

Habitat Fragmentation by a Levee and Its Impact on Frog Population in the Civilian Control Zone

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제방으로 인한 생태계 분절이 민간인통제구역 양서류에 미친 영향

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Abstract

We examined whether an artificial levee constructed on prime amphibian habitat influences fragmentation. Four different sites on both sides of a levee in the Civilian Control Zone(CCZ) were probed. Sites 1 and 2 are rice paddies on one side of the levee, and Site 3 is the stream that locates in the same side. All the three sites have water conditions of seasonal variance. On the other side, Site 4 consists of rice paddies with a stable condition of water supply, irrigated through a canal. The research sites were frequented and the frog populations were closely monitored. The investigation identified five species. *Pelophylax nigromaculatus* was the most frequent (n=295), followed by *Hyla japonica* (n=220) and *Glandirana rugosa* (n=124). Three *Bufo gargarizans* and eight *Rana coreana* were also found. The amphibians, however, were found to relocate themselves according to water condition to rice paddies or stream only within one side of the levee. Despite having ample sources of water and foods, Site 4 lacked large populations of frogs, even when droughts came. Both the species dominance index and the richness index indicated a more favorable living condition of the one side of the levee (Sites 1 and 2) over the other.

Key words : amphibians, Civilian Control Zone, levee, habitat fragmentation

요약

본 연구는 민간인통제구역에 건설된 제방으로 인한 생태계 분절이 양서류 서식지에 미치는 영향을 알아보기 위해 수행되었다. 이를 위해 제방 한편에 두 논(사이트 1, 2)과 제방 옆을 지나는 수내천(사이트 3), 그리고 제방 다른 편의 관개수로가 위치한 논(사이트 4)에 대해 7개월간에 걸쳐 조사를 실시하였다. 조사 결과, 주로 논과 수변지역에 많이 서식하는 참개구리(295개체), 청구개리(n=220개체), 옴개구리(124개체)가 주로 발견되었고 한국산 개구리(8개체)와 두꺼비(3개체)도 일부 확인되었다. 이 양서류들은 계절에 따른 물 공급 상황의 변화에 따라 논과 하천 지역에서 양적 변화를 보여 사이트 1,2,3에서 두드러지게 나타났으나 제방 반대편의 사이트 4에서는 풍부한 수자원에 불구하고 양적 변화가 적은 것으로 나타났다. 가뭄철 수내천에 물이 말라 이 지역 개구리들이 현저히 감소했을 때에도 물이 풍부하고 거리가 비슷한 제방 건너편의 사이트 4보다는 제방 같은 편의 사이트 1, 2 지역에서 다수의 개구리들의 존재가 확인되었다.

핵심용어 : 양서류, 민간인통제구역, 제방, 서식지 파편화

1. Introduction

The Demilitarized Zone, separating the two Koreas and with human activity being almost nonexistent here, has become a sanctuary for wildlife, as many in the scientific field have noted. Currently, many rare species are found in the DMZ, from the Gold Frog (*Pelophylax chosonicus*)

to the Long Tailed Goral (*Naemorhedus caudatus*) as well as a wide array of insect species. Most important are the numerous species of migratory birds, such as the infamous Red Crowned Crane commonly depicted in artwork throughout East Asia, and White-naped Cranes (*Grus vipio*) (Jeon, 2002; Sungchun Institute, 1996; Higuchi et al., 1996; Park et al., 2012)

Yet this small strip of biodiversity has been increasingly put under pressure. Construction and development have already affected South Korean part of the Civilian Control

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Line. What used to be pure wetland has been converted into rice paddies, roads, and levees (Park and Nam, 2013). A 42% increase in population and 55% increase in roads in the area was recorded. (Sung and Cho, 2012; John et al., 2003; Kim et al., 2011). Without laws properly protecting it from development and destruction, and the risk of an uncertain future amidst a tense political climate, the ecological future of the DMZ and nearby sites does not seem bright.

We wanted to find how development has affected the local ecosystems within the Civilian Control Zone (CCZ) which refers to a 5-to-10 km long swath of land between the DMZ proper and the Civilian Control Line in South Korea. In particular, habitat fragmentation can potentially be one of the most significant ecological problems that this area is currently facing. Fragmentation refers to a phenomenon in which a continuous stretch of habitat is divided into separate fragments (Hanski, 1999). Fragmentation that occurs due to human activity can lead to an irreversible loss of biological diversity (Olf and Ritchie, 2002; Wackernagel et al., 2002), by interfering in evolutionary processes (Levin, 1999), eradicating interior species population (Ehrlich and Ehrlich, 1981), and disrupting community interactions between populations (Wilcox and Murphy, 1985).

The CCZ has been directly affected through artificial habitat fragmentation. Sung and Cho (2012), as an example, reported that grass, agricultural, and forest habitats in Paju and Yeoncheon had been severely fragmented due to urban development in recent decades. Fragmented habitats and their impact on animal residents were investigated, as well (Park and Lee, 2002; Yoo et al., 2014). In a study comparing two sites in Kyunggi Province, it was found that more species of birds were observed in an agricultural area less fragmented by roads than the one more fragmented (Park and Lee, 2002). In the case of the CCZ, the feeding flock density of Red-crowned Cranes and White-naped Crane wintering in Cheorwon tended to become lower when closer to residential areas, military facilities, and roads with high traffic volume. (Yoo et al., 2014)

The studies abovementioned were a few cases addressing the issue of habitat fragmentation. In order to accumulate empirical data on habitat fragmentation and its impact on the ecological system, we examine how amphibians in the CCZ are influenced by fragmentation. When considering that amphibian populations worldwide is declining rapidly and the species is frequently deemed "indicator species" that display the relative health of the overall ecosystem (Waddle, 2006), monitoring amphibians (specifically frogs) in Korea

seemed urgent.

Regarding factors for habitat fragmentation, we examined a levee alongside a stream, with rice paddies on either side of the levee itself. There were governmental projects such as the "City of Paju stream implementation project," which addresses how streams in Paju will be used from January 2011 to December 2015 in a way to prevent floods, help agricultural production, and protect the environment. This project included the construction of levees wherever they are required, and the levee that is the main subject of our research today is one of them.

2. Methods

2.1 Study area

The study areas are Sunae stream and three nearby rice paddies in Paju, Kyunggi Province (37°91'14.30"N~37°91'51.76"N, 126°74'19.47"E~126°74'43.26"E). The area is located in the CCZ, a few kilometers south of the DMZ. The average annual temperature of the area is 10.2°C and average annual precipitation is 1,391mm.

We selected three rice paddies and a spot in Sunae stream itself, and visited the same four places once a month from March to September, 2014. The four sites have different characteristics (Fig. 1). Site 1 is close to a hill, humid with ponded water, and surrounded by rich bush that helps evade strong sunshine, high temperature, and predators. Various insects, such as beetles, butterflies, grasshoppers, crickets, and ants, were found in the foliage.

Site 2 has similar conditions to Site 1 except that the former is closer to the stream and more distant from the hill than the latter. Also, the slope to the stream is low and therefore Site 2 is more easily accessible to the stream. Site 3 is known as "Sunae stream," which flows into the Imjin River. Site 3, with flowing shallow water was also populated by many insects, but the water runs unlike the three other sites of paddies.

There was a levee next to the stream, and Site 4 consists of a group of rice paddies located across the levee. While we were not able to determine the exact population and species of insects available to the frogs in each site, it was noticeable that even a sweep of a net or hand in the shrubs or air of Site 4 produced some insects, implying a food-resource rich surrounding. Although Site 4 is another paddies with ants, grasshoppers, and much aquatic insects being found, it is somewhat different in two respects. First, it is separated from rest of the sites by a levee. Frogs, therefore, could move freely within Site 1, 2, and 3, but they have



Fig. 1. Location of the study area (left) and its zoomed-in view(right).

to cross the levee to reach Site 4. Secondly, an irrigation canal runs near the paddies, and water accordingly was provided in a stable manner regardless of the weather condition. In contrast, drought affected Sites 1–3 at some point in time.

2.2 Data collection

The investigation started in March 2014 and continued until September of the year. Five members of DMZ Ecology Research Institute participated in the data collection, which was conducted by walking around the perimeter of the rice paddies and stream, counting the number and species of frogs observed. A detailed procedure of the data collection was as follows:

- ① Applying the line transect sampling method (Burnham et al., 1980; Johnson and Routledge, 1985), the four sites were closely examined by walking along the rice paddies and bodies of water and observing and recording about amphibians detected in the two meter scope of the observer.
- ② Those detected were captured with a landing net so that the sensitive skin of amphibians would not be harmed.
- ③ Captured amphibians were temporarily stored in a bucket with water.
- ④ After the capturing was completed for one site, each amphibian was identified and relevant information, such as scientific name, sex if possible, degree of maturity (egg/

tadpole/ adult), snout vent length measured by vernier calipers, and location, was recorded.

⑤ Amphibians were released again after the identifying and recording were completed. When needed, some eggs and tadpoles were brought into the laboratory, and raised to identify species. They were released in the end to the place where they were captured.

2.3 Evaluation of biodiversity

The information on the amphibians identified in the field was categorized according to the site each was captured. In order to evaluate the biodiversity of each site, we calculated dominance index (Mcnaughton, 1967) and Biodiversity Index H' (Margalef, 1968). The DI was calculated by dividing the number of a particular species in a site by the total number of individuals in the site:

$$DI = n_i/N$$

(DI= dominance index;

n_i = the number of individuals of a particular species;

N = the total number of individuals in the site)

In the case of Biodiversity Index H' , Shannon–Weaver index (Rosenzweig, 1995) was calculated:

$$H' = -\sum P_i * \ln (P_i)$$

(H' = diversity;

$P_i = n_i / N$, $i=1,2,3,4,5$;

\ln = natural log)

Table 1. The monthly number of each species of amphibians observed in the four sites

Month	Egg mass	Tadpoles	<i>Hyla japonica</i>	<i>Bufo gargarizans</i>	<i>Rana coreana</i>	<i>Pelophylax nigromaculatus</i>	<i>Glandirana rugosa</i>
March	49	13	0	1	0	0	49
April	19	17000+	0	0	0	0	23
May	2	0	133	2	2	60	20
June	2	51	28	0	4	50	16
July	0	6	27	0	1	29	7
Aug.	0	0	23	0	1	114	7
Sep.	0	0	9	0	0	42	2
Total	72	17000+	220	3	8	295	124

Note: The egg masses and tadpoles were not identified since the main purpose of the current research is to investigate the distribution of adult frogs and their migration. The number of tadpoles was obtained by counting the number of tadpoles in a certain area (30cm*30cm) and using ratios to determine the total number(number of tadpoles captured : area of capture to X : total area).

3. Results

3.1 Species observed in the area

During the whole period of this study, five species of frog, egg mass, and tadpoles had been found: *Bufo gargarizans*, *Glandirana rugosa*, *Hyla japonica*, *Pelophylax nigromaculatus*, and *Rana coreana* (Fig. 2). Of these five species, *Pelophylax nigromaculatus* was the most frequently observed (n=295), followed by *Hyla japonica* (n=220) and *Glandirana rugosa* (n=124). Three *Bufo gargarizans* and eight *Rana coreana* were found as well (Table 1). In addition to these amphibians, a few species of reptile that feed on frogs, such as *Elaphe rufodorsata*, *Gloydus blomhoffi*, and *Rhabdophis tigrinus*, were also found in the areas except Site 3.

3.2 Population characteristics of the four sites

As *Pelophylax nigromaculatus* was the most frequently observed species of all the amphibians in the area, it was also the dominant amphibian species of the four sites except Site 1 where *Hyla japonica* was the most frequent. In the case of Site 3, the third-most frequently observed frog (*Glandirana rugosa*) was the dominant species in the beginning when the water ran through the stream (March ~ May). This pattern in general seemed to be consistent with the earlier findings that *Glandirana rugosa* prefers streams while *Pelophylax nigromaculatus* is frequently found in paddies (Chung et al., 2001; Gye, 2003).

The second-most frequently observed frog (*Hyla japonica*) was mostly found in Sites 1 and 2, where they can protect themselves from predators with their green color similar to that of the plants surrounding them (Fig. 3). It is possible that this is due to the fact that *Hyla japonica* is a tree frog, and prefers heavy foliage to large bodies of water. During the field research, they were first observed in May in Sites 1 and 2. Since then, we could not find



Zone. a= *Glandirana rugosa*; b=*Pelophylax nigromaculatus*; c= *Hyla japonica*; d= *Rana coreana*; e=*Bufo gargarizans*; f= egg mass; g= smaller tadpoles; h= mature tadpole

Fig. 2. Frogs observed in the four sites near Sunae stream in the Civilian Control Zone.

this species in other sites except for May and September when we found some in Sites 3 and 4.

The major purpose of this study is to examine whether the ecological system for the amphibians is fragmented by an artificial levee built in the Civilian Control Zone. This examination requires a comparison between the sites on both sides of the levee. When excluding the number of eggs and tadpoles whose species could not be determined, the

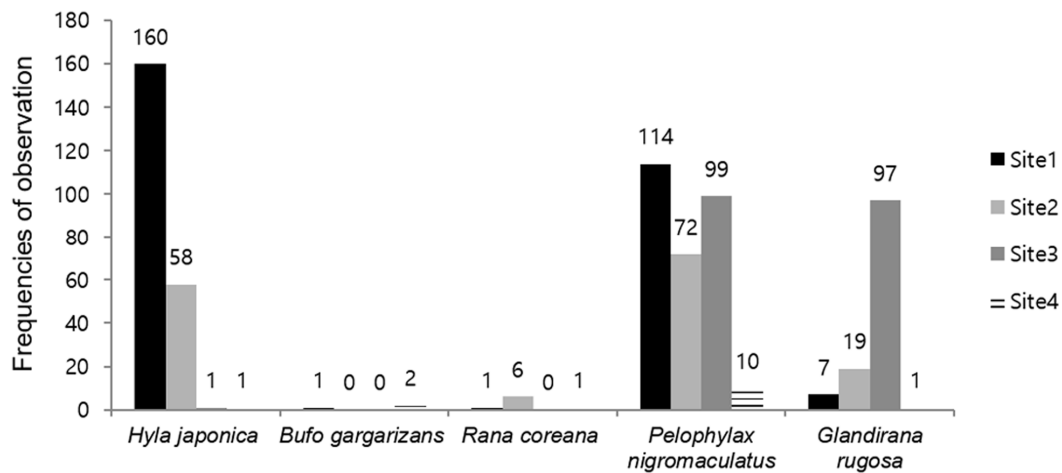


Fig. 3. Frequencies of observation of adult amphibians in the four sites.

most frogs were found in Site 1 (n=285), followed by Site 3 (n=197) and 2 (n=163). However, we found only 15 frogs in Site 4, even though the site also has a constant supply of water provided artificially through irrigation. Despite the most frogs originally being found in Sites 1 and 2, drought dried up the waters of the paddies, and the adult frogs were later found concentrated around Site 3, which still had water. The other side of the levee (Site 4) with much water was not populated by many frogs.

In addition, the two sites facing the levee showed a difference in ecological diversity (Table 2). The data from the Shannon–Weaver index showed that the relative richness of site 4 was much lower ($H' = 0.69$) than the average of Site 1 and 2 ($H' = 1.40$). Also, Site 4 tended to be dominated by a species, *Pelophylax nigromaculatus* ($DI = 0.67$), while Site 1 and 2 across the levee showed less tendency of dominance ($DI = 0.51$).

3.3 Pattern of migration over time

The relocation of the amphibians according to water situation in the four sites was also informative for figuring out habitat fragmentation. As seen in Fig. 4, most frogs were found in Sunae stream in Spring and April. Egg mass and numerous tadpoles were found in Sites 1 and 2 in April. (Table 1)

In the next month, Sunae stream started drying up and much more frogs were found in Sites 1 and 2, rather than 3, until July. *Glandirana rugosa* that was usually found in Site 3 in the beginning was observed more frequently in Sites 1 and 2 during the dry season (May ~ July). Accordingly, many dried up frog corpses were also found. At this time, the only remaining large bodies of water are on the other side of the levee, where the paddies are irrigated artificially (Site 4). Yet frog populations were much smaller compared to their counterparts on the other side of the levee. In fact, before the temperature started dropping in the autumn, frog populations were highly concentrated at

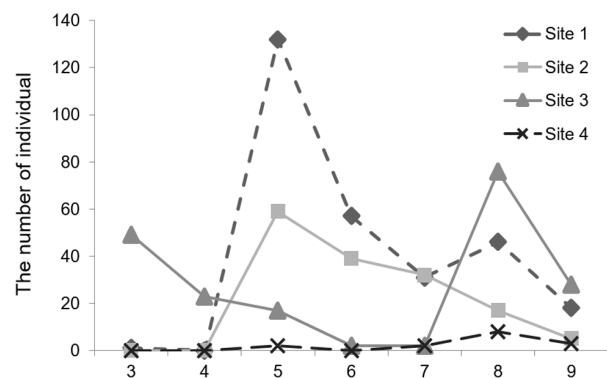


Fig. 4. The monthly number of adult amphibians observed in the four sites.

Table 2. Dominance and diversity of both sites across the levee

Site	Dominance (DI)		Diversity (H')		
	DI	Average	H'	Average	
Site 1	0.57	0.51	0.93	1.4	1.17
Site 2	0.46		1.93		
Site 3	0.5		0.72		
Site 4	0.67		0.69		

the edge of the levee, where adult frogs were constantly trying to move to the other side. In August, when Sunae stream was running again, the population of the amphibians in the stream rose again, and those in Site 2 reduced accordingly. These findings suggest that the amphibians have relocated their living areas according to water condition only within Sites 1, 2, and 3, which are not divided by an artificial levee.

4. Discussion

4.1 Implication

Together with the DMZ, the Civilian Control Zone has been considered as ecologically valuable areas with limited human access. The regions, however, are under pressure from human development, and a few studies have examined how agricultural/forest habitat has been fragmented (Sung and Cho, 2012), or how anthropogenic factors (i.e., human residence, military facilities, greenhouse, etc.) influence the distribution of the Red-crowned Crane and White-naped Crane wintering in this area (Yoo et al., 2014). We examined how habitats of amphibians in the CCZ are affected by a levee, considering the significance of amphibians as an indicator species for the overall health of the ecosystem.

As a result, the ecological fragmentation by the levee was actually associated with the limited pattern of frogs' movement; even though there was a permanent body of water over the levee, frogs could not relocate themselves to Site 4. Instead, they moved around Sites 1–3, depending on which area had the most water at the time. Naturally, many dried up frog corpses were also found. While *Hyla japonica* is less dependent on water and can move into the adjacent hills, the other two species are highly aquatic and populations ended up being highly concentrated where permanent bodies of water existed. We believe that this is a form of environmental fragmentation, a phenomenon in which an ecosystem is isolated from the rest of the environment due to numerous factors, in this case the levee.

In terms of habitat fragmentation studies, the effect of a levee has rarely been examined; an agricultural area less fragmented by roads was compared with the one more fragmented (Park and Lee, 2002), or the distance to residential areas, military facilities, and roads was considered (Yoo et al., 2014). The effect of a levee has been examined only in terms of geographical issues such as its impact on the height of the river bed (Brown, 1914). This study, in this respect, expands the scope of habitat fragmentation research, providing empirical information on the association between the levee and frog migration. Moreover, as the

DMZ itself is surrounded by North Korean wasteland and South Korean developed land, this study was a sort of microcosm showing the effects of environmental fragmentation on a species.

As animals such as the Red Crowned Crane mentioned earlier as well as the frog species are sensitive to human disturbances (the slightest scent or sight of a human may prompt cranes to permanently leave key breeding/feeding/nesting sites), they must be provided with plenty of space to avoid humans. In addition, features such as amphibian tunnels have shown great successes in linking amphibian populations together in the Eastern United States (Jackson, 1996) and Western Europe (Langton, 1989), allowing key migrations to occur across developed roads. Implementing systems such as the European Green Belt, linking central and eastern European ecosystems can link the DMZ to the eastern Baekdudaegan. Such methods can help preserve the overall health of the local animal and plant life.

East Asia does not have a particularly stunning record regarding sustainable development and conservation. Desertification and Yellow Dust in China, environmental fragmentation in Korea and invasive species in Japan are all signs that the region is still struggling in managing its environment. While the DMZ is wholly located in the Korean Peninsula, it may represent East Asia as a whole, and a potential key to preservation. The findings in the present study hint that a more active governmental program for assisting the migratory species in the DMZ as well as the CCZ is needed. These more ecological projects in the future can serve as a model for the rest of Asia to follow regarding sustainable development and environmental protection. Furthermore, many people cite the German reunification as a model on which the Koreas can follow, and it still holds in an environmental sense as well; the German Green Belt, a long line of bio-diverse forest was created along the former border between East and West Germany. Hopefully, we will be able to see a Korean Green Belt linking the Korean peninsula to the rest of Asia, both literally and symbolically. In light of habitat fragmentation research, the DMZ and CCZ have not been studied much. Field research focusing on the ranges and movements of wildlife should be further conducted in this area.

Lastly, it seems also worthwhile to mention some limitation of this study. The study areas of the current research are not comprehensive and limited to a few rice paddies and stream. This field study, therefore, has rather an experimental nature comparing rice paddies and stream on both sides of levee. In this respect, we could not completely control

for other conditions of each site. The habitats of amphibians including frogs are explained to be affected by climatic factors (i.e., precipitation and temperature), distance to waters or trees, availability of hiding place, duration of water supply, existence of coarse woody debris, and others (Semlitsch, 2008; Sinsch, 1988). We did not control for all these possible factors, even though we did observe paddy-preferring species such as *Pelophylax nigromaculatus* was populated only on the paddies of the one side of a levee, not the other. A further study comparing more comprehensive areas with controlling for other factors would be worthwhile to confirm the validity of this study.

Also, the pattern of frog migration over time was interpreted based on the monthly number of adult amphibians observed in the four sites; we did not exactly follow whether particular frogs moved from one site to another. A future study can adopt, for example, the visible implant fluorescent elastomer (VIE) to identify individual frogs (Davis and Ovaska, 2001).

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