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Report on the Eradication of Nutria (*Myocastor coypus* Molina, 1782), an Invasive Alien Species, from Jeju-do, South Korea[1a]

- Case of Songdang-ri, Jeju-si -

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제주도 침입외래생물 Nutria (*Mycastor coypus* Molina, 1782)의 퇴치 사례 보고[1a]

- 제주시 송당지역의 사례 -

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ABSTRACT

This study was conducted to eliminate *Myocastor coypus*Molina, 1782 (Nutria) from Jeju Special Self-Governing Province, South Korea. Habitat identification and eradication were carried out from September to November 2013, and a survey was carried out until June 2022 to check whether the eradication was successful. The habitat was identified with unmanned cameras, interviews, and literature surveys, and the capture was performed using the trapping method with food to attract nutria to the habitat area. The study area for the follow-up survey, which was set relatively wide considering nutria's home range, included wetlands and rivers within 4.0 ㎢of the habitat area (eradication area). As a result, nutria's habitat was confirmed only at Songdang Ranch, Songdang-ri, of Jeju Island, with traces of habitat (footprints, excrement, and burrows) confirmed in waterways and ponds within the pasture. Eight individuals were captured, including four females, three males, and one individual in too advanced a state of decay to identify the sex. The follow-up survey thoroughly investigated the habitat and its surroundings, focusing on three areas with permanent water, Seongeup Reservoir, Cheonmi Creek, and Molsuni Pond, but no signs of habitat were identified. Therefore, it is determined that nutria inhabiting Jeju Island has been completely eradicated. It is believed that the successful eradication of nutria in the Jeju Special Autonomous Region was possible due to a synergy between

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1) the eradication of nutria at the beginning of the settlement phase through rapid capture after confirming the nutria habitat and 2) the delayed expansion period because of rare presence of wetlands, where water is constantly stagnant, on Jeju Island. These results imply that quickly identifying the ecological characteristics of the species and preventing disturbances before they or at the beginning of the ecological disturbance through control and eradication at the initial stage of settlement before the expansion stage is an effective measure to cope with the influx of alien species.

KEY WORDS: NUTRIA, ERADICATION, TRAPPING, HABITA, ECOLOGICAL DISTURBANCE

요 약

본 연구는 제주특별자치도에 유입된 *Myocastor coypus* Molina, 1782 (Nutria)의 퇴치를 위해 이루어졌다. 서식확인 및 퇴치는 2013년 9월부터 2013년 11월까지 이루어졌고, 그후 퇴치 성공여부를 확인하기 위해 2022년 6월까지 조사가 이루어졌다. 서식 확인 및 포획은 무인카메라, 청문조사, 문헌조사, 먹이유인을 통한 트랩 포획법을 사용하여 진행하였다. 후속조사는 Nutria의 행동반경을 감안하여 조사범위를 비교적 넓게 설정하여 서식지역(퇴치지역)을 중심으로 4.0㎢ 내 습지 및 하천 조사를 진행하였다. 그 결과 서식 확인지역은 제주특별자치도 제주시 구좌읍 송당리 소재의 송당목장에서만 발견되었으며, 방목장 내 수로와 연못에서 서식흔적(족적, 배설물, 굴)이 확인되었다. 포획개체는 총 8개체였으며, 암컷 4개체, 수컷 3개체였다. 1개체는 서식확인 시 확인되어 부패 정도가 심해 암·수의 구별이 어려웠다. 후속조사는 설정한 조사범위 내 항시 물이 있는 성읍저수지, 천미천, 몰순이못을 중심으로 서식지와 그 주변을 정밀조사하였으나 서식흔적이 확인되지 않았다. 따라서, 제주도에 서식하는 Nutria는 완전히 퇴치된 것으로 판단된다. 제주특별자치도에서 Nutria의 퇴치가 성공적으로 이루어진 것은 Nutria의 서식 확인 후 빠른 포획을 통해 정착단계 초기에 퇴치가 이루진 것과 제주도 지질 특성상 물이 항시 고여있는 습지가 드물어 확장의 시기가 늦어진 것이 시너지 효과를 일으켜 성공적인 퇴치가 이루어진 것으로 판단된다. 이 결과들은 외래종의 유입에 대한 대처는 그 종의 생태특성을 신속하게 파악하고, 올바른 대처를 통해 확장단계 이전 정착 초기 단계에서 관리 및 퇴치를 통해 교란이 일어나기 전 또는 교란 초기에 차단하는 것이 매우 효과적인 방법임을 시사한다.

주요어: 제주특별자치도, 생태특성, 서식지역, 트랩 포획, 교란

INTRODUCTION

Alien species refer to organisms that are artificially or naturally introduced from a foreign country or outside area and that exist outside their original place of origin or habitat. With continued economic development from global industrialization and the corresponding increase in transportation such as aviation and shipping, the scope of human activities such as international trade and movement between countries has greatly expanded. Moreover, increased movement of living organisms due to anthropogenic or natural causes such as climate change has led to the spread of alien organisms (Wilson, 1995; Williamson, 1996; Banks *et al.*, 2015). The Convention on Biological Diversity defines an alien species as one that threatens an ecosystem, habitat, or species, and the International Union for the Conservation of Nature (IUCN) defines alien species as ones that settle in natural or semi-natural ecosystems or habitats, cause change, and threaten indigenous biodiversity.

Nutria has since been designated as one of the world's top 100 invasive alien species according to the IUCN (Lowe *et al.*, 2000; Kil *et al.*, 2015). Currently, the Ministry of Environment of the Republic of Korea has designated and manages 35 species of wild animal as ecosystem-disturbing wildlife that has been artificially or naturally introduced from foreign countries, and that disturb or are likely to disturb the balance of the ecosystem. Among them, Myocastor coypus Molina, 1782 (Nutria) is native to parts of South America, including southern Brazil, Bolivia, Paraguay, Uruguay, Argentina, and Chile (Cabrera and

Yepes, 1940; Abbas, 1998). Nutria was introduced to South Korea in 1985 for food and fur production. However, many introduced individuals began to inhabit the wild after farms stopped breeding and managing them (Kinler, 1992; Woods *et al.*, 1992; Bounds, 2000; Carter and Leonard, 2002). Nutria damage is mainly caused by feeding and digging. Specifically, nutria cause damage by digging burrows in rivers and causing flooding of waterways, by collapsing levees or dams, and gnawing vegetables, grains and fruits in cultivated land (Schitoskey *et al.*, 1972; Linscombe *et al.*, 1981; D'adamo *et al.*, 2000). Nutria was first bred in Jeju Special Self-Governing Province in 1994, with approximately 7,000 nutria bred on 11 farms. However, the profitability of nutria farming declined sharply because of an absence of distribution channels. As farmhouses gradually gave up breeding nutria, they released the animals into nature. At the end of 2010, all nutria farms in Jeju Special Self-Governing Province had stopped breeding (Lee *et al.*, 2012; Kim and Oh, 2017). Furthermore, because of the climate characteristics of Jeju Special Self-Governing Province, many nutria exist in locations gradually threatened by global warming, causing serious damage and a major ecological disturbance that threatens protected areas of this province (Kil *et al.*, 2012). The appearance of nutria in the natural ecology of Jeju Special Self-Governing Province was reported intermittently in the 2000s, with trace information confirming their habitat in the mid-mountainous waterway of Mt. Hallasan (National Institute of Environmental Research, 2008, 2011; Kil *et al.*, 2011; National Institute of Ecology, 2015).

To date, several studies have been published on the habitat of nutria in Jeju Special Self-Governing Province. However, a study by Kim and Oh (2017) is the only example of research into nutria management. Therefore, the aim of this study is to follow the work of Kim and Oh (2017) by describing the successful eradication of nutria, an ecosystem-disrupting species inhabiting Jeju Special Self-Governing Province.

MATERIALS AND METHODS

1. Research area

A Study on Jeju Special Self-Governing Province, Inland Wetlands of D/B Creation Data (Jeju Green Environment Center 2013) was a major wetland survey conducted in Jeju Special Self-Governing Province from 2011 to 2013, which confirmed the locations of nutria habitat traces. In addition, previous monitoring studies on ecosystem-disrupting species confirmed habitat traces in the pasture area of Songdang-ri, Gujwa-eup, Jeju-si, Seongeup-ri, Pyoseon-myeon, Seogwipo-si (Figure 1), and an area with a radius of 2 km (Kil *et al.*, 2011; Lee *et al.*, 2012). Therefore, these areas were selected for the

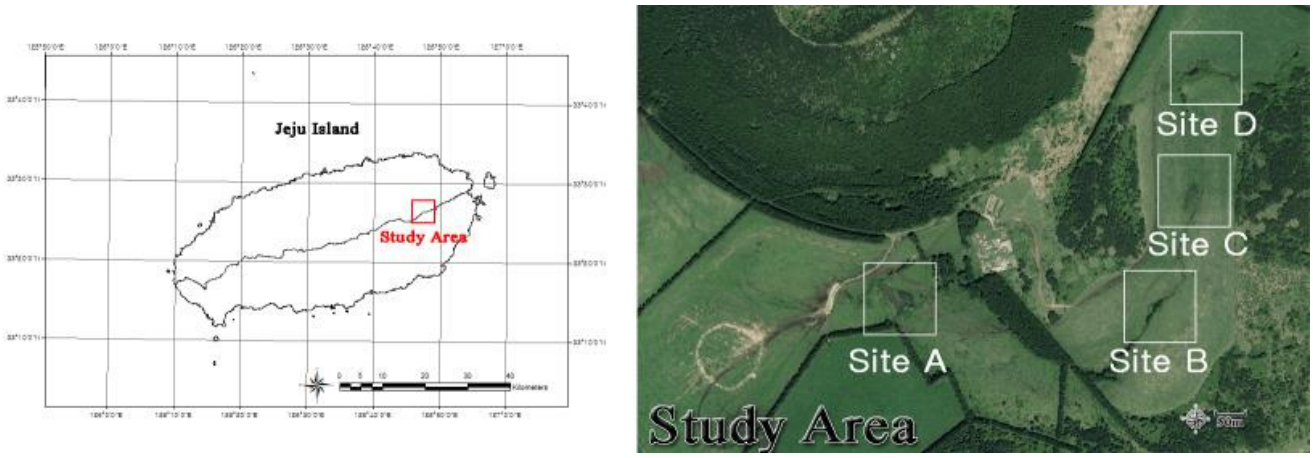

Figure 1. Map of survey locations. Surveys were conducted where habitat traces (footprints, burrows, excrement, etc.) were confirmed, i.e., in the waterway of Songdang Ranch around Songdang-ri, Gujwa-eup, Jeju-si, Seongeup-ri, Pyoseon-myeon, Seogwipo-si, and Jeju-si. Site A: Water tank connected to the waterway for cattle to drink; Site B: wetland where water is permanently stagnant in the middle of the waterway; Sites C and D: wetlands where water gathers temporarily in rainy weather.

eradication of nutria and follow-up investigations in this study (Kim and Oh, 2017).

2. Dates of surveys

Field surveys and capture were conducted from September 3, 2013, to November 26, 2013. After the last individual was captured on November 26, 2013, the first follow-up survey was conducted until December 2015. Subsequently, to determine whether the final eradication was successful, a second follow-up survey was conducted at least once per month for approximately six years and six months, until June 12, 2022, by expanding the expected range of habitat to include other wetlands. A total of 164 surveys were conducted in this study.

3. Investigation method

Suspected areas of nutria habitat were selected by referring to a press release and conducting interviews with ranch owners and ranchers. In addition, an unmanned camera (Browning Trail Camera, model BTC-7A, USA) was installed along the water system, which is essential for nutria habitat, and field surveys were conducted in and around the water system. In the field survey, a number of traces (i.e. footprints, excrement, and burrows) were investigated.

Ten unmanned cameras were operated to confirm nutria habitat and capture nutria. Six unmanned cameras were installed at locations A and B (Figure 1), where water was permanently stagnant, and all habitat traces (excrement, footprints, and burrows) were confirmed (Figure 2i, ii, iv, v). In addition, two cameras were installed at locations C and D, where only excrement was confirmed, and the water was temporarily pooled to check whether nutria had been captured or currently inhabiting the area.

Live traps of two sizes (106 × 50 × 60 cm; 152 × 40 × 46 cm; self-produced, made in South Korea) were used for trapping. A total of eight traps were installed along the water system by installing two traps in each location with confirmed habitat traces (visual observation, excrement, footprints, burrows, etc.). Therefore, the food used for catching was a mixture of plant food (sweet potato, radish, Chinese cabbage, carrot) and animal food (fish cake, sausage). Each trap was installed in a place where root plants did not thrive along the water system, and the food was placed inside the trap. In total, 200 g of carrots, 300 g of Chinese cabbage, 500 g of radish, and 200 g of sweet potatoes were used as vegetable feed, and 100 g of sausage and 100 g of fish cake were used as animal feed. A small amount of food was scattered outside each trap and used as bait. At intervals of 1–4 days, the trap bait was exchanged, capture was confirmed, and the surrounding area was investigated for habitat traces.

According to Milholland *et al.* (2010), the home range of nutria is 14.8 ha for males and 2.9 ha for females, reaching a maximum of 0.148 km^2. In the follow-up survey conducted after nutria eradication, the survey range

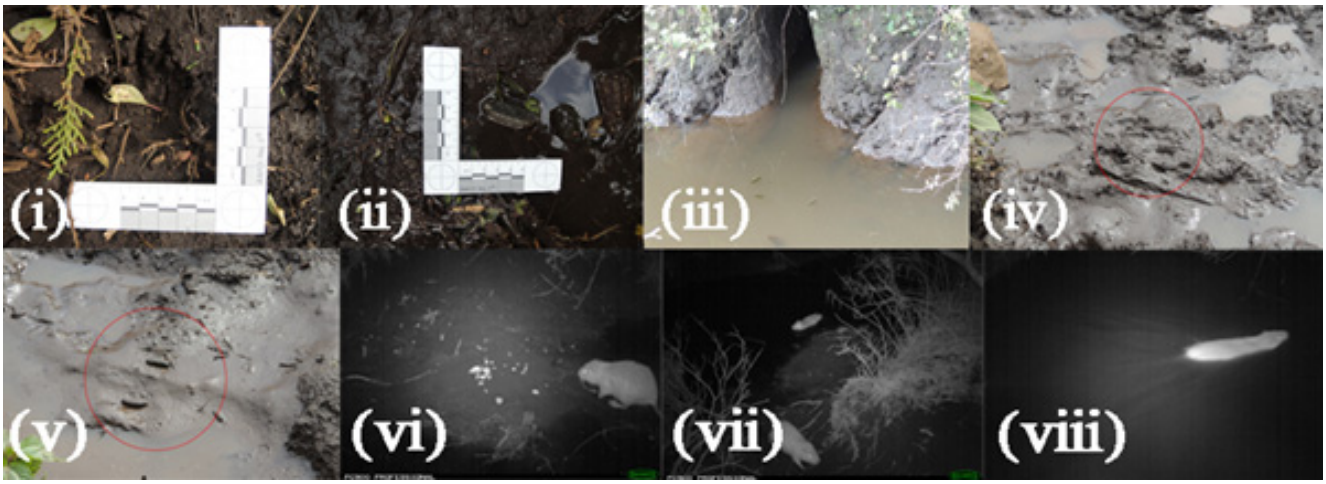

Figure 2. Nutria habitat traces and nutria captured by unmanned cameras. i, iv: Nutria footprints; ii, v: nutria feces; iii: nutria cave; vi, vii, viii: capture by unmanned cameras.

was set by referring to these home ranges. On Jeju Island, temporary wetlands may occur because of rainfall; therefore, the investigation scope had to be relatively broad. Specifically, a survey area of 4.0 ㎢ centered on the habitat area (eradication area) was employed for follow-up investigations. The success or failure of rodent eradication was determined according to the 'wait and see' method, which has been used since the first successful eradication of rodents on Maria Island, New Zealand, in 1964 (Nathan *et al.*, 2015). The 'wait and see' method observes the appearance area for two years, looking for any re-appearance of the species or re-reproduction after approximately two years. According to this method, eradication is declared successful if the same species does not emerge after two breeding seasons (approximately two years) (Nathan *et al.*, 2015; Russell and Broome, 2016; Russell *et al.*, 2017).

RESULTS AND DISCUSSION

1. Unmanned camera investigation

Nutria were not confirmed by the unmanned cameras at locations C or D, but were photographed 15 times (Figure 2vi, vii, viii) at locations A and B (Figure 3). The nutria active period was between 21:17 and 02:48, which is consistent with previous results (Wood, 1992) that nutria inhabiting Jeju Island are nocturnal and mainly active at night, as for wild nutria in South Korea and other countries. However, in one of the 50 field surveys conducted during the nutria capture campaign, an individual was observed feeding during the daytime at approximately 15:30. This behavior is indicative of their freedom to roam for food during the daytime if feeding activity was insufficient at night.

2. Nutria capture

The presence and habitat traces (wooden dogs, excrement, footprints, and burrows) of nutria were confirmed through literature and monitoring in the waterway crossing the Songdang Ranch. A total of 11 observations were made at location A, including one visual observation, four excrement traces, three footprints, and two burrows. At location B, two visual observations (different individuals), three excrement traces, one footprint, and one burrow were confirmed, totaling seven

Figure 3. Nutria identification and capture.

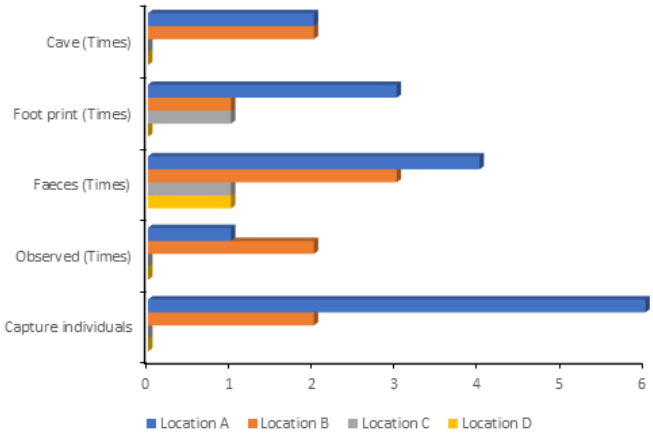

Figure 4. Habitat traces and capture individuals identified at each location.

Table 1. Survey and Capture data of Nutria

Times	Date	Result of survey	Survey contents
1	14, Jul.	1 individual	preliminary survey
2	3, Sep.	-	survey of nutria
3	12, Sep.	-	survey of nutria
4	26, Sep.	-	survey of nutria
5	9, Oct.	-	survey of nutria
6	15, Oct..	excreta, cave, foot print	setting live trap and survey of nutria
7	17, Oct.	excreta, cave	setting unmanned camera, live trap and changed bait
8	18, Oct.	live nutria, cave	setting unmanned camera and survey of nutria
9	20, Oct.	-	
10	24, Oct.	-	
11	26, Oct.	capture 1 individual	
12	27, Oct.	-	
13	28, Oct.	capture 2 individuals	
14	31, Oct.	-	
15	1, Nov.	capture 2 individuals	
16	2, Nov.	capture 1 individual	check unmanned camera, changed bait and survey of nutria
17	3, Nov.	excreta	
18	4, Nov.	excreta	
19	6, Nov.	-	
20	8, Nov.	capture 1 individual	
21	9, Nov.	-	
22	14, Nov.	-	
23	17, Nov.	-	
24	21, Nov.	-	
25	26, Nov.	-	

observations. At location C, one excrement trace and one footprint were confirmed, and at location D, only one excrement trace was confirmed. Of these, five live individuals and one dead nutria were captured at location A, and two individuals were captured at location B; thus, a total of eight nutria were captured in this study (Figure 4, Table 1). In locations A and B, where both nutria presence and habitat traces were confirmed, grassland was more widely distributed than the shrubs around the river. In contrast, grassland and shrubs were mixed around locations C and D. Location A was a pond formed in the middle of a waterway crossing the Songdang Ranch, and location B had permanently stagnant water among the connected waterways (Figure 3). At locations C and D, wetlands formed with temporary stagnant water during rainfall episodes. Previous studies have reported that nutria prefers to inhabit areas where water is permanently stagnant and grassland is dominant (Gosling, 1979; Lee *et al.*, 2012). Therefore, the locations of nutria captured in our study is consistent with those reported by previous research.

One of the captured individuals had been dead for a long time, with substantial deterioration and only the hair and skull remaining; thus, it was not easy to distinguish its sex. Four of the seven confirmed specimens were female and three were male. Therefore, the proportion of females was higher at 57.14%. However, placenta and mammary gland development were not conspicuous in the fallopian tubes of the captured female nutria, so they were unlikely to have previously given birth (Kim and Oh, 2017).

Several complex factors, such as lack of water and food and interference from natural enemies, are valid reasons for the observed reproduction failure of the captured nutria. However, the number of individuals living on Jeju Island was significantly smaller than that in other regions; therefore, the contributing factors could not be identified because of a lack of population parameters. Nutria are herbivores and feed mainly on plant food, but can also feed on both fish and insects (Miyazaki *et al.*, 2022); therefore, it is difficult to explain reproduction failure by an absence of food. Also, as a rodent, nutria can conceive all year round, give birth to approximately 10 individuals at a time, and have a gestation period of approximately 130 days (Wood, 1992), which makes reproduction very easy. Therefore, reproduction failure because of natural enemies is also unlikely. As such, the amount of water is considered the most likely reason for reproduction failure. This conclusion should be corroborated by future research into the correlation between various surrounding conditions and reproductive failure in an area with sufficient parameters.

3. Follow-up study

There are three permanent wetlands within 4.0 ㎢ of the primary nutria habitat in Jeju Special Self-Governing Province: the Seongeup Reservoir (Figure 5b), Cheonmicheon stream (Figure 5c), and Molsuni Pond (Figure 5d). Temporarily unnamed small wetlands were excluded from the follow-up study (Figure 5a). Seongeup Reservoir is a relatively large artificial managed reservoir of approximately 236 ㎡. Cheonmicheon stream is usually dry, and surrounded by sparsely regular wetlands; Figure 3c shows the location where the wetlands are maintained within the survey range. Molsuni Pond is a permanent but shallow wetland that is relatively small except when it rains. Including the nutria eradication area, habitat traces such as feces, footprints, and burrows were investigated for approximately six years and six months, predominantly in these wetlands. Interviews with residents and workers were conducted over the same period, but no habitat traces or presence were confirmed. Therefore, according to the 'wait and see' method (Nathan *et al.*, 2015), nutria were considered to have been completely eradicated.

4. Nutria management plan

The first official record of Nutria's escape or release from the Korean Peninsula was open in 2006. However, because of a delay in administrative procedures, nutria were only designated as an ecosystem disturbance organism on June 1, 2009, approximately three years later. In 2013, the possibility of eradicating nutria was reviewed while operating a pilot eradication project. In 2014, a plan was established to eradicate before they attained a widespread distribution, and full-scale eradication began (Ministry of Environment, 2014). As such, after nutria were first identified in the wild, the full-scale eradication project began approximately seven years later. Species expansion in a new area goes through the following stages: establishment, expansion, and saturation after migration

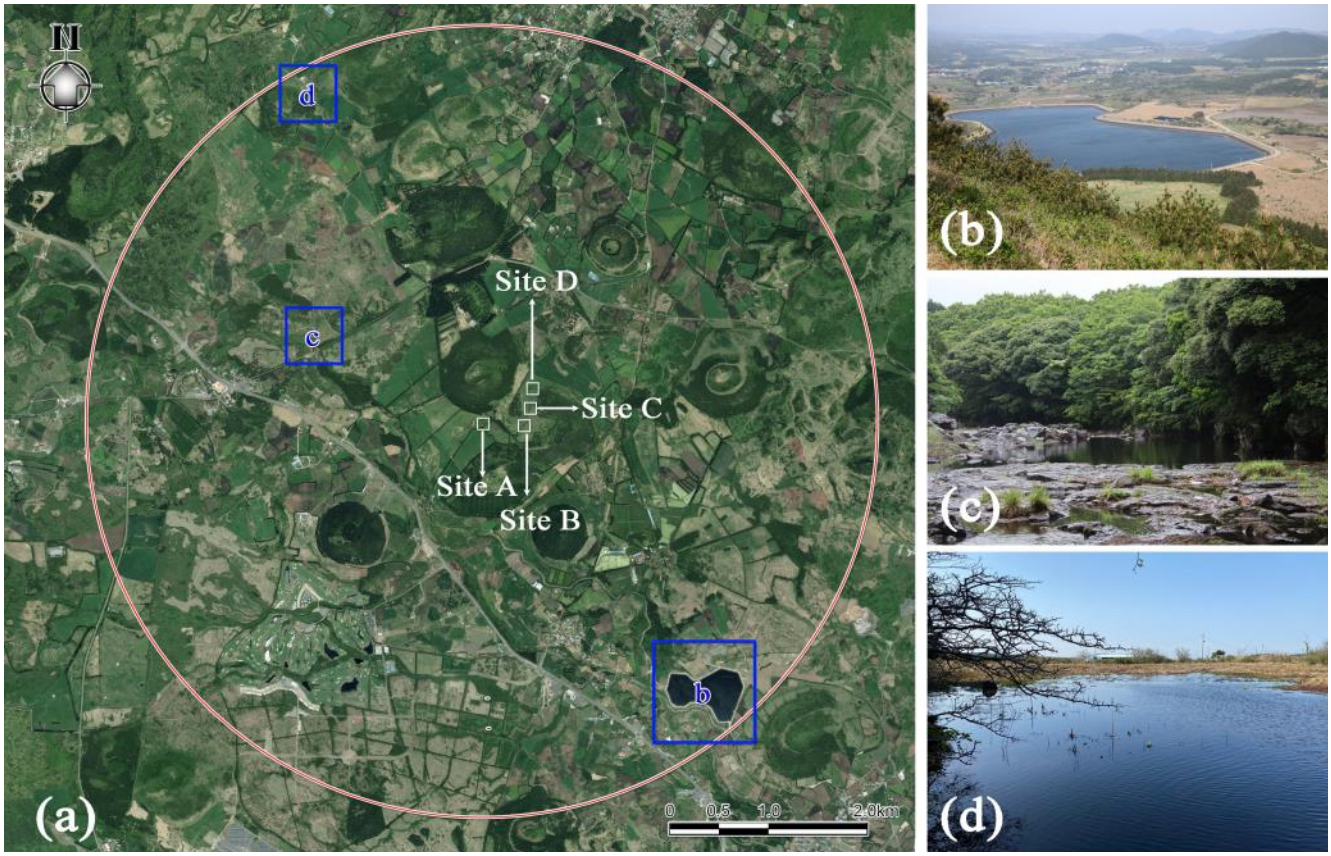

Figure 5. Major wetlands within a 4-km radius of nutria habitats. A. Expected range of nutria habitat; B. reservoir of Seongeup; C. Choen-mi Cheon; D. Molsuni Pond wetland.

(Shigesada and Kawasaki, 1997). In the case of the Korean peninsula, full-scale management (capture and eradication) began only after entering the expansion stage following the initial stage of nutria introduction and settlement (Kil *et al.*, 2011; Lee *et al.*, 2012; National Institute of Ecology, 2015; Kim and Oh, 2017). By this time, nutria had already spread to Busan, South Gyeongsang province, Daegu, North Gyeongsang province, and North Chungcheong province, centering on the Nakdong River water system.

Previous studies could not confirm nutria habitats on Jeju Island because their results were based on data from interviews and literature. However, Kil *et al.* (2011) confirmed their habitats by observing footprints, feces, burrows, and carcasses. Then, in mid-2013, research on capture and management methods began, and nutria capture occurred relatively quickly. The soil of Jeju Island comprises porous volcanic rocks and volcanic ash, so water is rapidly absorbed as groundwater after precipitation. Therefore, most rivers remain dry, except in rainy weather (Jung & Yang, 2009), which greatly restricts the movement and diffusion of nutria. As such, it is likely that the habitat range of nutria spread more slowly on Jeju Island than on the mainland. These geological features and rapid response created a synergistic effect, resulting in successful nutria eradication.

In conclusion, the introduction of alien species can be effectively managed by rapidly identifying the ecological characteristics of the species then taking corrective measures in the early stages of establishment, prior to the expansion stage, when concerns about ecosystem disturbance are first confirmed. The most effective method involves blocking the introduction of foreign species either before or at the beginning of ecosystem disturbance.

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