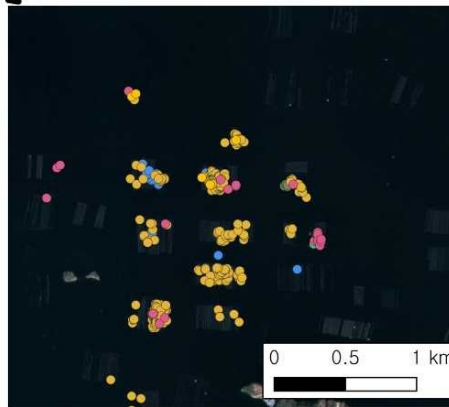
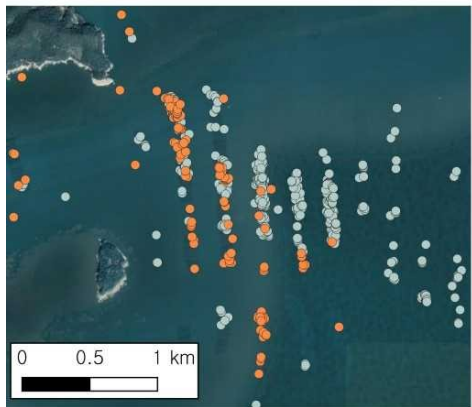


Choi et al. (2016) Scientific Reports



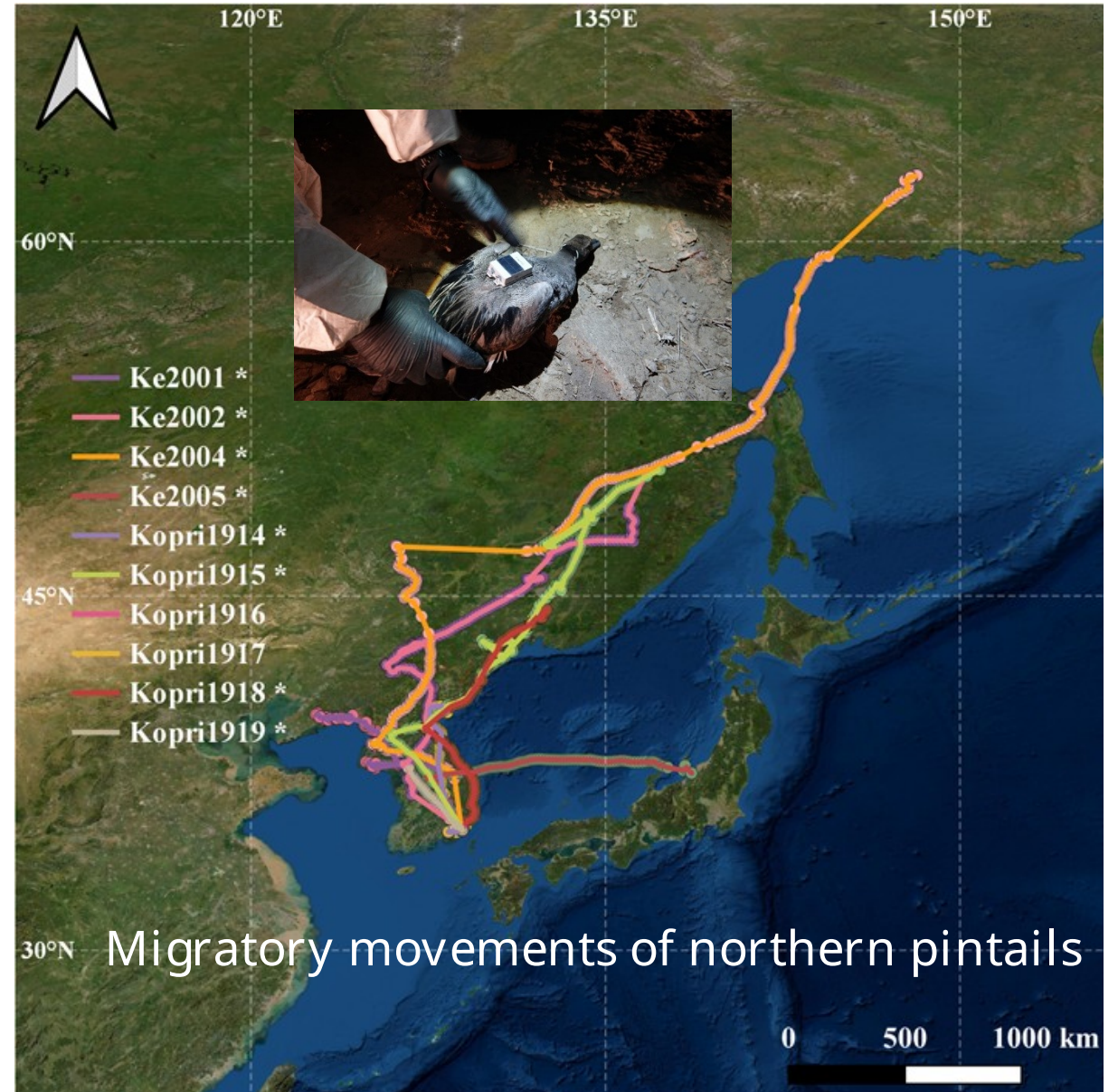
Libourel, Lee et al. (2023) Science

Research background: Bio-logging in Korea



Individual ID	
●	bpn1721_winter1
●	bpn1721_winter2
●	bpn1721_winter3
●	kopri1901_winter
●	kopri1907_winter
●	rcees1809_winter1
●	rcees1809_winter2
●	vt15081_winter1
●	vt15081_winter2

Movements of vega gulls



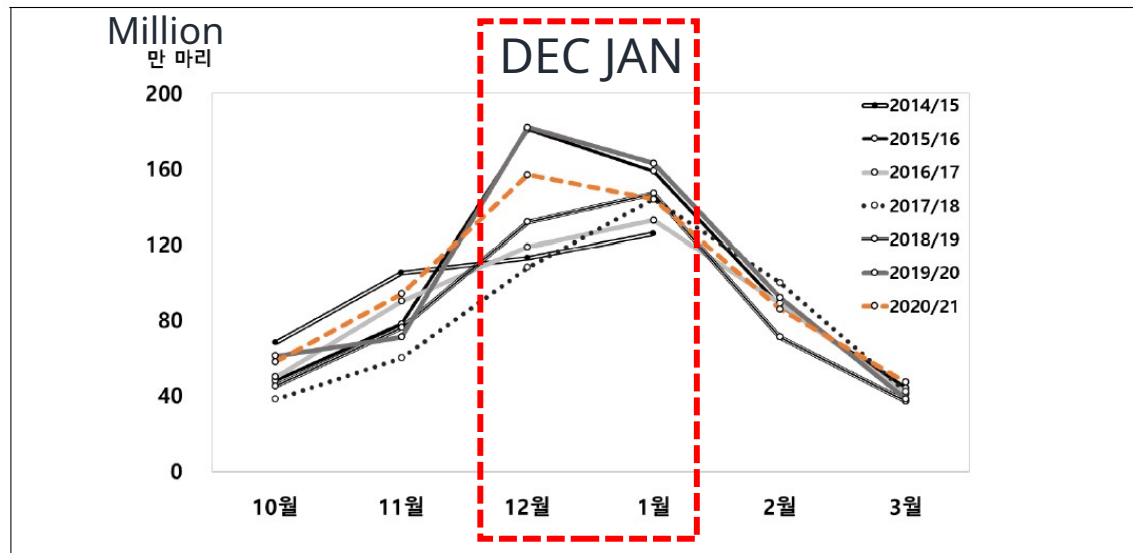
Migratory movements of northern pintails

INTRODUCTION

Background: HPAI Outbreaks in Korea

Number of wintering birds in Korea

〈그림 2-6〉 2014~2021년 월별 철새 도래 현황

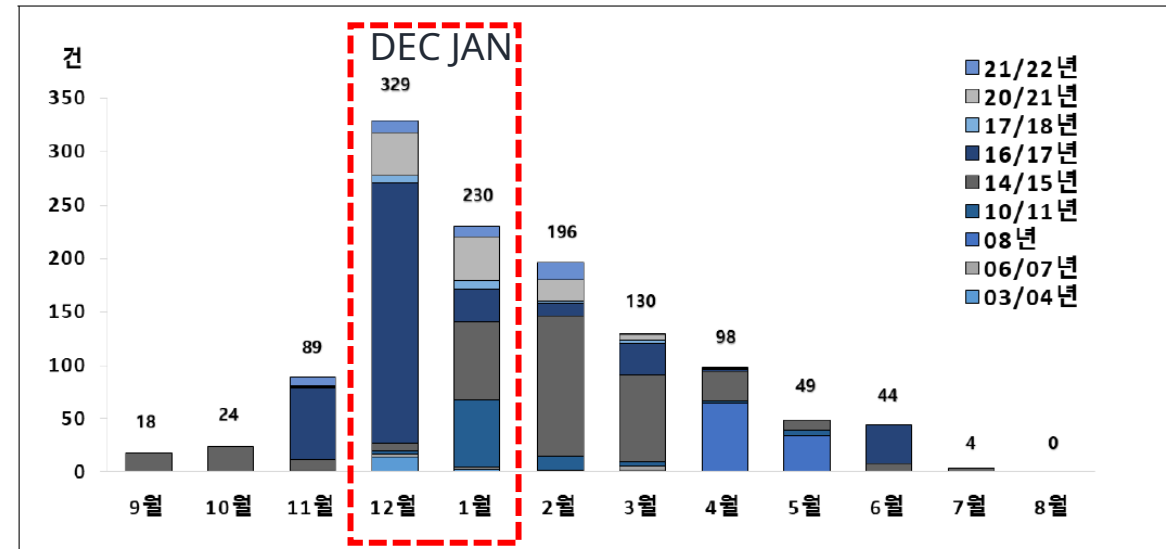


자료: 농림축산식품부, 농림축산검역본부(각 연도). 고병원성 조류인플루엔자 역학조사분석보고서를 이용하여 저자 작성.

Number of monthly HPAI cases

〈그림 2-3〉 월별 고병원성 AI 발생 건수

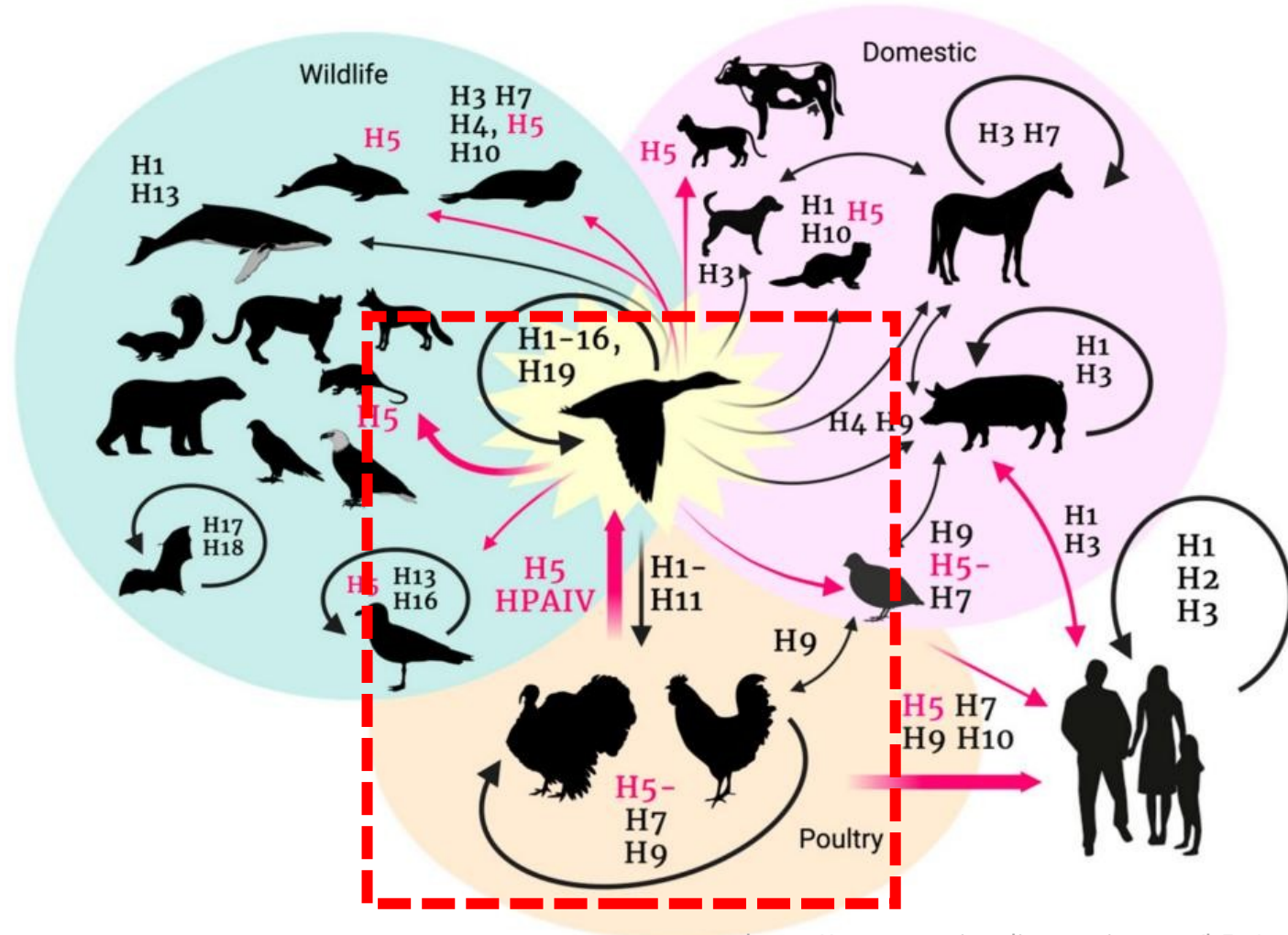
Kim et al. (2022)



자료: 농림축산식품부 내부자료를 이용하여 저자 작성.

- Winter **migratory birds** are recognized as the primary **reservoirs of AI**.
- The highly pathogenic avian influenza (HPAI) **epidemic season** closely coincides with the **overwintering period of migratory birds** in Korea.

Avian influenza transmission

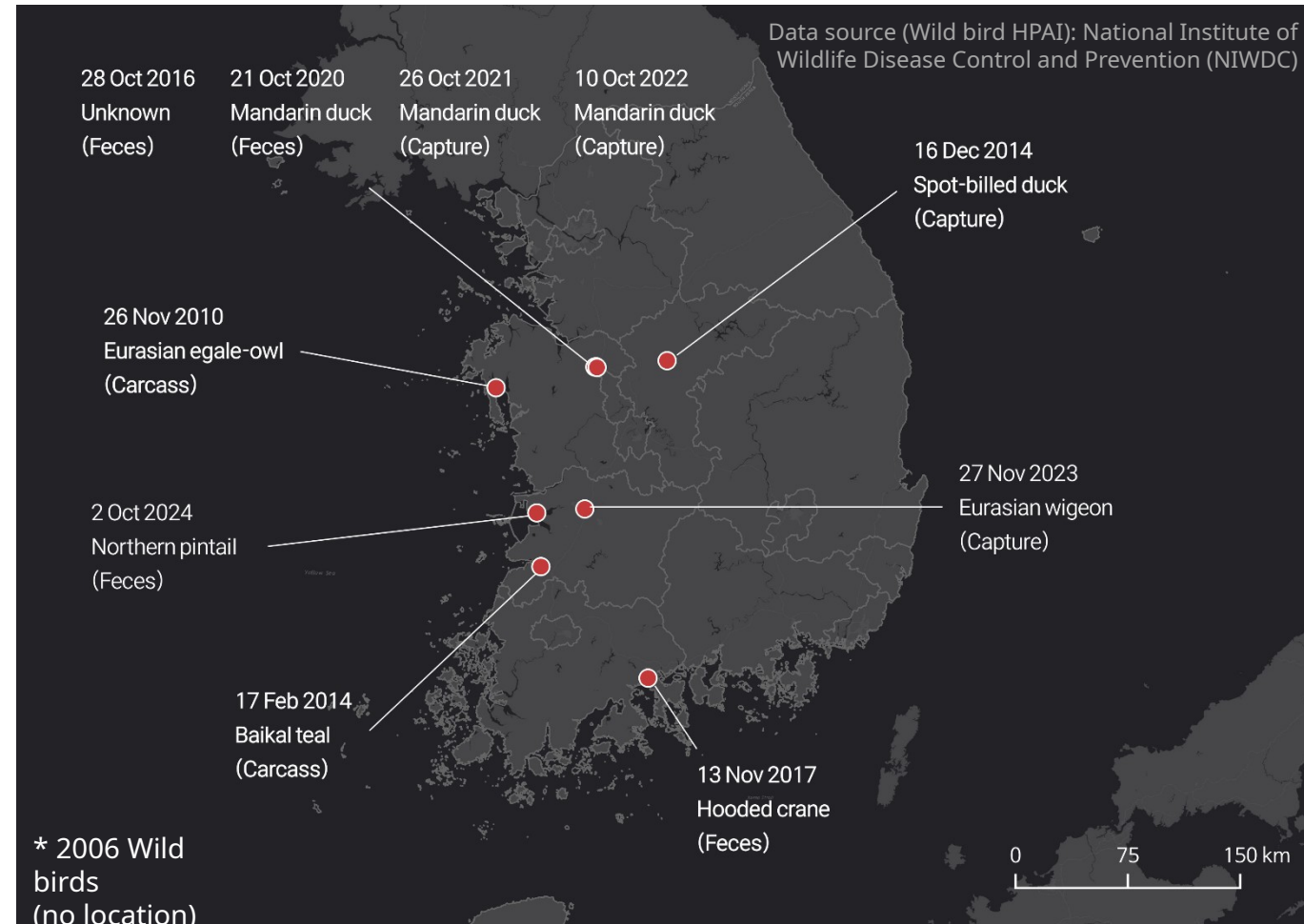


<https://www.creative-diagnostics.com/h5n1-antibodies-and-antigens.htm>

- Avian influenza:
An acute viral respiratory disease affecting wild birds and poultry, with zoonotic potential for human

INTRODUCTION

Background: HPAI Outbreaks in Korea



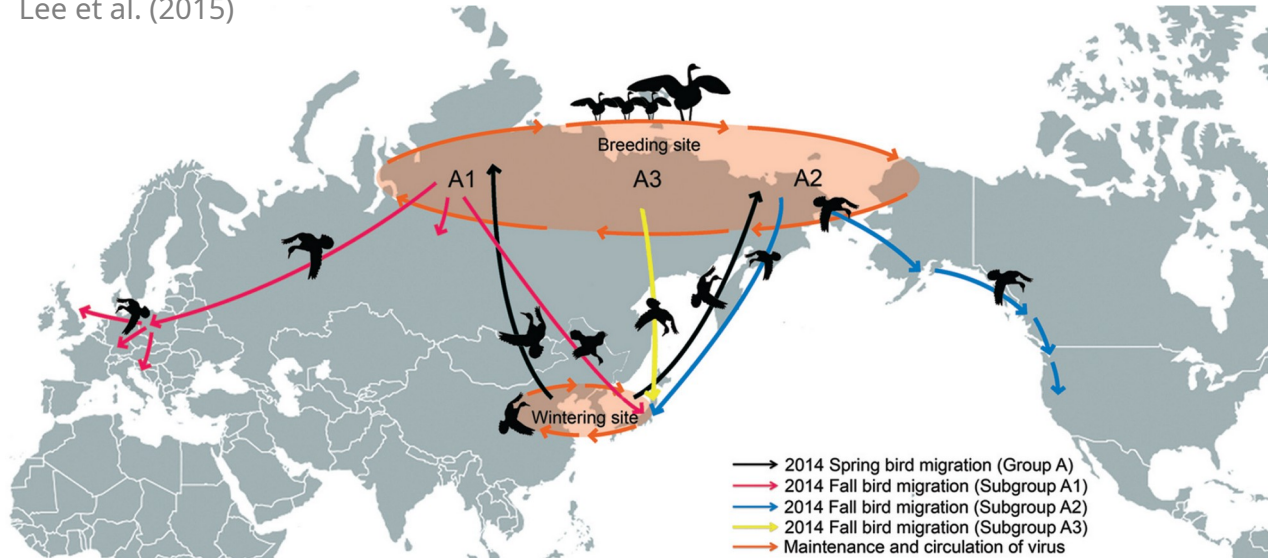
First annual reports of HPAI (highly pathogenic avian influenza) in wild birds

Outbreaks have occurred **every winter** since 2020 in wild bird and poultry.

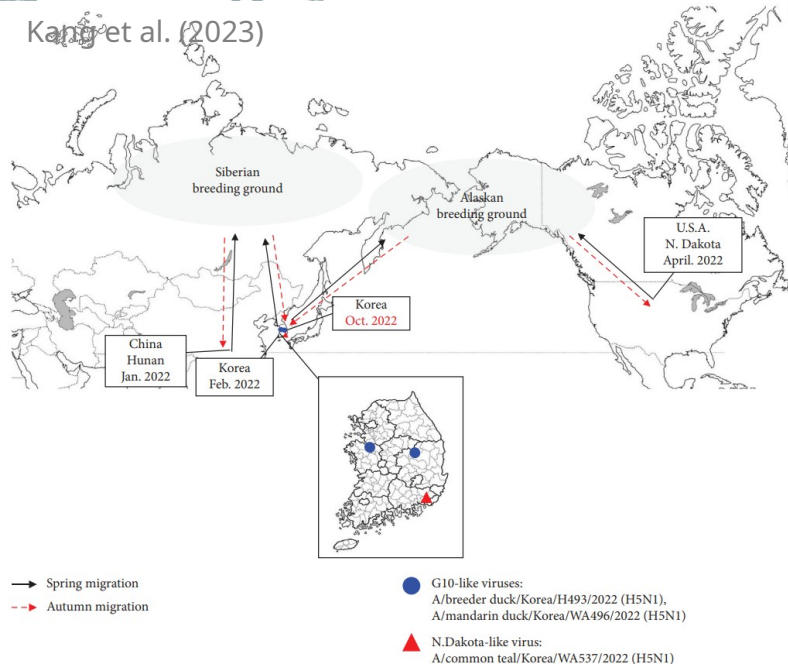
INTRODUCTION

Background: HPAI Outbreaks in Korea

Lee et al. (2015)



Kang et al. (2023)

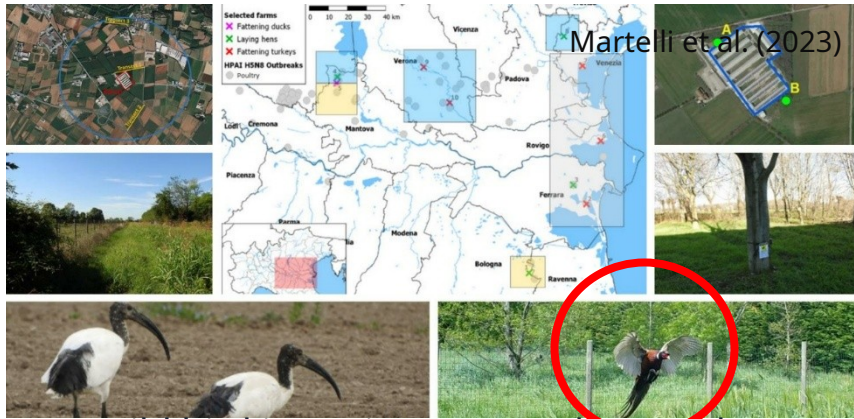


Pathway of virus introduction

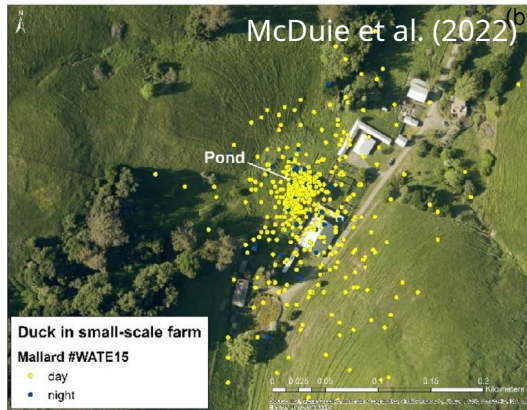
- Migratory birds breeding in high-latitude regions (Arctic, Eurasia, Alaska) overwinter in Korea, representing the most widely accepted route of HPAI virus introduction.
- However, the detailed transmission process remains poorly understood:
 - **Which wild bird species** are primarily responsible for introducing the virus to poultry
 - Whether transmission occurs directly from migratory wild birds to poultry, or indirectly via resident birds as intermediate hosts

INTRODUCTION

Background: Global Case Studies of Wild bird – Poultry Interactions



Wild bird intrusion at an Italian poultry farm



GPS tracking of wild birds within livestock facilities in the US



Free range geese in Germany



Poultry farm In Korea

- Previous international studies have demonstrated a direct transmission interface, documenting wild birds intruding into poultry farms.
- However, it remains unclear whether these patterns observed abroad apply to the situation in Korea.

Research Objectives

1. Estimate the mechanisms of AIV transmission from wild birds to domestic

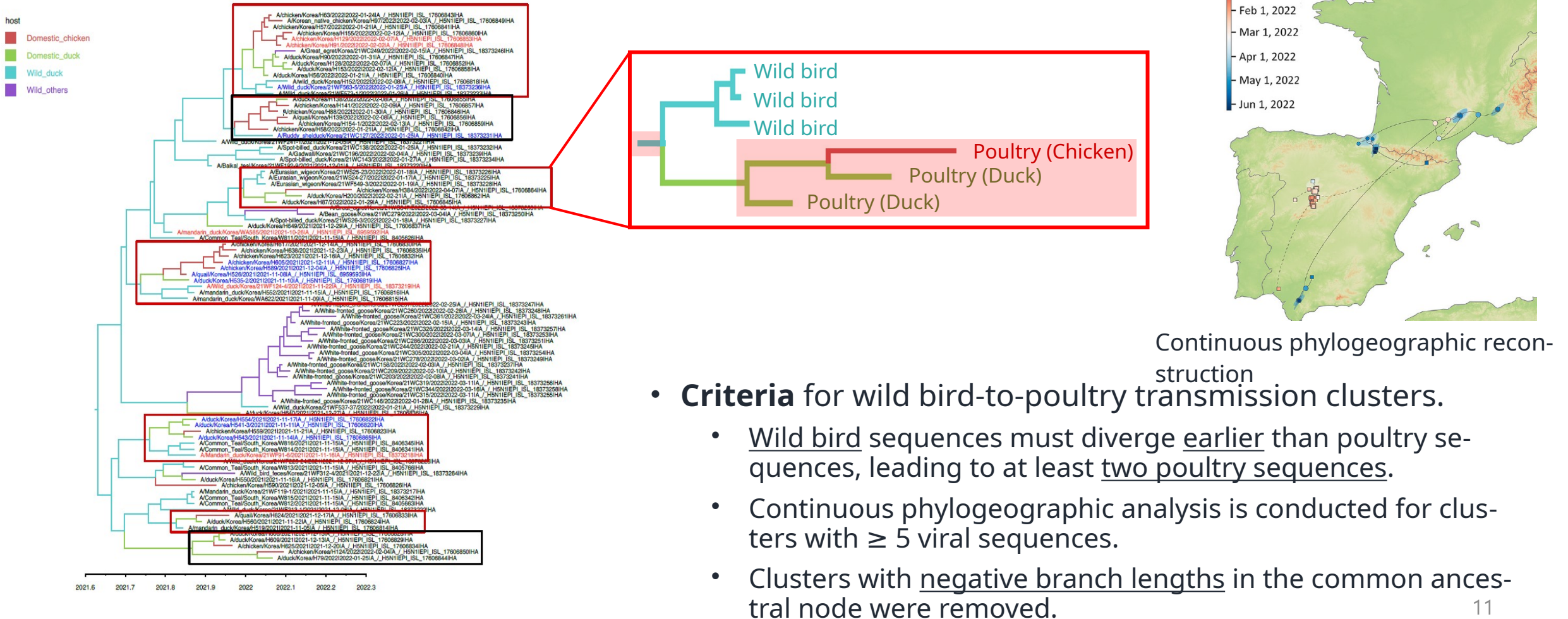
accelerometers to examine the behaviors

METHODS

Continuous Phylogeographic Reconstruction

Identify **viral clusters** indicative of **wild bird-to-poultry** transmission and reconstruct continuous phylogeography.

21-22



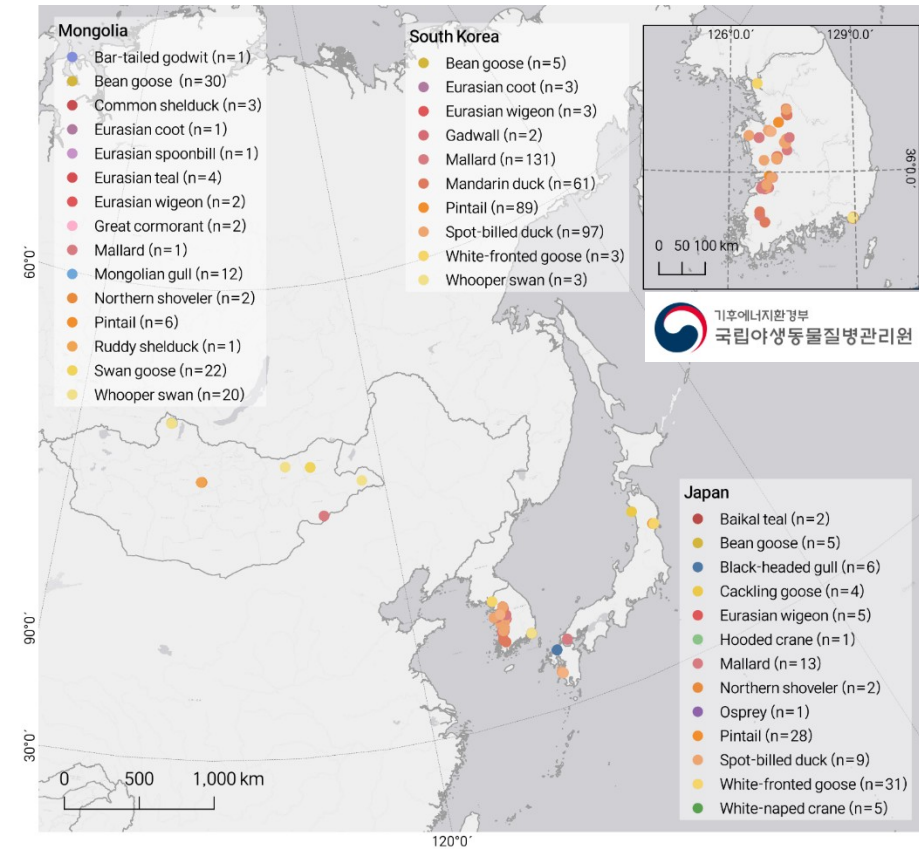
METHODS

Study Sites and Data Collection

- **Study Period:** 2020.07. – 2025.06.
- **Capture sites:** Korea, Mongolia, and Japan
- **Study Species:** 25 species, 617 individuals

Bar-tailed godwit, Baikal teal, Bean goose, Black-headed gull, Cackling goose, Common shelduck, Eurasian coot, Eurasian spoonbill, Eurasian teal, Eurasian wigeon, Gadwall, Great cormorant, Hooded crane, Mallard, Mandarin duck, Mongolian gull, Northern shoveler, Northern pintail, Osprey, Ruddy shelduck, Spot-billed duck, Swan goose, White-fronted goose, White-naped crane, Whooper swan

- **Device:** Solar-powered GPS-GSM transmitter



Capture locations of GPS-tagged wild birds



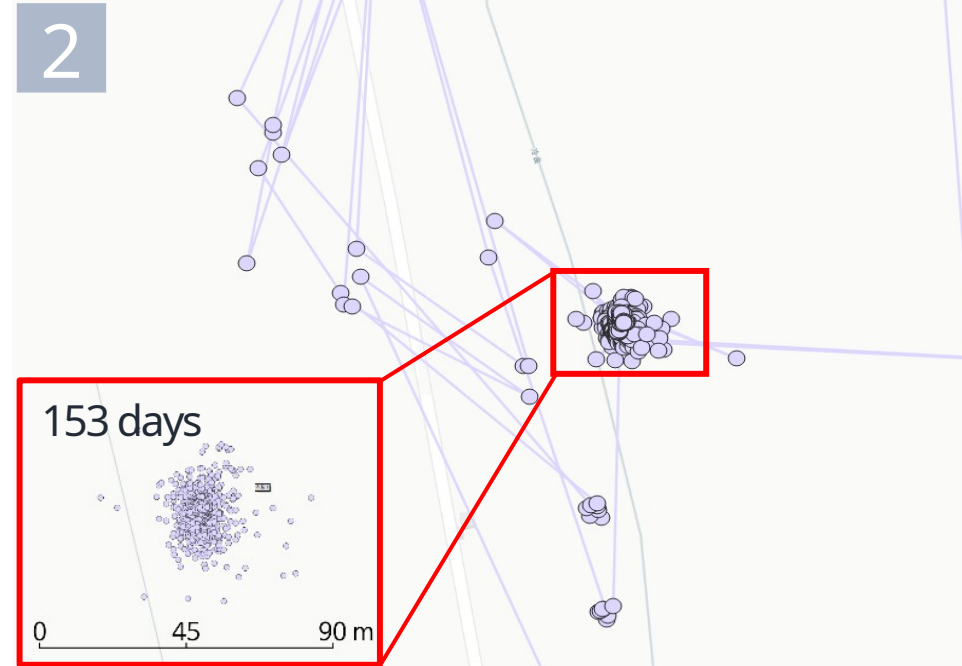
Field capture of wild birds (2024/25)

METHODS

Evaluation of Wild Bird Approaches to Poultry Farms: Filtering GPS data



Removal of abnormal speed data
(Thompson et al., 1961; Miller et al., 2005; McDuie et al., 2019)



Removal of data from suspected
device detachment (Sergio et al., 2018)

METHODS

Evaluation of Wild Bird Approaches to Poultry Farms

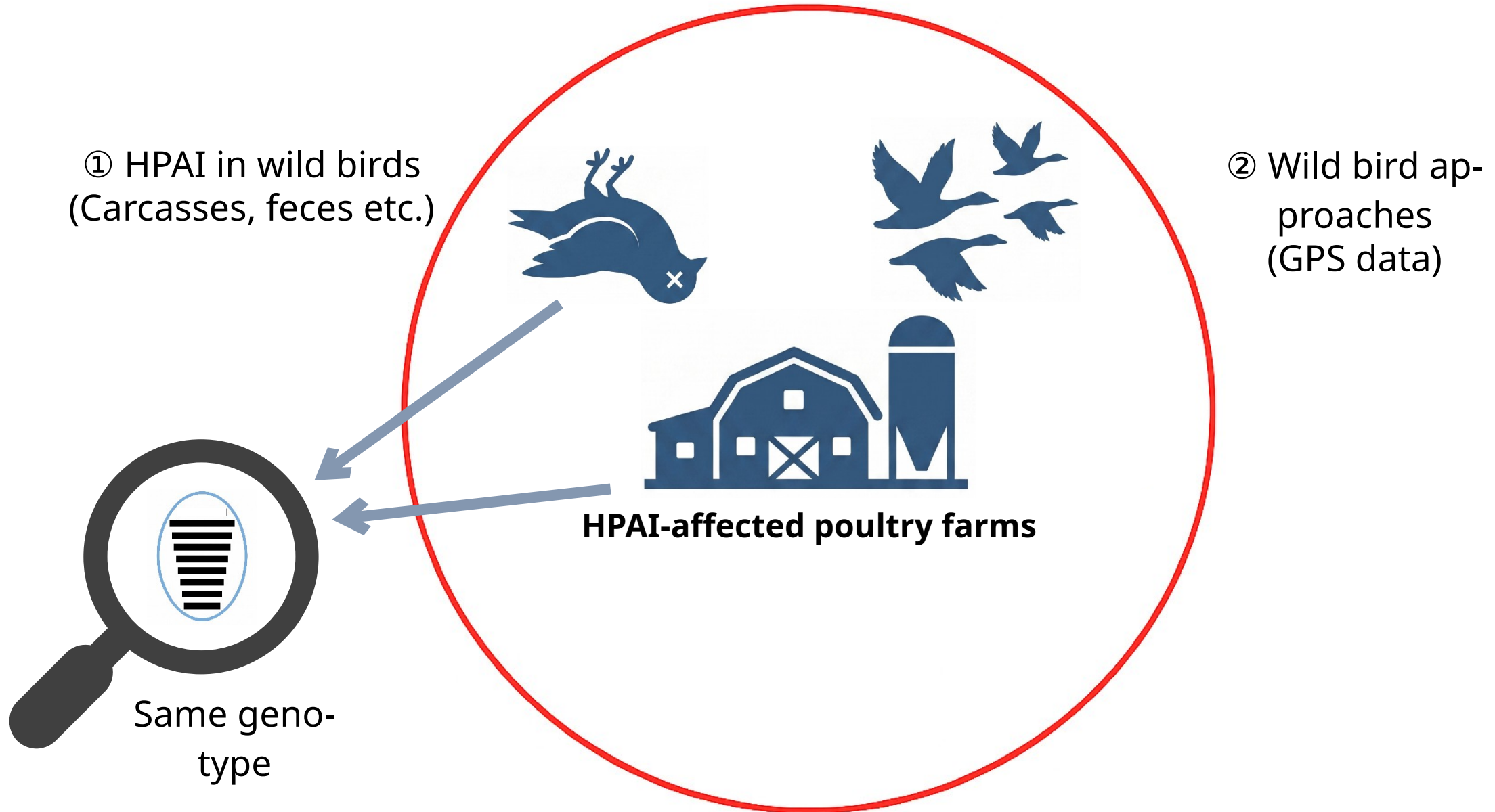
- Defining the '**Potential Zone**' for poultry farms susceptible to wild birds.
 - Spatial extent encompassing the active movement range of wild birds.
 - Based on the daily movement ranges of waterfowl (*Anseriformes*) (Johnson et al., 2014; McDuie et al., 2022)

HPAI-affected poultry farms



METHODS

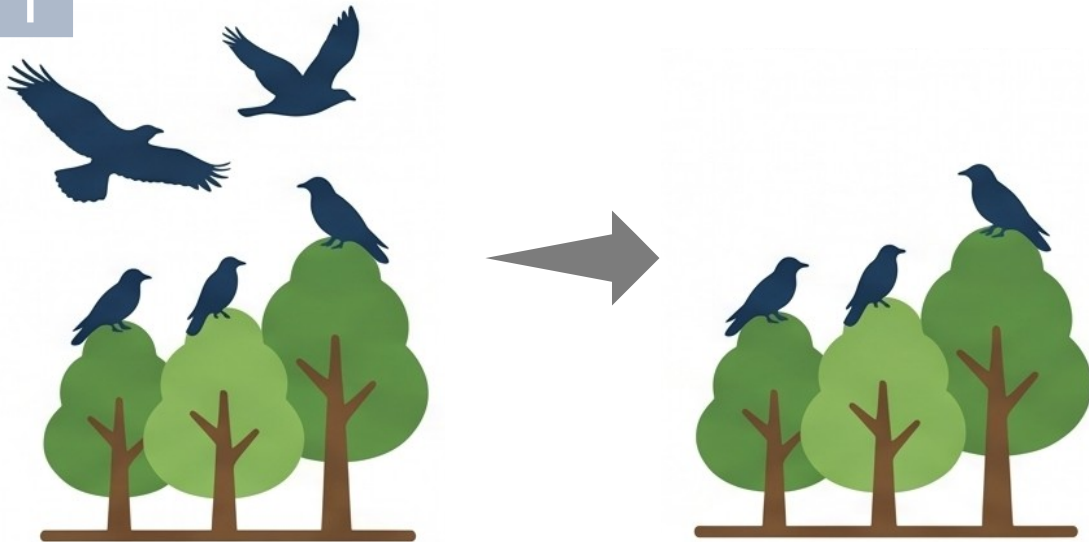
Evaluation of Wild Bird Approaches to Poultry Farms



METHODS

Wild birds habitat use

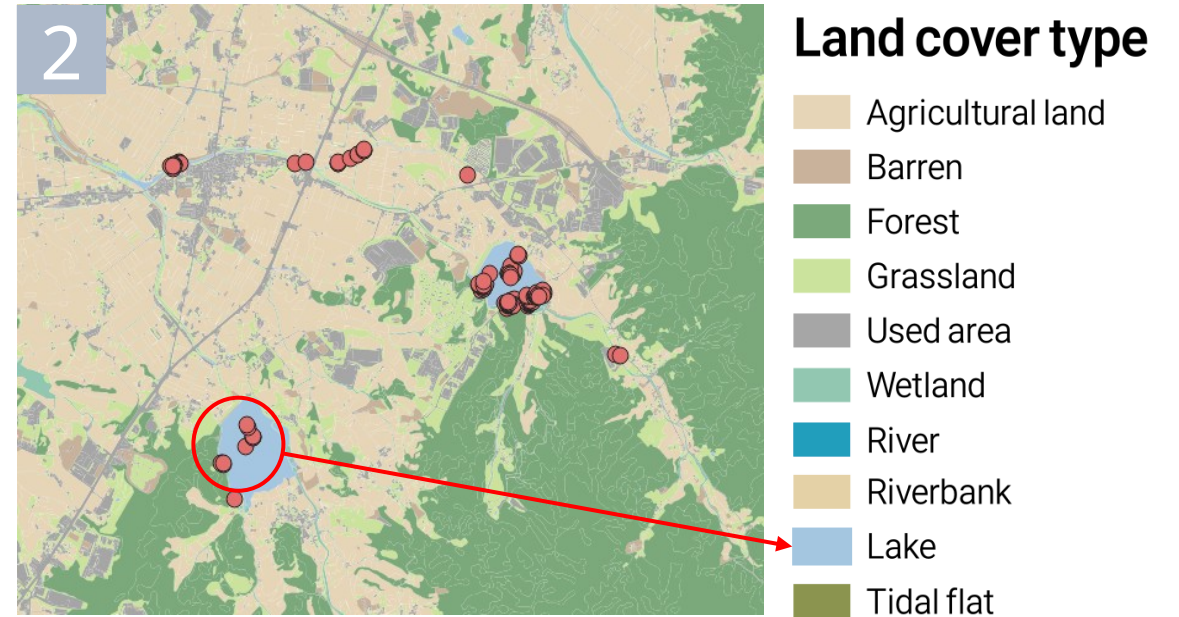
1



Eliminated all movements that could potentially be flighted

(Miller et al., 2005; McDuie et al., 2019)

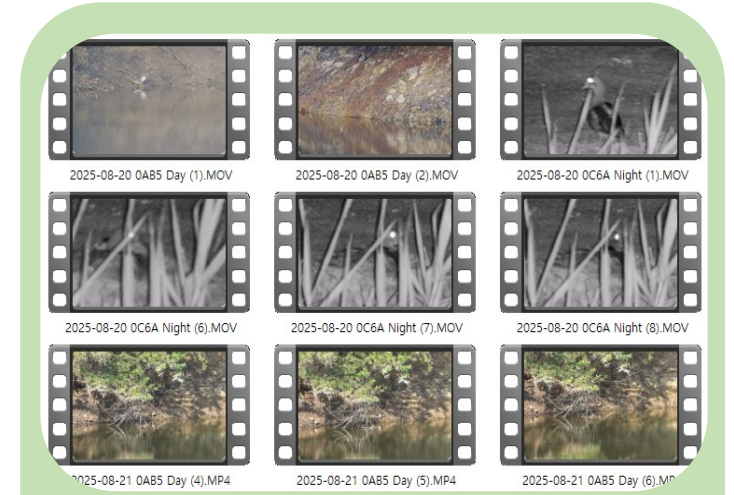
2



Land cover type sampled at each GPS fixes and proportion of fixes per land cover type calculated per individual.

METHODS

Mandarin duck with GPS and accelerometer



Video-recordings

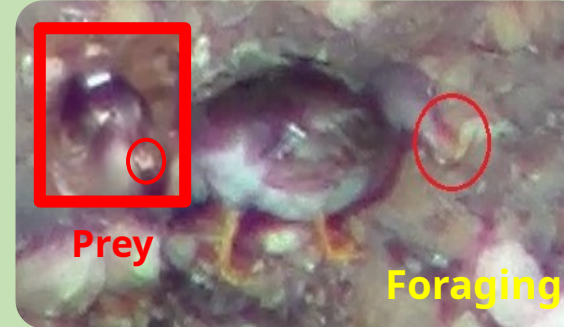
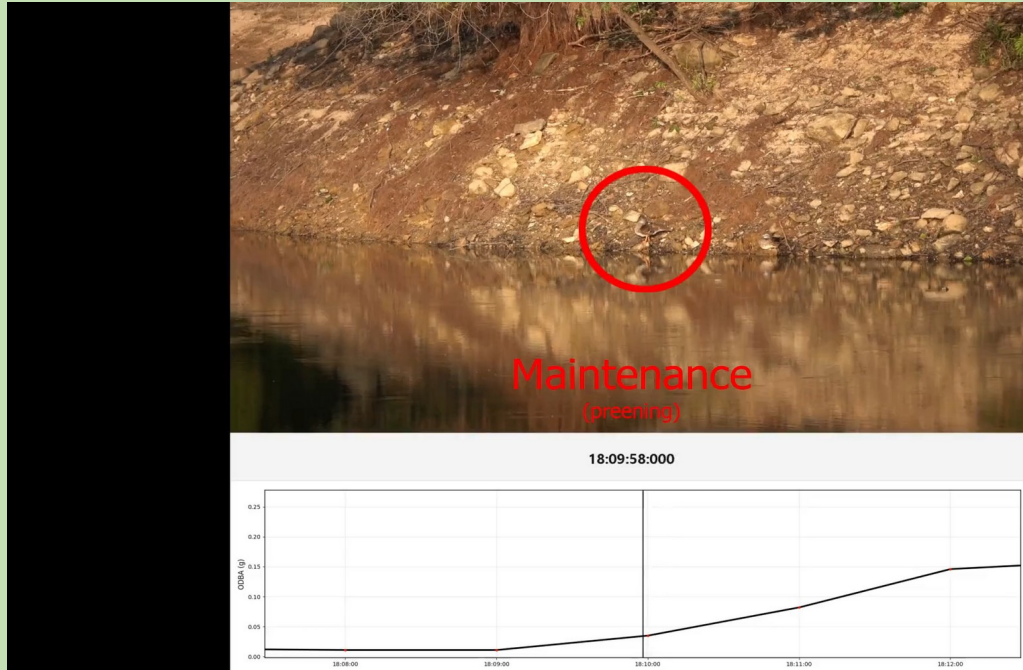


UID	Transmitting time	Collecting time	ODBA
1200000a	2025-08-20T08:01:50.426Z	2025-08-20T08:00:00Z	1700
1200000a	2025-08-20T08:01:50.426Z	2025-08-20T08:01:00Z	1860
1200000a	2025-08-20T08:11:49.922Z	2025-08-20T08:02:00Z	1310
1200000a	2025-08-20T08:11:49.922Z	2025-08-20T08:03:00Z	2450
1200000a	2025-08-20T08:11:49.923Z	2025-08-20T08:04:00Z	1280
1200000a	2025-08-20T08:11:49.923Z	2025-08-20T08:05:00Z	2050
	20T08:11:49.923Z	2025-08-20T08:06:00Z	1500
	20T08:11:49.923Z	2025-08-20T08:07:00Z	1270
	20T08:11:49.923Z	2025-08-20T08:08:00Z	1180
	20T08:11:49.923Z	2025-08-20T08:09:00Z	980
	20T08:11:49.923Z	2025-08-20T08:10:00Z	1240
	20T08:11:49.923Z	2025-08-20T08:11:00Z	1000

Overall Dynamain Body accelera-
tion (ODBA)

METHODS

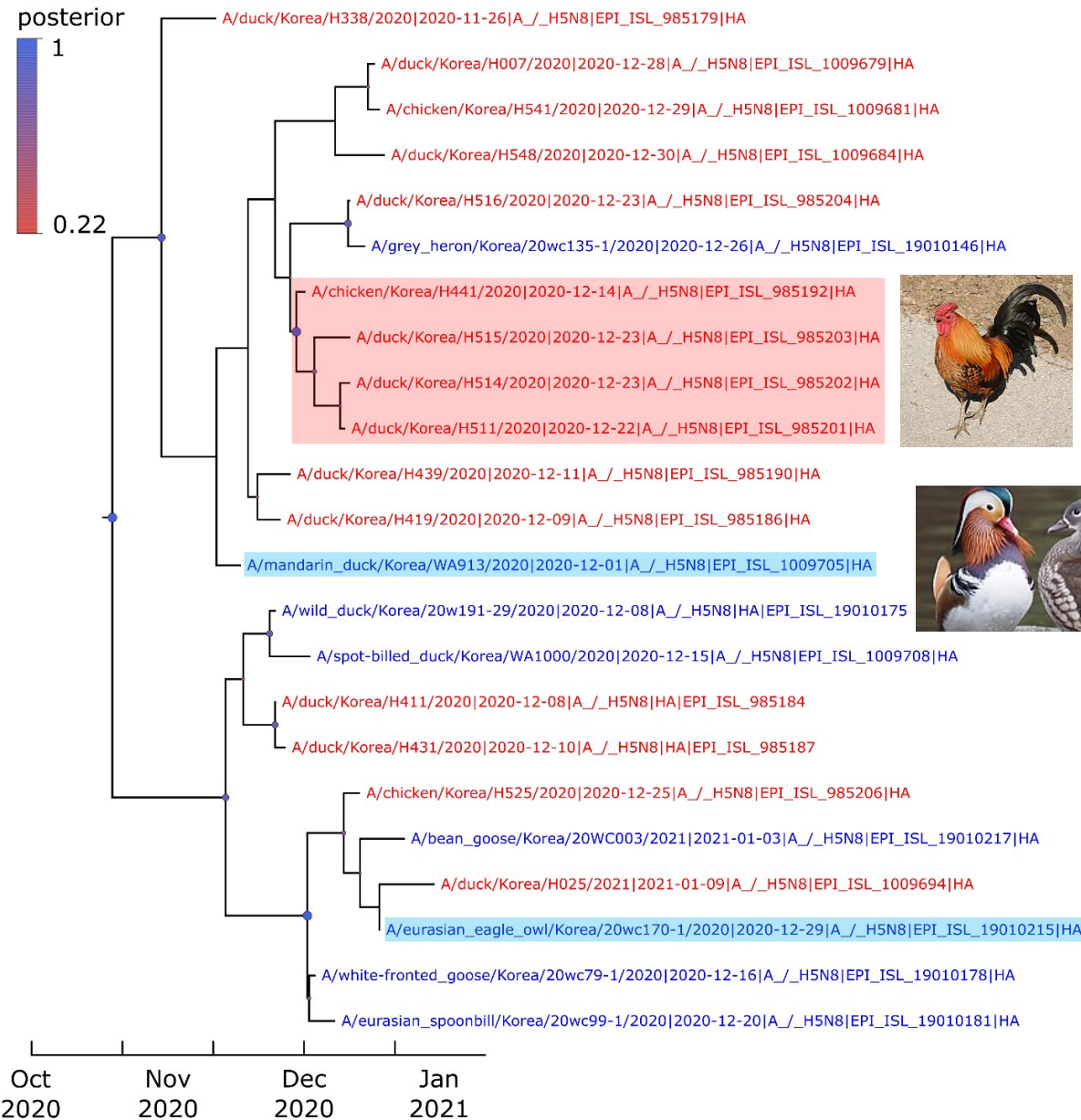
Mandarin duck with GPS and accelerometer



Recording **acceleration (every 1 min)** + **video-recording**

RESULTS

Spatiotemporal Dispersal of HPAI



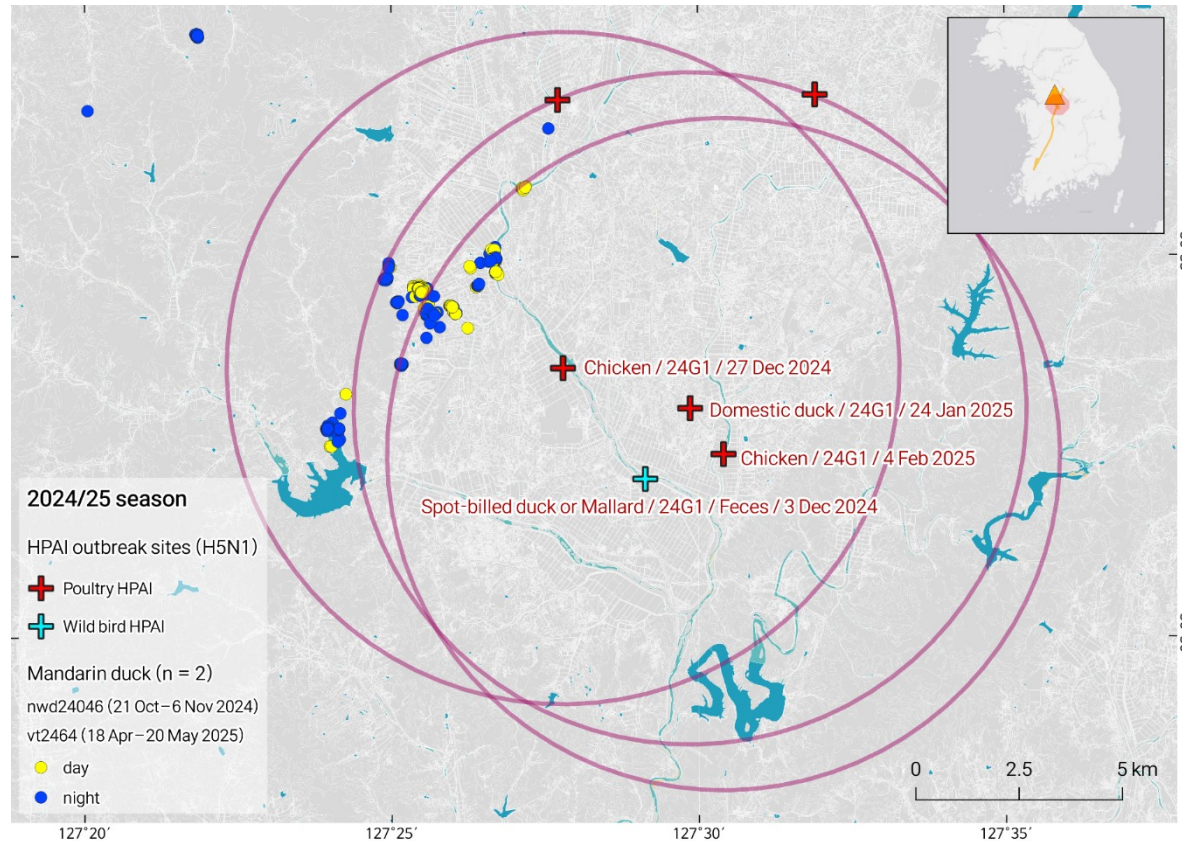
Common patterns across clusters

- **Poultry-derived viruses** forming a **clade** (6/7 clusters)
 - tMRCA of the poultry clade falls within the winter transmission season in Korea (October–February)
- Cluster tMRCA predominantly falls within the breeding season of wild birds (July–September)
- Wild ducks — primarily Mandarin duck and Spot-billed duck — as **the earliest-detected** wild bird hosts (5/7 clusters)
- **Raptors** were consistently **detected later** than waterfowls.

RESULTS

Evaluation of Wild Bird Approaches to Poultry Farms

2024/2025 season



Season	Same genotype cases & Wild bird approach cases
2020/21	2
2021/22	5
2022/23	3
2023/24	0
2024/25	3

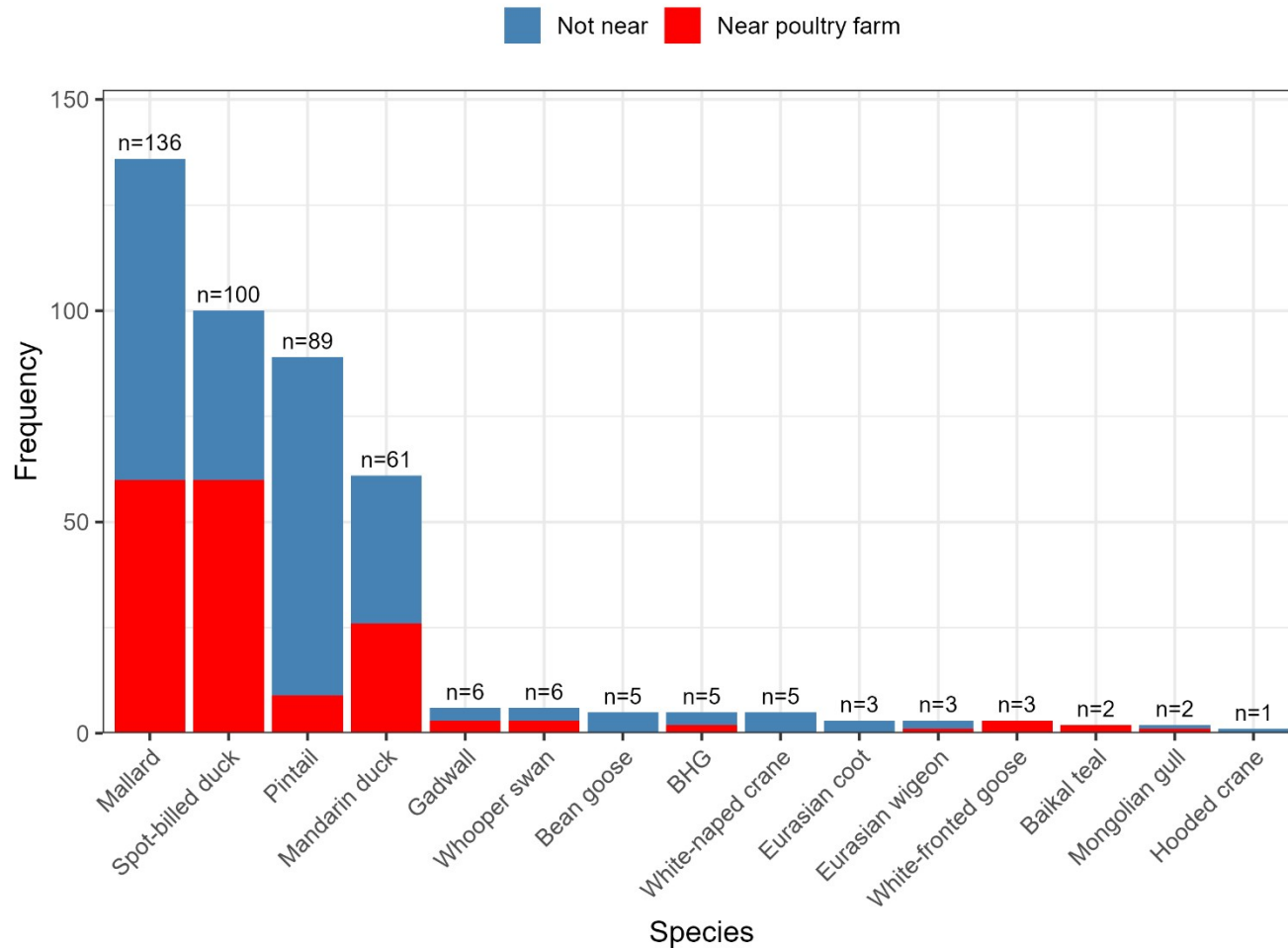
- Repeated in **winter season**:
 - Wild birds approached HPAI-outbreak poultry farms.
 - Identical HPAI genotypes occurred in wild birds near the farms.
- Predominantly driven by **waterfowl** species (including Spot-billed ducks, Mallards, Whooper swans, Gadwalls, Northern pintails, and Mandarin ducks.)

Of 64 GPS-tagged wild birds, 24 approached poultry farms
Same genotype cases & Wild bird approach cases: 3
Species neared poultry farm: Mandarin duck, Northern pintail, Mallard

RESULTS

Evaluation of Wild Bird Approaches to Poultry Farms

- When examining poultry farm approaches by species, **Mallard, Mandarin duck, and Spot-billed duck** were observed to approach poultry farms most frequently.



Mallard
(left: female, right: male)



Mandarin duck
(left: male, right: female)



Spot-billed duck



Northern Pintail

RESULTS

Wild Birds Habitat Use

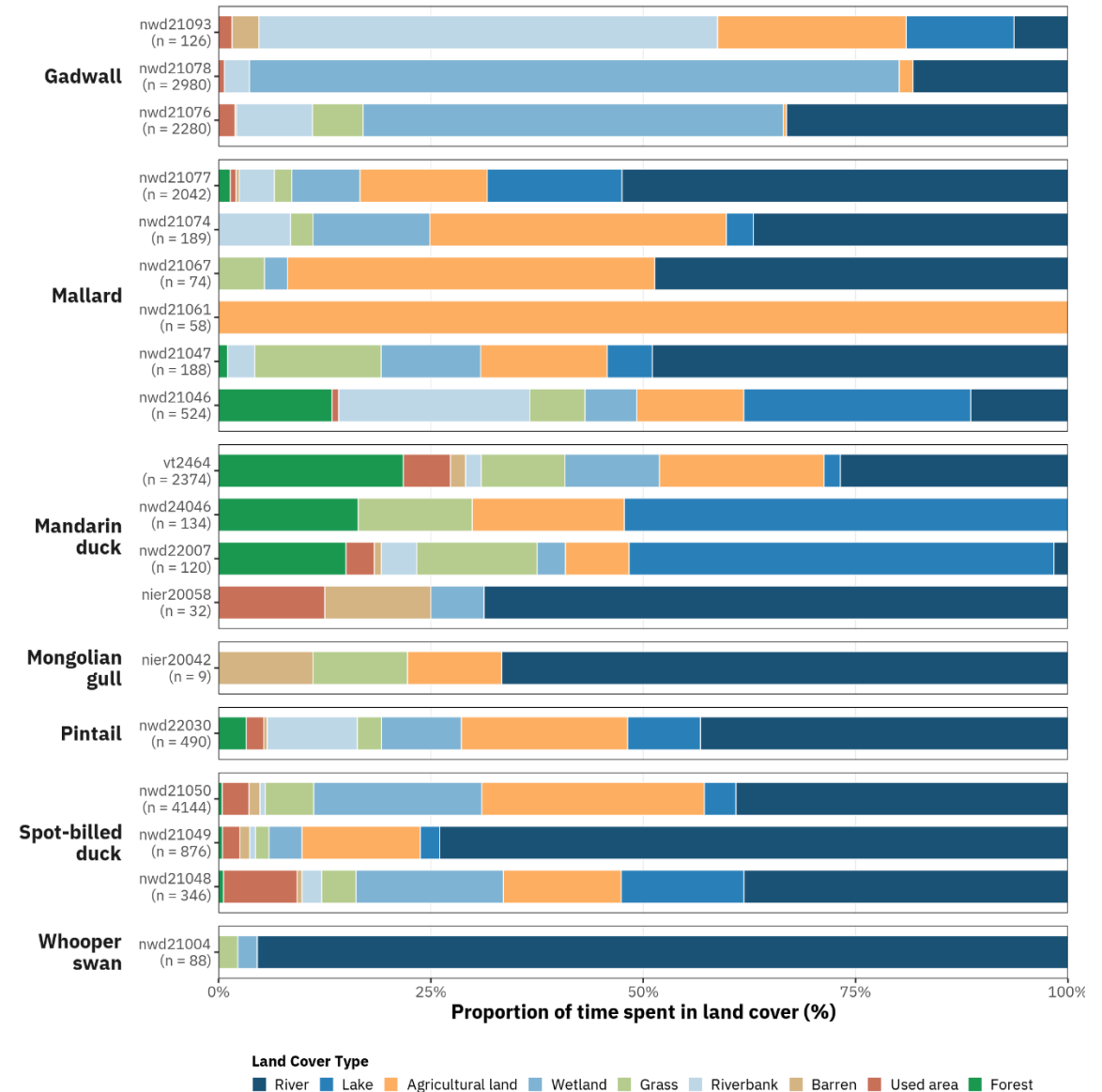
- 19 individuals (7 species) approached poultry farms where wild bird AIV of identical genotype was detected nearby

Common pattern

- Water body use significantly higher than other terrestrial habitats in all individuals (GLM, $p < 0.05$).

Species-specific patterns

- Gadwall($n=3$): Water bodies ($87.4 \pm 12.9\%$) > Agricultural ($8.1 \pm 12.3\%$) > Other terrestrial ($4.5 \pm 3.7\%$) — all individuals ($p < 0.05$).
- Mallard($n=6$): Water bodies ($66.0 \pm 10.6\%$) highest in 5/6 individuals ($p < 0.05$).
- Spot-billed duck($n=3$): Water bodies ($72.1 \pm 8.8\%$) > Agricultural ($18.0 \pm 7.1\%$) > Other terrestrial ($9.4 \pm 4.3\%$) > Forest ($0.5 \pm 0.1\%$) — all pairs significant ($p < 0.05$).
- Mandarin duck ($n=4$): Water bodies significantly higher than other terrestrial habitats in all individuals ($p < 0.05$).



Individuals that approached poultry farms

RESULTS

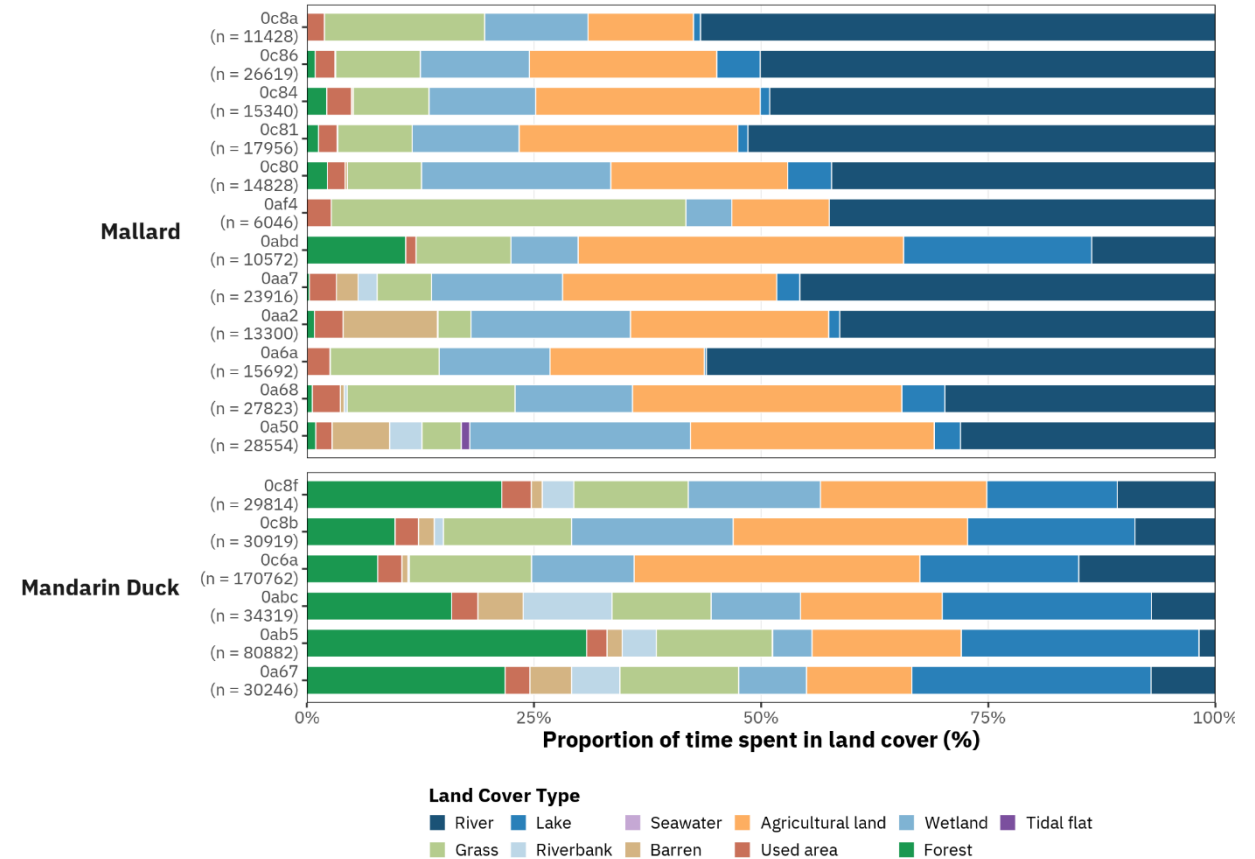
Wild Birds Habitat Use

Mallard (n=12)

- Water bodies showed the highest use proportion in all 12 individuals ($59.9 \pm 9.3\%$), followed by agricultural areas ($22.2 \pm 7.1\%$) and other terrestrial habitats ($16.2 \pm 8.9\%$) in 10/12 individuals.
- Water bodies use significantly higher than agricultural areas, other terrestrial habitats, and forest in all individuals (GLM, all $p < 0.001$).
- Forest ($1.7 \pm 3.0\%$; $n = 11$) and saline habitats ($0.1 \pm 0.3\%$; $n = 2$) were rarely used

Mandarin duck (n=6)

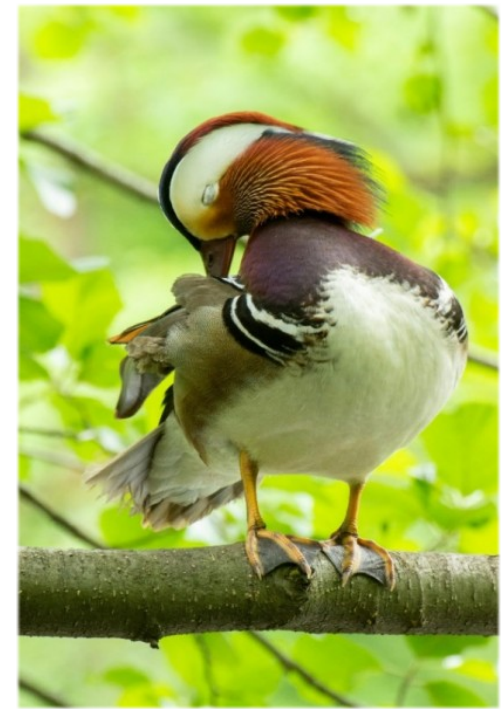
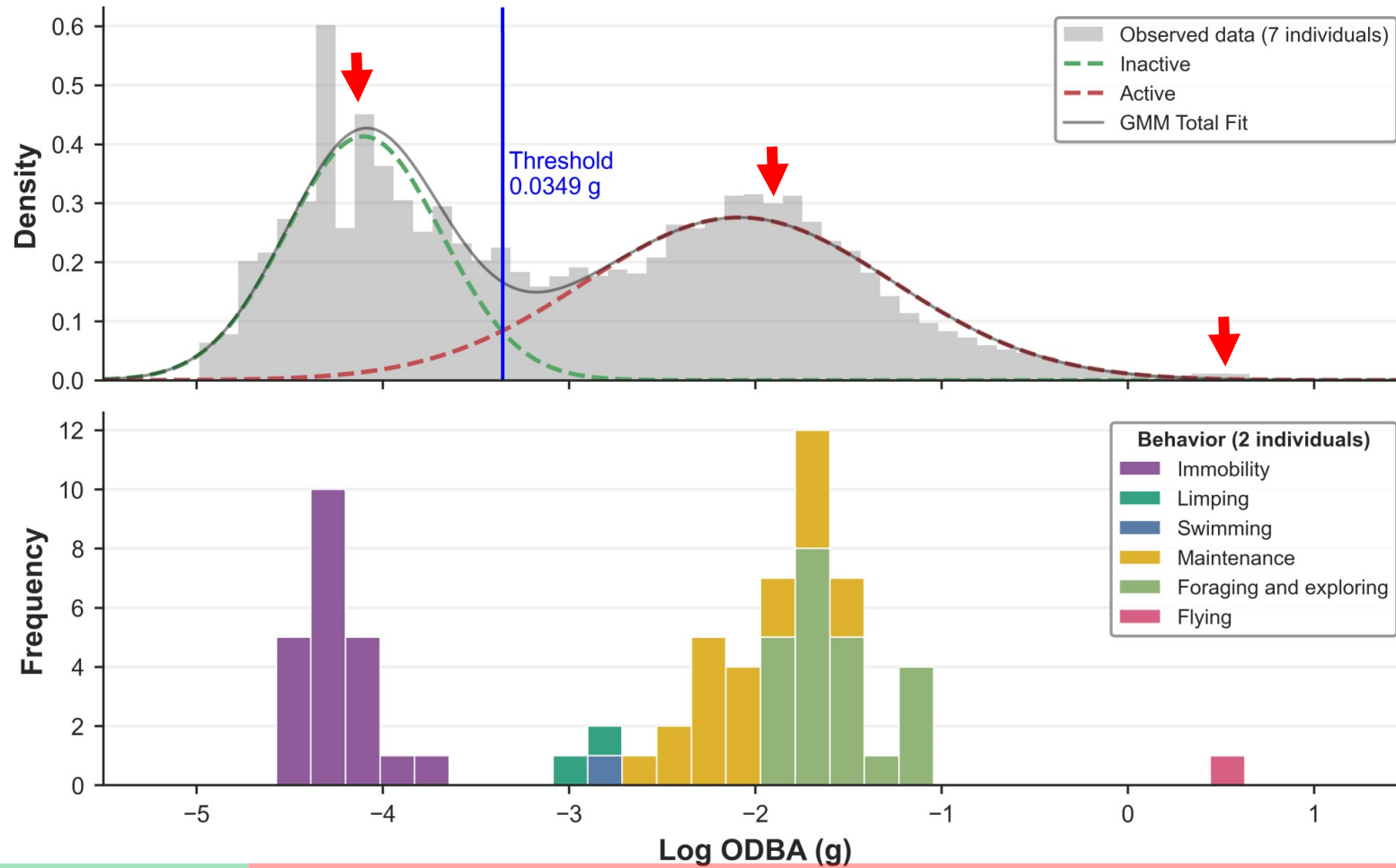
- Water bodies showed the highest use proportion in all 6 individuals ($44.2 \pm 4.6\%$).
- Water bodies use significantly higher than agricultural areas, other terrestrial habitats, and forest in all individuals (GLM, all $p < 0.001$)



**10 min interval GPS data from
Mallard and Mandarin Duck**

RESULTS

Mandarin duck acceleration and video-recordings



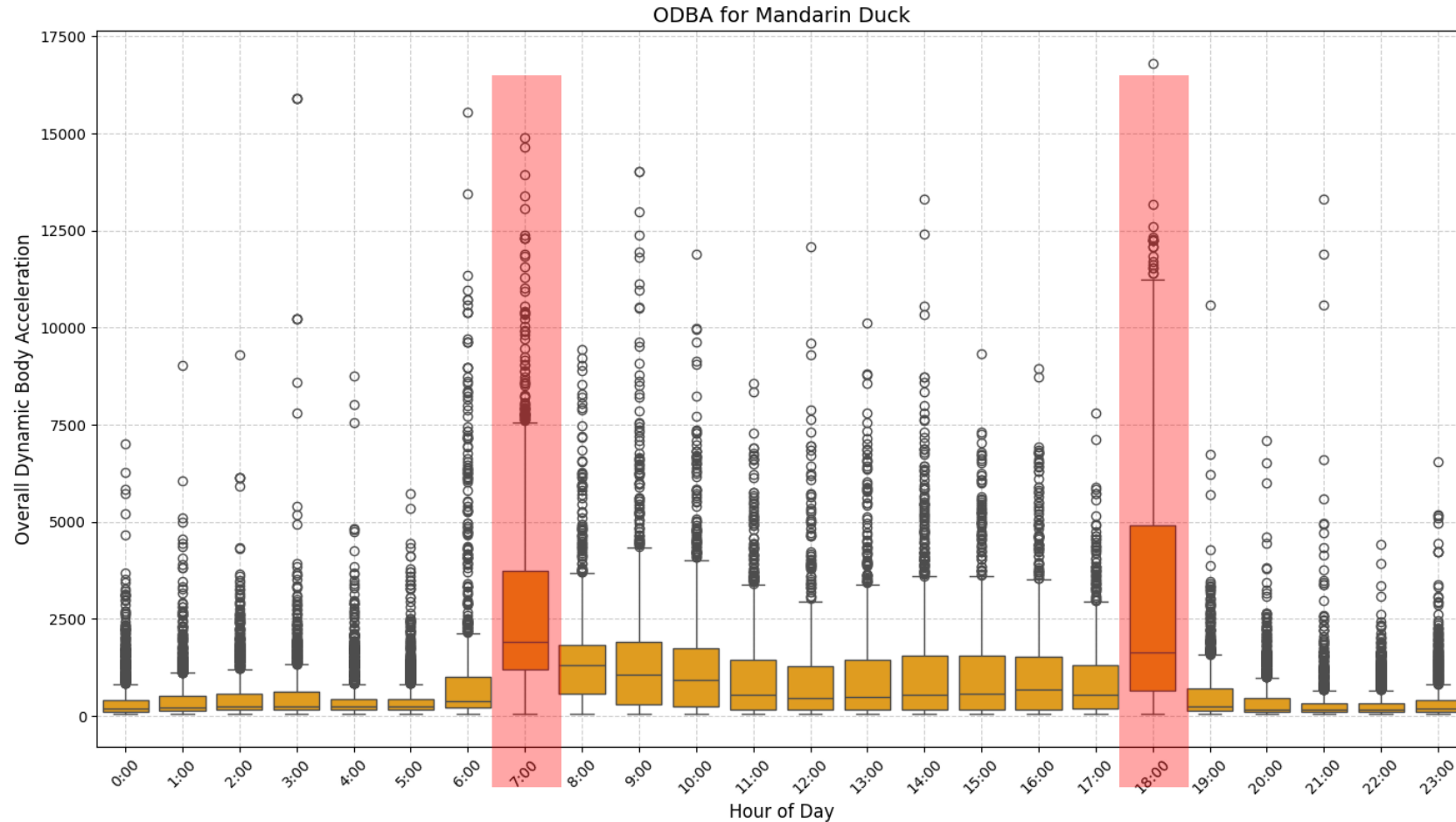
Classification of behaviors with ODBA data

1. Immobility,
2. Foraging and other movements on land/water
3. Flying



RESULTS

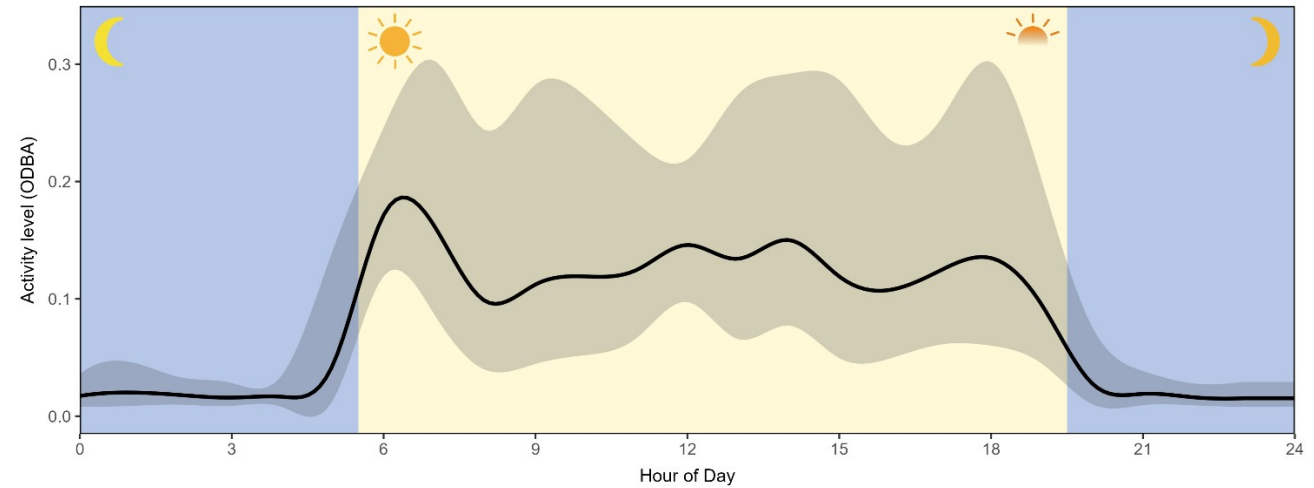
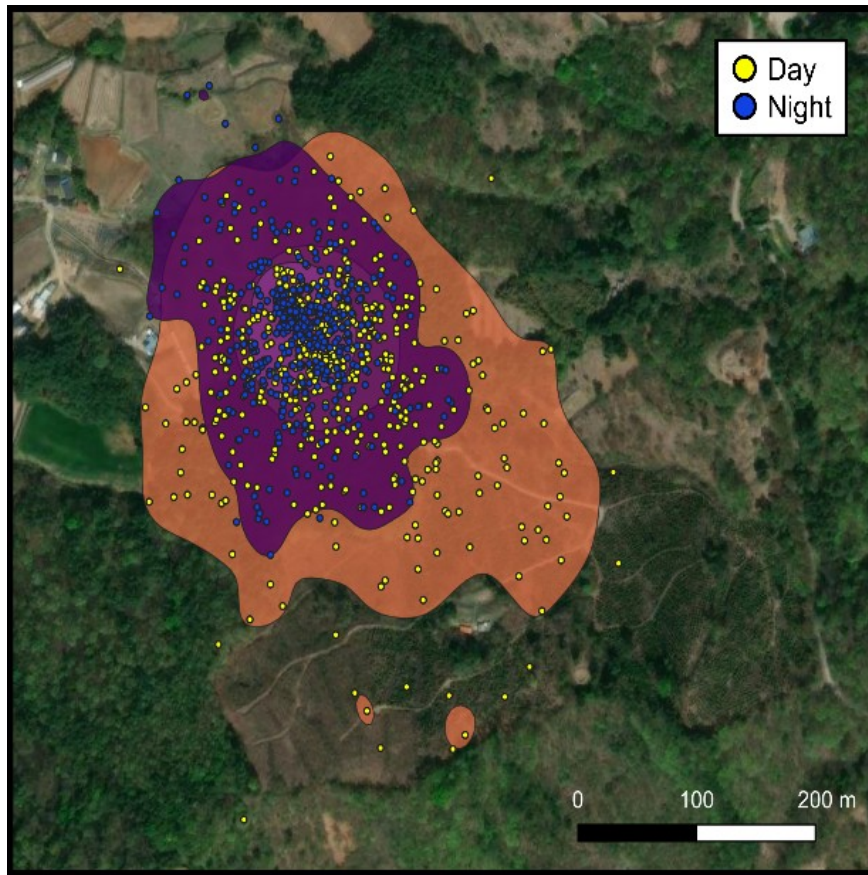
Mandarin duck acceleration



- Most active at near sunrise and sunset time (with flying)
- Foraging and/or swimming at daytime
- Resting at nighttime

RESULTS

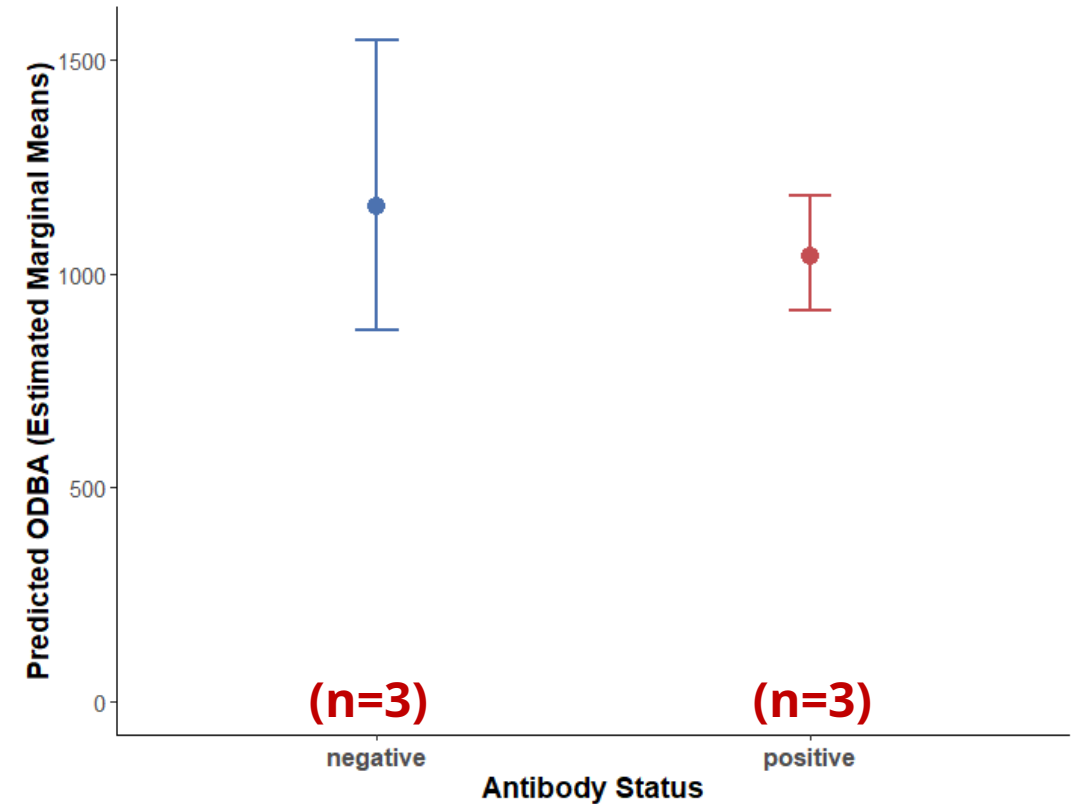
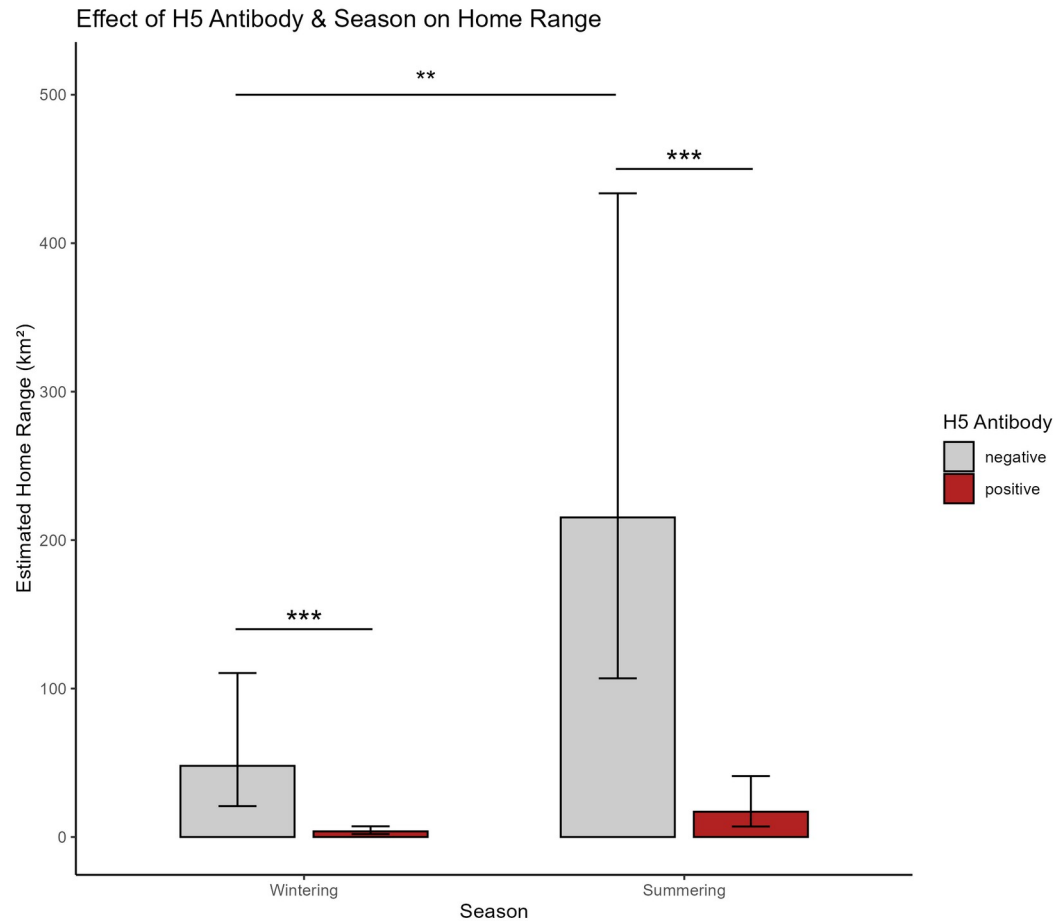
Mandarin duck acceleration



- More moving distances at daytime
- Still, the movements are highly concentrated in their home ranges (within 0.04 km²)

RESULTS

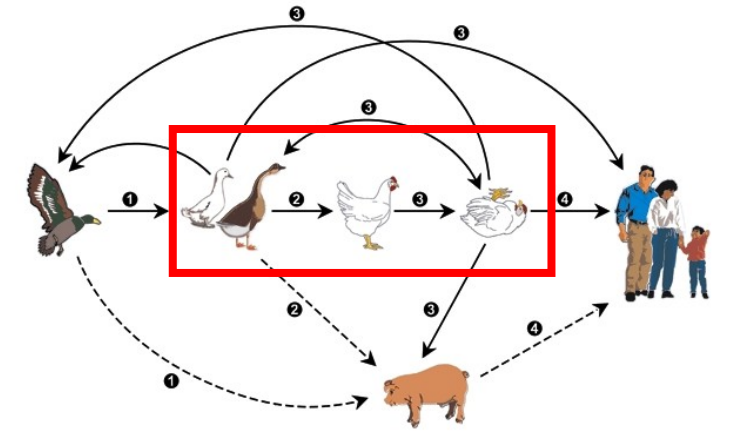
Mandarin duck acceleration with H5 antibody



- Individuals with H5 antibody had less home ranges both in summer and winter
- Individuals with H5 antibody had less active than others

DISCUSSION

1. In 6 out of 7 clusters, at least 4 poultry farms were grouped into a single cluster.
 - This pattern indicates **farm-to-farm transmission**
 - Transmission mediated by indirect contact through sequential visits of vehicles (feed/egg transport, manure management, and biosecurity operations) (Yoo et al., 2021)
2. Raptors were consistently detected later than waterfowls.
 - This delayed infection in raptors reflects a **secondary transmission** route via the consumption of infected birds (Ringenberg et al., 2024)



Farm-to-farm transmis-
sion



Raptor predation on wild birds

<https://www.youtube.com/watch?v=jRDeI7P3Tps>

DISCUSSION

3. Every winter season, wild birds approached poultry farms.

- In particular, Mallards, Mandarin ducks, and Spot-billed ducks were the primary species observed approaching poultry farms, and are considered bridging hosts for **initial viral introduction**
- **Mallards** showed the highest HPAI detection rates during 2019–2022 (Na et al., 2022), while **Mandarin ducks** are regarded as the index host in which the virus is first detected (Lee et al., 2011; Jeong et al., 2020)
- All three species are **partial migrants**; if the virus spreads from migratory to resident individuals, it could circulate domestically year-round
- The three species also show **overlapping habitat use** (Yun et al., 2022), creating conditions that facilitate efficient viral transmis-

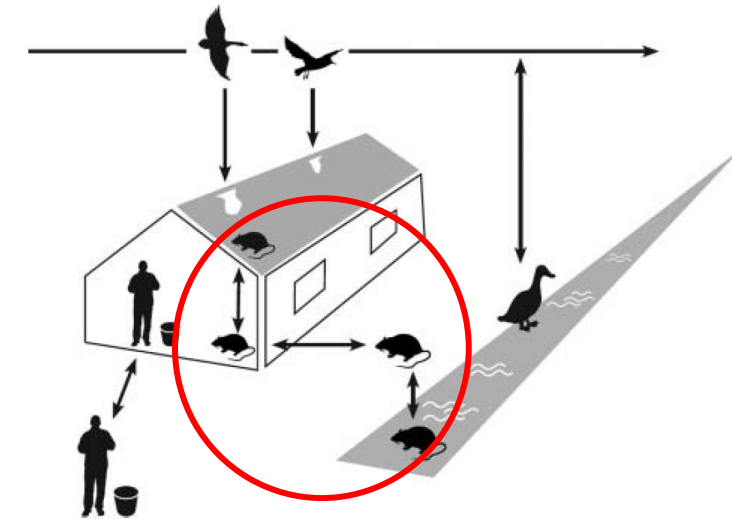


Wild duck flocks using reservoirs

<https://www.ecotiger.co.kr/news/articleView.html?idxno=5443>

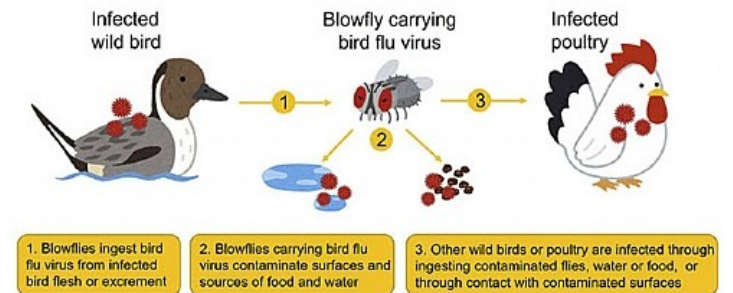
DISCUSSION

3. Every winter season, wild birds approached poultry farms.
 - Tracking data show wild birds closely approaching farms without direct physical contact
 - Direct farm entry by wild birds were not observed (minimum distance: 43.95 m)
 - Therefore, the virus is highly likely transmitted via **indirect intermediate vectors** (e.g., vehicles, workers, rodents, or flies) rather than direct interaction. (Fujita et al., 2024; So et al., 2019; Velkers et al., 2017)
4. All species predominantly used water bodies.
 - Water bodies used by wild birds should therefore be designated as high-risk zones and incorporated into **biosecurity**



Rodent entry into farms

(Velkers et al., 2017)



Source: Kyushu University

Transmission of AI via blowflies

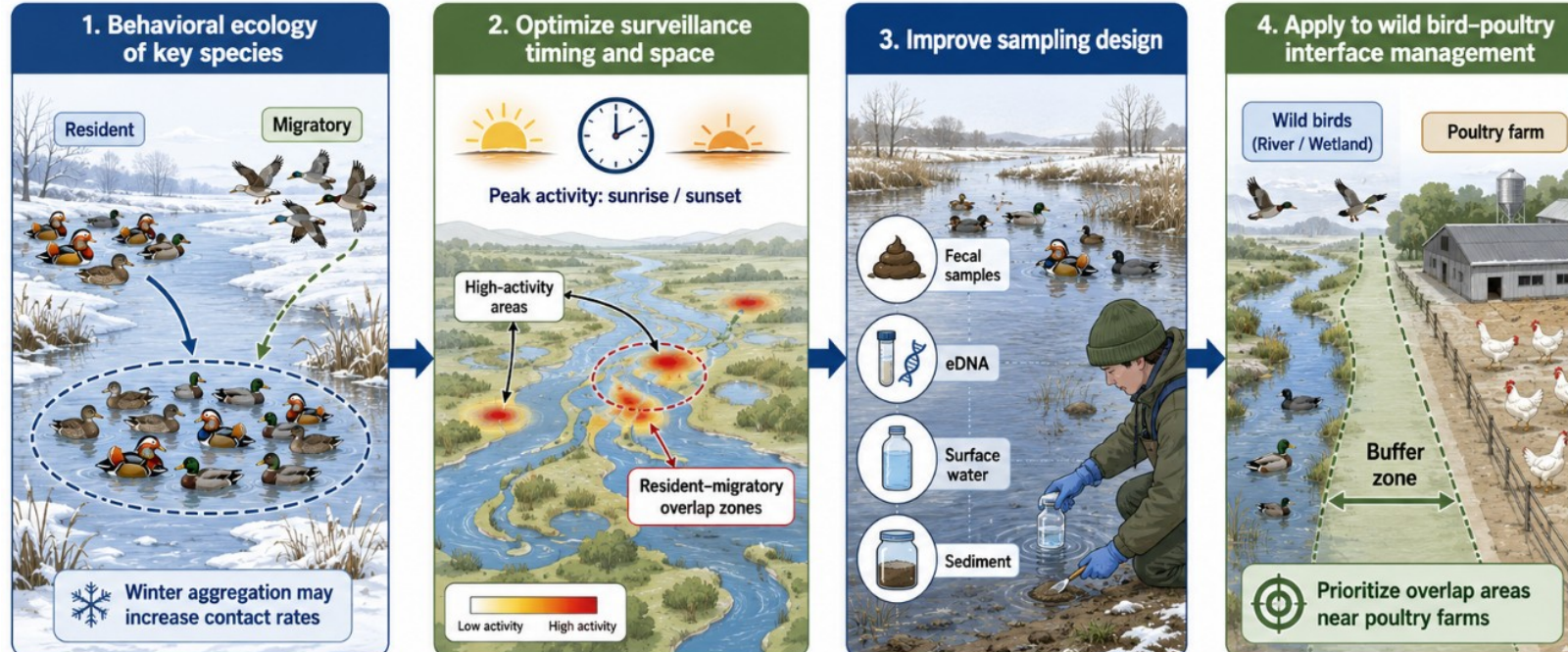
(Fujita et al., 2017)

DISCUSSION

5. Different habitat use of mandarin ducks

- Apply their behavior ecology to prevent disease prevention
- Optimization of surveillance timing → sunrise and sunset time
- Prioritization of surveillance areas → in high-activity zones
- Improvement of sampling design → considering their aquatic

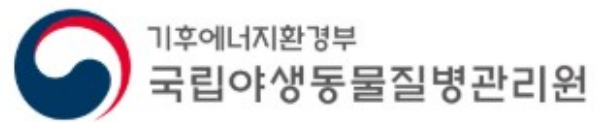
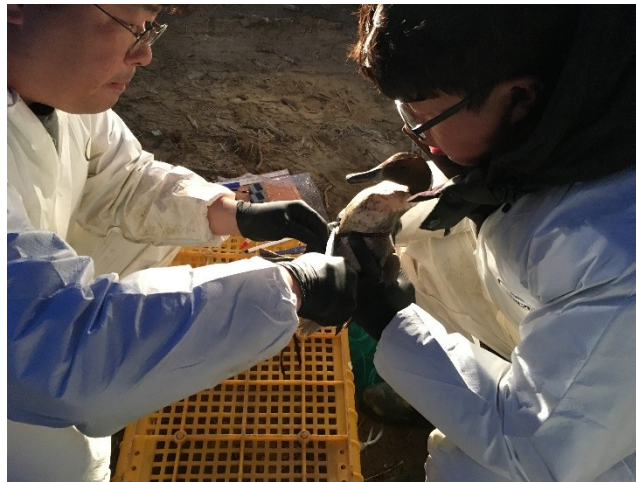
habitats



Thank you!



Yoo bin Lee



Dr. Hyunjun Cho



Prof. Dong-Hun Lee
Ye-ram Seo